UNIVERSIDAD PONTIFICIA COMILLAS

ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA (ICAI)

OFFICIAL MASTER'S DEGREE IN THE ELECTRIC POWER INDUSTRY

Master Thesis

"Analysis of opportunities and implications associated with the use by different agents of new information available through remote monitoring"

Author: Ana Mª Orejas Doce

Supervisor: Pablo Lobo Roldán

Madrid, July 2014

Master's Thesis Presentation Authorization

THE STUDENT:

ANA Mª OREJAS DOCE

Signed: Date: 10/ 07/ 2014

THE SUPERVISOR:

PABLO LOBO ROLDÁN

Signed Date: 10/ 07/ 2014

Authorization of the Master's Thesis Coordinator

Dr. Javier García González

Signed: Date: 10/07/2014

ABSTRACT

During the recent years important changes have been taking place in the power sector due to the new technological advances with the purpose of improving the whole system's efficiency. Smart Meters (Medidores Inteligentes in Spanish) play an important role. Thanks to this new monitoring system, consumers will not be a passive agent of the system anymore, being an active agent and producing impacts on the rest of the system with their actions.

The aim of this paper is to identify how the new information available through the Smart Meters is going to affect to the agents of the power system in Spain (Transmission System Operator, Distributors, Generators, Retailers and Consumers). Thanks to the data available it could be analyzed how the progressive introduction of the Electric Vehicle is going to affect to the distribution networks.

In this way there could be localized the points to be treated carefully due to the imminent transformation of the Electric Power System.

RESUMEN

Durante los últimos años se han producido grandes cambios en el sector eléctrico debido a los nuevos avances tecnológicos con el propósito de mejorar la eficiencia del sistema en general. En ello juegan un importante papel los Smart Meters o Medidores Inteligentes. Gracias a estos nuevos sistemas de monitoreo, los consumidores dejarán de ser un agente pasivo del sector eléctrico a convertirse en un agente activo produciendo impactos en el resto del sistema con sus acciones.

El propósito de este estudio es identificar cómo va a afectar la nueva información disponible a través de los Smart Meters a los agentes del sistema eléctrico en España (Operador del Sistema-TSO, Distribuidores, Generadores, Comercializadores y Consumidores). Gracias a la información disponible se podrá analizar cómo afectará la progresiva introducción del Vehículo Eléctrico a las redes de distribución.

De esta manera se podrán localizar qué puntos habría que tratar con más detalle debido a la inminente transformación del Sistema Eléctrico.

TABLE OF CONTENTS

INTRODUCTION

INTRODUCTION

Electricity cannot be stored; that is the reason why there should be a continuous balance between production and demand.

Consumers demand energy at the moment they need to use it and the system has to provide the energy needed at those specific moments. Because of that, it is really important to know how demand behaves to forecast as better as

The penetration of smart-meters at home is a fact that is going to make easier to know the real profile of consumption and adapt system's operation at real time.

Smart meters represent a general benefit future for generators, transmission systems operators, distributors, retailers and consumers.

In the majority of the systems, consumers do not receive the adequate signals to do a correct management of their electricity consumption. Nowadays this is starting to change.

European legislation has promoted the implementation of remote management systems with the target that at least the 80% of the European consumers will have to be equipped with smart meters before 2020. Some of the regulations which applied are:

- The Directive 2006/32/EC (Article 13) and the Directive 2005/89/32 (Article 15) explicitly mention the use of remote control systems.
- European Renewable Energy Directive 2020.
- Directive 2009/72/EC concerning common rules for the internal market in electricity requires the implementation of intelligent systems.

In order to accomplish with this, the Spanish regulation sets according to the Royal Decree 1110/2007[1]:

The basic equipment type 5 should allow time discrimination measures, able to manage at least six programmable periods. For each period is recorded and stored the active and reactive energy, the maximum power per quarter time and the date and time of maximum.

The measurement equipment type 5, should be integrated into a system of remote telemetry and implanted by the responsible of the corresponding reading.

These systems shall consist of the following elements: measurement equipment and control (Accountant, elements function power control switches, displays, etc.), located at the measuring point , the computer management system, which manages information flows and the operation of measuring and control equipment, and the system of communication between them. Additionally, intermediate hubs may be

[1] Real Decreto 1110/2007, de 24 de agosto, por el que se aprueba el Reglamento unificado de puntos de medida del sistema eléctrico.

installed to act as a liaison between the measurement and control equipment and computer management system.

The minimum functional specifications of remote control systems should be:

- Remote reading of the records of active and reactive energy and power, necessary for billing of energy and rates, or other uses that would be required, such as inclusion in a representative consumer panel.
- Remote reading of the records of the quality parameters.
- Parameterization of the measuring equipment remotely, including setting periods of time discrimination and the contracted power.
- Enabling control mode power demand, demand meter or device power control.
- Remote synchronization with regular hubs.
- Remote control power: disconnection and reconnection of supply, both for the management of high and low supplies to the implementation of management plans demand.
- Finally, the system must have capacity to manage loads, in order to reduce demand at critical times.

This is included in the SUBSTITUTION PLAN ordered by the old CNE, actual CNMC, establishing in the Order IET/290/2012 that starting the process in 2008, in 2014 the 35% of consumers should have at their homes Smart Meters, in 2016 the 70% should be installed and in 2018 the 100% of the Spanish consumers should count with remote monitoring.

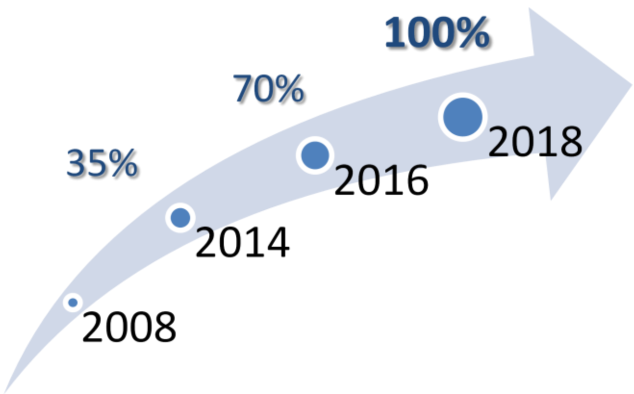


Figure 1: Evolution of smart meters' integration.

The last information published says that in 2014 Endesa has installed 4M of smart meters, Iberdrola 2M, Gas Natural Fenosa 880.000, E.ON 630.000 and EDP 240.000. Taking into account that in Spain there are about 22M of costumers, it can be seen that the country is a bit delayed in order to the objectives.

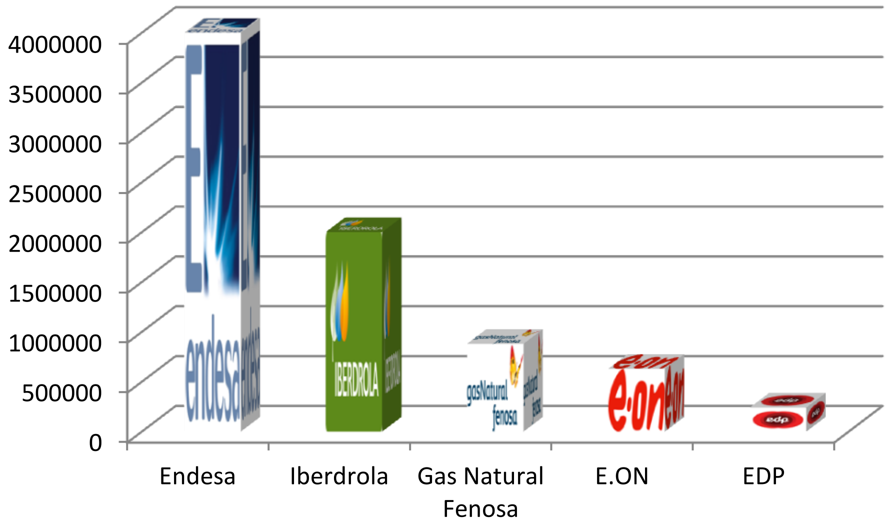


Figure 2: Representation of smart meters installed by each company. (Source El Economista 08/04/2014)

It has to be considered the progressively introduction of the electric vehicle in the Spanish system. There are different programs to incentivize the acquisition of an electric vehicle and this tendency is suppose to increase in the next years.

In Spain the target is to reach 250,000 plug-in vehicles at the end of this year 2014. This is done in order to accomplish with the European goal of 1 million electric vehicles on the roads for 2020.

The penetration of smart meters plus active demand-side participation and the electric vehicle are going to play an essential role in the electrical system as a whole, impacting in the economy, the security of supply and the climate change.

STATE OF THE ART

STATE OF THE ART

The impacts that smart meters are going to have in the system are high.

Real-time balance of supply and demand would be facilitated, which is especially important when intermittent generation has large shares of production (Conchado and Linares, 2012). If Demand management is well promoted, consumers would help to imprive the Security of Supply (Affonso et al. 2006) and losses would be reduced as well (Shaw et al., 2009).

Smart meters and demand response will facilitate the penetration of interrupted generation (distributed generation, RES), which leads into a decrease of the CO2 emissions in the long term. This would help to achieve the European targets of CO2 reductions for 2020 and the zero CO2 emissions target for 2050. (Haney et al. 2009)

In the following figure, it can be appreciate the importance of early investment in the demand-side (1); the long term role of renewables (2); and the reduction of fossil fuel generation to achieve European emission targets (2020 and 2050) (3). (Haney et al. 2009)

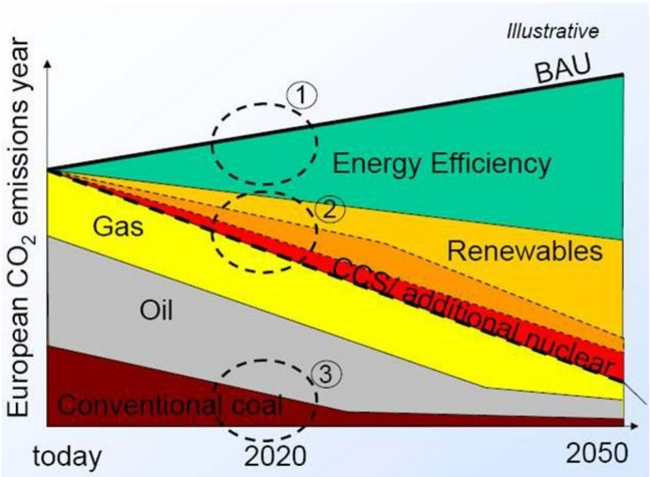


Figure 3: Investor's perspective: strategic choices to achieve European CO2 charges. (Source: Neuhoff - 2007)

Metering will facilitate the iteration between agents and also the impacts that one have in another.

The impact that demand response can have on the agents of the system can be strong. The principal result of this kind of programs will be switch demand from peak hours with higher prices to off-peak hours where prices are lower. Therefore it has to be correctly chosen the signal that consumers are going to receive in order to manage their consumption and their behavior. According with the literature about this topic, a classification of these signals and their objectives is represented in Table 1.

Classification Criteria	Dualities		References
Purpose	*Reliability*	*Economics*	(RMI, 2006)
Trigger factor	*Emergency-based*	*Price-based*	(Faruqui and Hledik, 2007)
Origin of signal	*System-led*	*Market-led*	(IEA, 2003)
Type of signal	*Load response*	*Price response*	(RMI, 2006)
Motivation method	*Incentive-based*	*Time-based rates*	(FERC, 2006; US DOE, 2006)
Control	*Direct load control*	*Passive load control*	(DTE Energy, 2007)

Table 1: Categorization of DR programs (*Source: Conchado A., Linares P. The economic impact of DR on power systems. A survey of the state of the art.*)

Pricing response programs are the ones that give consumers more incentives to manage their energy demand:

- Time-of-use (TOU): Variation on the price depending on different blocks of time (ex-ante determined).
- Real-time pricing (RTP): Dynamic method. Different prices for different hours of the day and for different days of the week.
- Critical-peaking pricing (CCP): Combination of time-of-use (TOU) and real-time pricing (RTP). Dynamic method based on a time-of-use structure supplemented with a separate rate that applies to the critical peak hours. (Haney et al., 2009).

To reach an effective demand response, consumers should be provided with enough information. This implies that smart-meters should be easy to understand, with a friendly display where to make consultations without complications. Also bills should have the key data and be well explained.

Smart-meters are the first stair in the way to avoid asymmetry information and to reduce the environmental impact of generation.

Smart meters would facilitate plug-in electric vehicles, electrotechnologies, renewable energy sources integration, expanded energy efficiency and electrification energy benefits. (EPRI, 2011)

According to Haney et al. 2009 assessing the case for smart meters is a complex process. Regardless of the country or regional context, there is a need for systematic analysis of impacts across the supply chain. The impacts of investing in smart metering can be traced from retail through distribution, transmission, the wholesale electricity market, and finally to the costumer.

Haney et al. 2009 also conclude that when the business case, the cost and benefits, the technology deployment and the demand response are adequately addressed, smart metering has the potential to contribute in a cost-effective way to a number of policy goals including improving security of supply, facilitating the integration of renewable to the grid, avoiding peaks in fossil generation and tackling fuel poverty. They also say that smart metering should be seen as a tool in promoting more active demand and innovation in equipment for demand-side management. A policy and regulatory framework that encourages innovation, cost reduction and above all interoperability will ensure that smart metering is a tool that can evolve in response to the needs of customers, networks, suppliers and the electricity market as a whole.

ERGEG 2007 recognizes that the use of smart metering has to be analyzed within a national context, taking into account the characteristics of the national market and the regulatory model for metering. Notwithstanding market models, ERGEG would recommend that functional requirements for smart meters are established in order to guarantee minimum services for customers and reduce investment risk for meter operators. The use of technical standards both within and between countries should be promoted and third party access to metering data should be established.

As Pérez-Arriaga, I. et al. 2013 concluded, new meter and appliance technologies allow consumers to react to local and upstream generation patterns and prices. Traditional downstream power flows from sources connected to the transmission grid to consumers at the distribution level are challenged by local distributed generation and local means of electricity trade. These changes are driven by the newly emerging broad range of distributed energy resources, be it distributed generation, local storage, electric vehicles or demand response, and pose challenges for DSOs and their regulation alike. Regulation needs to ensure that DSOs are not negatively affected by the market penetration of Distributed Energy Sources with respect their ability to manage the system and to finance all needed system tasks.

METHODOLOGY

METHODOLOGY

The data provided to do this study belongs to 201 Smart Meters installed in Calle Pensamiento, Sevilla. It is illustrated in Figure 4.

Figure 4: Maps of Sevilla (*Source Google Maps and Design Ana Orejas*)

The information given is:

- Records 2 days each 1 minute.
    - March, 29th and 30th.
- Records 12 days each 5 minutes.
    - February 17th to 29th.
- Records demand curves each 15 minutes.
    - 201 meters.
    - From September 30th to October 20th.

The most interested data for this Thesis are the demand curves each 15 minutes. As it is said before, we have information of 201 meters, but at the end there were used 179 due to some data was no well registered.

The time line is 3 weeks, but we are going to extrapolate it to 1 month in order be more explicative.

The information that we can find in each Excel sheet comes in 6 columns, where the parameters are:

- Id Smart Meter
- Active Energy values kWh
- Valid active energy (Yes or No)
- Reactive Energy values kVar.h
- Valid reactive energy (Yes or No)
- Date

This can be seen in the Table below.

Id. Smart Meter	New values active energy	Valid active energy	New values reactive energy	Valid reactive energy	Date
86021601C003	0.0090	Yes	0.011	Yes	30/09/2011 16:30
86021601C003	0.023	Yes	0.031	Yes	30/09/2011 16:45
86021601C003	0.0050	Yes	0.0050	Yes	30/09/2011 17:00
86021601C003	0.026	Yes	0.033	Yes	30/09/2011 17:15
86021601C003	0.0020	Yes	0.0020	Yes	30/09/2011 17:30

Table 2: Excel Sheet Data.

The first thing done was to organize de information. In order to do this, an Excel sheet for each meter was created. Then the values not valid were cancelled and it was changed the situation of the columns to just have the important data, which is:

- Id Smart Meter
- Data
- Active Energy Values kWh
- Reactive Energy Values kVar.h

They are represented in the Table below.

Id. Smart Meter	Date	New values active energy	New values reactive energy
86021601B5B6	01/10/2011 00:15	0,066	0,05
86021601B5B6	01/10/2011 00:30	0,032	0,001
86021601B5B6	01/10/2011 00:45	0,045	0,015
86021601B5B6	01/10/2011 01:00	0,082	0,061
86021601B5B6	01/10/2011 01:15	0,08	0,061

Table 3: Excel sheet with the organized information.

After this, the next step was to plot each curve to see the behavior of the consumers and to proceed to the validation as it is shown in Figure 5.

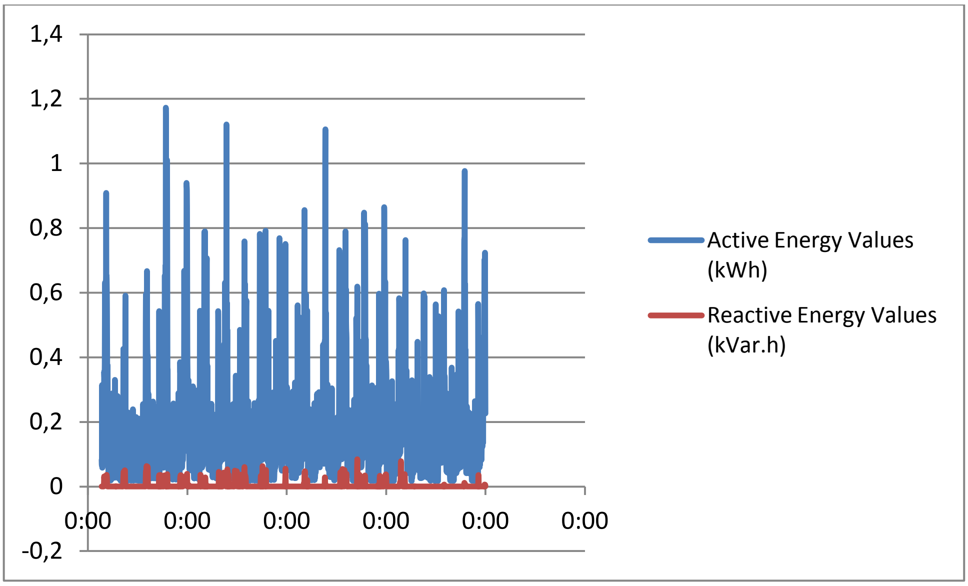


Figure 5: Active and Reactive Energy of a random consumer

As it was said at the beginning of this document, the initial number of smart meters was 201. Once the validation process was done, the final number of smart meters used for the study was 179; it means that 22 curves were eliminated.

After the validation, the first analysis to carry out is "Smart Meters' Power Study".

In this section, the Power Contracted of all of the customers is compared to their real power demanded. An Excel table is created with this purpose. To materialize the value of Power Contracted through the Active Energy in each ¼ hour during 3 weeks, it is applied:

$$Power\ (kWh) = \frac{Energy\ (kWh)}{t\ (h)}$$

Where t=0.25h because the Energy is provided each 15 minutes.

It can be seen the percentage of Power Contracted that each costumer demand and the amount of money paid for the PC extrapolated to the year (because the data used is for a 3 week period).

	Id Meter	Power Contracted KW	Maximum Active Energy KW(1/4h)	Maximum Power KW	% PC	Payment for present PC (€ year)
Data (0)	86021601B5B6	3,45	0,593	2,372	68,75362319	131,2498197
	86021601B75B	4,4	0,688	2,752	62,54545455	167,3910744
	86021601B929	5,5	0,76	3,04	55,27272727	209,238843
	86021601BA5D	4,4	0,655	2,62	59,54545455	167,3910744
	86021601BA64	4,4	0,863	3,452	78,45454545	167,3910744

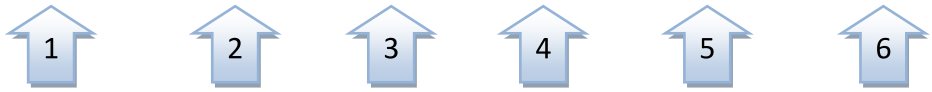


Table 4: Present Power Consumed

Each time that Maximum Power Consumed is bigger than Power Contracted (4 > 2), the percentage of power contracted exceeds 100%, column 5 (%PC) is going to be colored in red.

	Id Meter	Power Contracted KW	Maximum Active Energy KW(1/4h)	Maximum Power KW	% PC	Payment for present PC (€ year)
Data (0)	86021601DFA3	4,6	1,173	4,692	102	174,9997596

Table 5: Identification of excess in Power Consumed

According to these results, it is made a subdivision of the results in which can be distinguished 4 consumption trends:

- Consumers with a power demanded over 105% of the Power Contracted.
- Consumers with a power demanded between 100% and the legal 105% of Power Contracted.
- Consumers with a power demanded between the 50% and the 100% of their Power Contracted.
- Consumers with a power demanded inferior to the 50% of the Power Contracted.

The next step would be to adapt of all the consumers to their real power demanded. The "Resolution of September 8th 2006" establishes standardized powers (kW), which are shown in Table 4:

U=230V
0
0,345
0,69
0,805
1,15
1,725
2,3
3,45
4,6
5,75
6,9
8,05
9,2
10,35
11,5
14,49

Table 6: Standardized Powers

Following this, Power Contracted of consumers would be shifted into normalized values (7) according to their real needs. Also the payment for Power Contracted during the year is actualized.

	Id Meter	Power Contracted KW	Maximum Active Energy KW(1/4h)	Maximum Power KW	% PC	Payment for present PC (€ year)	New standardized PC	Payment for new PC (€ year)
Data (0)	86021601B5B6	3,45	0,593	2,372	68,75362319	131,2498197	3,45	131,24982
	86021601B75B	4,4	0,688	2,752	62,54545455	167,3910744	3,45	131,24982
	86021601B929	5,5	0,76	3,04	55,27272727	209,238843	3,45	131,24982
	86021601BA5D	4,4	0,655	2,62	59,54545455	167,3910744	3,45	131,24982
	86021601BA64	4,4	0,863	3,452	78,45454545	167,3910744	4,6	174,99976
	1	2	3	4	5	6	7	8

Table 7: PC shifted into normalized values

The new meters can be programmed and do not depend on the standardized values of Intensity. Therefore, in the future the maximum power contracted could be fixed, instead of with normalized values, with the real values of maximum power that consumers would need.

This last assumption is applied in the study, having the following table as result.

	Id Meter	Power Contracted KW	Maximum Active Energy KW(1/4h)	Maximum Power KW	% PC	Payment for present PC (€ year)	New standardized PC	Payment for new PC (€ year)	Non-standardized PC (no tolerance)	Payment for new N-S PC (€ year)
Data (0)	86021601B5B6	3,45	0,593	2,372	68,75362319	131,2498197	3,45	131,24982	2,372	90,23900647
	86021601B75B	4,4	0,688	2,752	62,54545455	167,3910744	3,45	131,24982	2,752	104,6955084
	86021601B929	5,5	0,76	3,04	55,27272727	209,238843	3,45	131,24982	3,04	115,652015
	86021601BA5D	4,4	0,655	2,62	59,54545455	167,3910744	3,45	131,24982	2,62	99,67377612
	86021601BA64	4,4	0,863	3,452	78,45454545	167,3910744	4,6	174,99976	3,452	131,3259066

Table 8: PC shifted into non-standardized values

With Smart Meters it is expected some sort of Demand Response. While consumers are going to have access to information about their real consumption it has to be analyzed the impacts that a future shift on tariffs, better adapted to their consumption profile, could have in the incomes for the system through the access tariffs.

In order to study these impacts, the energy consumption of each of the consumers is going to be analyzed for the 3 types of tariffs 2.0.:

- 2.0 A → Without hourly discrimination.
- 2.0 DHA → Hourly discrimination of 2 periods.
- 2.0 DHS → Hourly discrimination of 3 periods.

TEA (Active Energy Term) €/kWh

Without discrimination
0,044027

2 PERIODS	
P1	P2
13-23	0-13 23-24
0,062012	0,002215

3 PERIODS		
P1	P2	P3
13-23	0-1 7-13 23-24	1-7
0,062012	0,002879	0,000886

Table 9: Energy term €/kWh

In the tables, as before, there is going to appear:

- Id Meter (1)
- Date (2)
- Time (3)
- Values of Active Energy (4)

And 3 new columns:

- Without discrimination (5) → € that a consumer pays for the amount of energy consumed corresponding to that specific moment with the tariff 2.0 A.
- 2 Periods (6) → € that a consumer pays for the amount of energy consumed corresponding to that specific moment with the tariff 2.0 DHA.
- 3 Periods (7) → € that a consumer pays for the amount of energy consumed corresponding to that specific moment with the tariff 2.0 DHS.

Id. Meter	Date	Time	Values E. Active	Without discrimination	2 periods	3 periods
86021601DFA3	30/09/2011 16:30	16:30	0,082	0,003610214	0,005084984	0,005084984
86021601DFA3	30/09/2011 16:45	16:45	0,065	0,002861755	0,00403078	0,00403078
86021601DFA3	30/09/2011 17:00	17:00	0,314	0,013824478	0,019471768	0,019471768
86021601DFA3	30/09/2011 17:15	17:15	0,058	0,002553566	0,003596696	0,003596696
86021601DFA3	30/09/2011 17:30	17:30	0,058	0,002553566	0,003596696	0,003596696

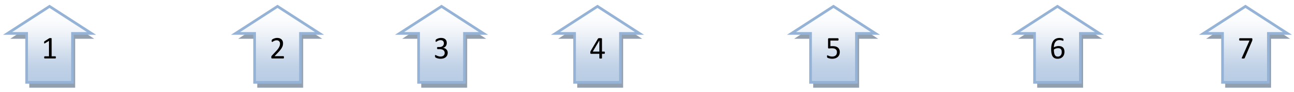


Table 10: Cost of Energy depending on type of tariff

These last columns were computed multiplying the values of Active Energy (kWh) by it cost at that moment (€/kWh).

For the column number 5, without discrimination, the computation is easy, because it just have to be multiplied the values of column 4, Values of Active Energy, by:

TEU0 (€/KWh)
0,044027

In the case of columns 6 and 7, 2 and 3 periods, it has to be taken into account the hour in which the consumption of energy is done, because there are different payments depending on the hourly interval.

In order to do this, there were implemented formulations which allow differentiating between hours.

For column 6, hourly discrimination of 2 periods, the values of Active Energy have to be multiplied by:

TEU1 (€/KWh)
0,062012
TEU2 (€/KWh)
0,002215

A distinction has to be done with the hours where the consumption is done. For this, it is elaborated a formula in which it is said that:

- If the consumption is done between **13:00** hours and **23:00**, multiply the values of Active Energy in column 4 by **TEU1**.
- If the consumption occurs in **other hours** out of this interval, the Active Energy should be multiplied by **TEU2**.

The same differentiation should be done for column 7, hourly discrimination of 3 periods, where the values of Active Energy should be multiplied by:

TEU1 (€/KWh)
0,062012
TEU2 (€/KWh)
0,002879
TEU3 (€/KWh)
0,000886

As it has been done in the previous case with 2 periods, for 3 it is develop a formula to distinguish between the three intervals.

- If the consumption of Active Energy it is done between **13:00** and **23:00**, these values in column 4 are multiplied by **TEU1**.
- If the consumption of Active Energy it is done between **1:00** and **7:00**, these values in column 4 are multiplied by **TEU3**.
- If the consumption of Active Energy it is done out of both two intervals, values in column 4 are multiplied by **TEU2**.

With this, it can be analyzed the differences when the same consumer is in one tariff or another.

The next step will be to sum all of the quantities paid by each consumer in each one of the three tariffs. In this way it is obtained the aggregated quantities if all of the consumers are in tariff 2.0A (without discrimination), tariff 2.0DHA (2 periods) or tariff 2.0DHS (3 periods).

In order to make a deep analysis, it is going to be study which of the tariffs suits better for each consumer creating the optimum scenario. This would mean the scenario where the system receives fewer incomes for the energy term of the access tariff.

To create the optimal situation, for each individual consumer will be taken into account the tariff which represents the minimum payment that the client does, it means the tariff that fits the better with his/her energy consumption profile. This will be done for all of the consumers. After this, there will be a result indicating the percentage of people in each of the tariffs for the Optimal Situation.

With this information, it is calculated the average saves that individuals can make in this Optimal Situation. It is identified too, the consumer that saves the maximum quantity changing into the tariff that fits better with his/her consumption.

Also it is done a comparison between the incomes by access tariff for the Optimal Situation mentioned before, and the maximum income scenario in which all of the consumers have a tariff without hourly discrimination.

The study that follows now, it is the analysis of the simultaneity.

To develop it, it is needed the aggregation of all of the energy (kWh) quarterly consumption curves and then convert it into power consumed (kW) through:

$$Power\ (kWh) = \frac{Energy\ (kWh)}{t\ (h)}$$

Then the Power aggregated curve is plotted to see the common behavior.

The next step is to calculate the Power of the supply connection (Spanish acometida). This study is going to be carried out for a block of 25 houses, considered the most representative consumption curves during the day October, 18th 2012. It was chosen this day because it is Thursday and it represents a normal week day.

The 25 curves were organized as follows:

	Hour	1	2	3	4	5	6	7	8	9	10	11	12
18/10/2011 00:00	0:00:00	0,057	0,069	0,111	0,048	0,106	0,144	0,051	0,039	0,101	0,063	0,049	0,006
18/10/2011 00:15	0:15:00	0,054	0,066	0,11	0,035	0,105	0,149	0,047	0,04	0,117	0,025	0,057	0,055
18/10/2011 00:30	0:30:00	0,053	0,061	0,113	0,051	0,077	0,125	0,062	0,059	0,138	0,04	0,045	0,035
18/10/2011 00:45	0:45:00	0,053	0,036	0,101	0,029	0,062	0,109	0,051	0,056	0,065	0,024	0,036	0,037
18/10/2011 01:00	1:00:00	0,051	0,036	0,06	0,038	0,046	0,063	0,049	0,055	0,082	0,039	0,056	0,017
18/10/2011 01:15	1:15:00	0,026	0,036	0,059	0,047	0,288	0,059	0,036	0,043	0,101	0,017	0,024	0,045

... 25

Table 11: 25 most representative consumption curves.

There are used a formula and some coefficients extracted from the "Reglamento electrotécnico para la baja tensión" in the BOE[2] as follows:

- Simultaneity Coefficient (CS):

$$CS = 15.3 \times (n - 21) \times 0.5$$

n= number of houses

- Simultaneity Factor (FS):

$$FS = \frac{CS}{n}$$

[2]REAL DECRETO 842/2002, de2 de agosto, por el que se aprueba el Reglamento electrotécnico para baja tensión. Reglamento electrotécnico para baja tensión e instrucciones técnicas complementarias (ITC) BT 01 a BT 51.

- Adscript Power (PA):

$$PA\ (kW) = 5.75$$

- Power of supply connection (PAcometida):

$$PAcometida\ (kW) = FS \times PA \times n$$

Once the Power of the supply connection was calculated, all of the curves are aggregated and then it is computed the sum of Maximum Power reached by each consumer at their maximum consumption moment. This is done selecting the maximum of each curve.

Plotting all of these curves, it can be seen and evaluated the actual supply connection's capacity that is going to be needed for the future demand fluctuations.

The Electric Vehicle's study was developed in collaboration with Pablo Lobo (thesis supervisor).

For this study there were used the previous 25 consumption curves.

	Hour	1	2	3	4	5	6	7	8	9	10	11	12
18/10/2011 00:00	0:00:00	0,057	0,069	0,111	0,048	0,106	0,144	0,051	0,039	0,101	0,063	0,049	0,006
18/10/2011 00:15	0:15:00	0,054	0,066	0,11	0,035	0,105	0,149	0,047	0,04	0,117	0,025	0,057	0,055
18/10/2011 00:30	0:30:00	0,053	0,061	0,113	0,051	0,077	0,125	0,062	0,059	0,138	0,04	0,045	0,035
18/10/2011 00:45	0:45:00	0,053	0,036	0,101	0,029	0,062	0,109	0,051	0,056	0,065	0,024	0,036	0,037
18/10/2011 01:00	1:00:00	0,051	0,036	0,06	0,038	0,046	0,063	0,049	0,055	0,082	0,039	0,056	0,017
18/10/2011 01:15	1:15:00	0,026	0,036	0,059	0,047	0,288	0,059	0,036	0,043	0,101	0,017	0,024	0,045

Table 12: 25 most representative consumption curves.

... 25

All of the power demanded at each times are aggregated in a last column (25 aggregated demands). After this, they are analyzed the situations of 1, 5, 10, 15 and 25 electric vehicles starting to charge when people arrives home until the morning.

It was assume that each electric vehicle demands 3.7 kW, therefore there are created new columns for each value of EV's penetration, in which it is applied:

$$Total\ power\ demand\ (kW) = Consumers'aggregated\ demand + [3.7(kW) \times number\ EV]$$

25 aggregated demand	+ 1 EV	+ 5 EV	+ 10 EV	+ 15 EV	+25 EV	Supply Connection
9,684	13,384	28,184	46,684	65,184	102,184	99
10,004	13,704	28,504	47,004	65,504	102,504	99
10,816	14,516	29,316	47,816	66,316	103,316	99
8,644	12,344	27,144	45,644	64,144	101,144	99
7,972	11,672	26,472	44,972	63,472	100,472	99
8,18	11,88	26,68	45,18	63,68	100,68	99

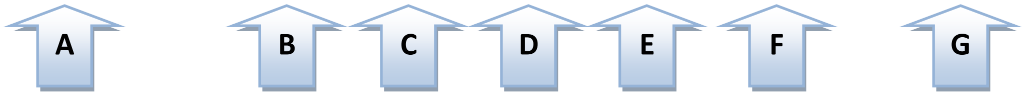


Table 13: Power Consumption with different levels of EV's penetration.

The supply connection calculated for these houses is 99 kW; therefore it is going to be a cap of 99 kW in order not to exceed this limit.

The value chosen would be:

- When the value in B, C, D, E, F is lower than the value in G (99 kW), it is chosen the value in B, C, D, E, F.
- When the value in B, C, D, E, F is greater than the value in G (99 kW), it is chosen the value in G (99 kW).

BEFORE

Supply Connection	+ 1 EV	+ 5 EV	+ 10 EV	+ 15 EV	+25 EV
99	13,384	28,184	46,684	65,184	102,184
99	13,704	28,504	47,004	65,504	102,504
99	14,516	29,316	47,816	66,316	103,316
99	12,344	27,144	45,644	64,144	101,144
99	11,672	26,472	44,972	63,472	100,472
99	11,88	26,68	45,18	63,68	100,68

Table 14: Power Consumption without limits.

AFTER

Supply Connection	+ 1 EV	+ 5 EV	+ 10 EV	+ 15 EV	+25 EV
99	13,384	28,184	46,684	65,184	99
99	13,704	28,504	47,004	65,504	99
99	14,516	29,316	47,816	66,316	99
99	12,344	27,144	45,644	64,144	99
99	11,672	26,472	44,972	63,472	99
99	11,88	26,68	45,18	63,68	99

Table 15: Power Consumption applying limits.

There will be plotted the curves after the application of the supply connection's limit.

For 175 consumers it is developed the same study but just for 0 electric vehicles and for 100% of penetration, this means 175 electric vehicles.

The supply connection capacity in this case applying the BOE formulas and parameters is 530 kW, so the demand would be limited by this value with the control system (CS).

Again, but with the new values:

- If power demanded by consumers + EV is greater than the maximum supply connection capacity (530 kW) the value used will be the limit, 530 Kw.
- If power demanded by consumers + EV is lower than the maximum supply connection capacity (530 kW) the value used will be power demanded by consumers + EV.

	Hour	175 households	+175 EV	Max Power with CS	+175 EV with CS
03/10/2011 00:00	0:00:00	63,472	685,072	530	530
03/10/2011 00:15	0:15:00	57,996	679,596	530	530
03/10/2011 00:30	0:30:00	50,684	672,284	530	530
03/10/2011 00:45	0:45:00	49,908	671,508	530	530
03/10/2011 01:00	1:00:00	43,76	665,36	530	530
03/10/2011 01:15	1:15:00	39,624	661,224	530	530

Table 16: Power consumption 175 households + 175 EV.

SMART METERS' POWER STUDY

SMART METERS' POWER STUDY

First Results

This study was done with 179 meters, checking the Contracted Power and the maximum power reached for each one in the period of 3 weeks.

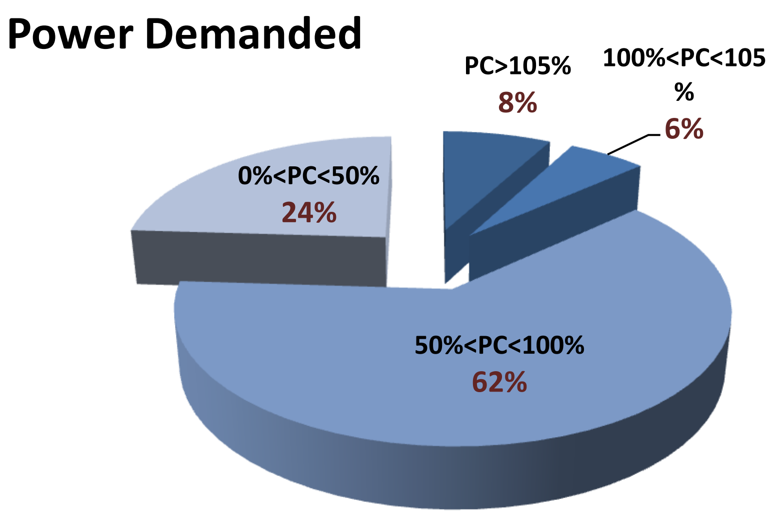
The principal results that came up were:

136 out of 179 consumers were spending more than the 50% of the Contracted Power and 24 of them over the 100% of the Contracted Power, which indicates that probably they do not have ICP and are defrauding. This is a positive result of the new smart meters penetration; the fraud can be detected easily and rapidly.

43 out of these 179 consumers were below the 50% of the Contracted Power. This group of people could reduce their Power Contracted. This would have a high impact on the retribution for the whole system through the access tariffs because in this sample the possibility of percentage of people that could reduce their Power Contracted supposed a 24% of the total consumers, which is not a small quantity.

This result opens the door to recalculate the tariffs, meaning an increase in the fix term, pay more for Power Contracted.

Total Meters	179	100,00%	
PC>105%	14	7,8212%	13,4078%
100%<PC<105%	10	5,5866%	
50%<PC<100%	112	62,5698%	86,5922%
0%<PC<50%	43	24,0223%	



Adaptability of Power Contracted

Nowadays the fix term of power contracted TPA for the tariff 2.0 (Power Contracted less or equal than 10 KW) is established in 38,043426 €/kW and year.

If all of the consumers adapt their Power Contracted to the real one that they can reach some of them should increase it and others, most of them, should decrease it.

With the data that it is been analyzed it can be seen that adding all of the quantities paid by the sample of consumers taken into account, the total amount paid for power contracted in the present is around 27.018€.

If these people adjust their PC to their real necessities, changing their PC into new normalized values, it causes a decrease on the incomes for the power system as a whole of 4.880€ (18% reduction of power contracted), so the new incomes would be 22.137€.

Finally, as the new meters can be programmed and do not depend on the standardized values of Intensity, in the future the maximum power contracted could be fixed, instead of with normalized values, with the real values of maximum power that consumers would need. If we apply this to the case study, the reduction in incomes for fix term would be around 8.422€ respect to the present value of 27.018€ (31% decrease of power contracted), being the new income quantity 18.595€.

A summary of the results is presented in the following tables and graphs:

	Retribution for PC	€
	Present	27018
Adjusting PC	Normalized Values	22137
	Non Normalized Values	18595

Table 17: Results' Summary

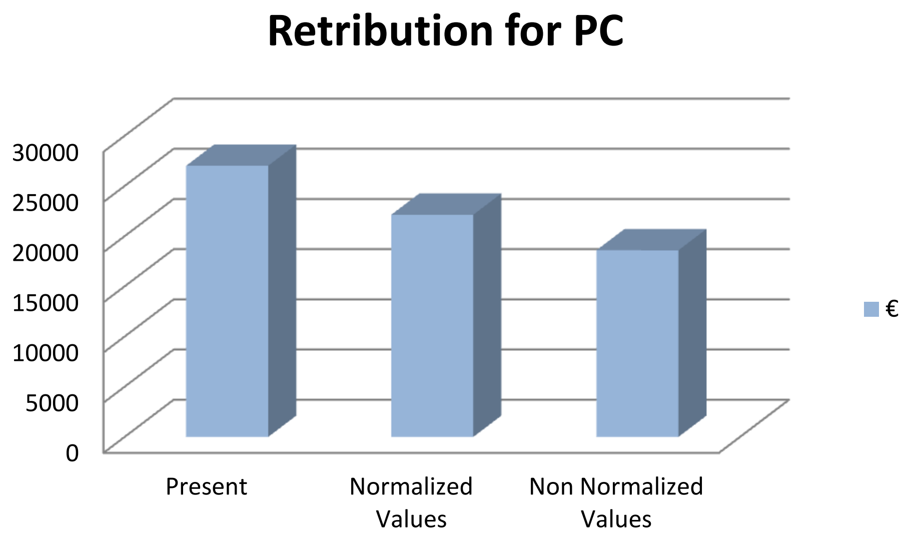


Figure 6: Retribution for Power Contracted.

For the PVPC (Precio Voluntario del Pequeño Consumidor) which fix term of power contracted (TPU) is 4 more euro than the precious one (42,043426 €/KW and year) due to commercial margin, we obtain that the actual amount paid for power contracted is 29.858€.

Adjusting the power contracted into normalized values the result would be 24.465€ (5.393€ less).

In the hypothetic case of changing the power contracted into no-normalized values the incomes decrease gets to 20.550€ (9.308€ less than the actual value).

A summary of the results is presented in the following tables and graphs:

	Retribution for PC	€
	Present	29858
Adjusting PC	Normalized Values	24465
	Non Normalized Values	20550

Table 18: Results' Summary PVPC.

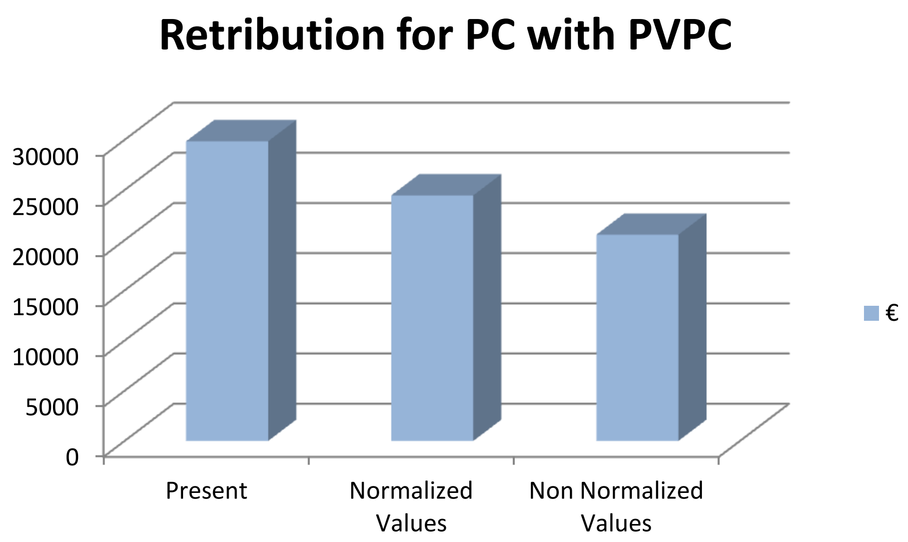


Figure 7: Retribution for Power Contracted with PVPC.

Making a deeper analysis of the impact that this commercial margin of 4€ represent in the incomes for the power contracted. In the first table the data represents the numerical differences between retribution of the first case (with commercial margin) and the second one (without commercial margin, PVPC tariff), and in the figure it can be seen how much this commercial margin represents over the total remuneration for power contracted.

	Retribution for PC	€
	Present	2840
Adjusting PC	Normalized Values	2328
	Non Normalized Values	1955

Table 19: Differences' Summary.

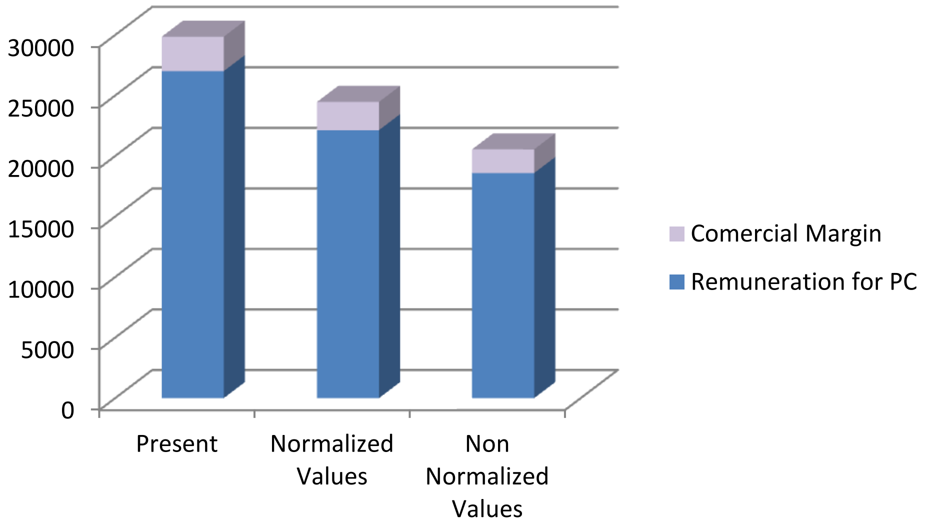


Figure 8: Comparison of Retribution for Power Contracted.

IMPACT OF HOURLY DISCRIMINATION

IMPACT OF HOURLY DISCRIMINATION

In this chapter it is analyzed the effect of the application of hourly discrimination due to the different kind of access tariffs (1, 2 and 3 periods tariffs).

The data that used belongs to the summer period. Therefore, the tariffs to be applied are the following ones:

TEA (Término de Energía Activa) €/kWh

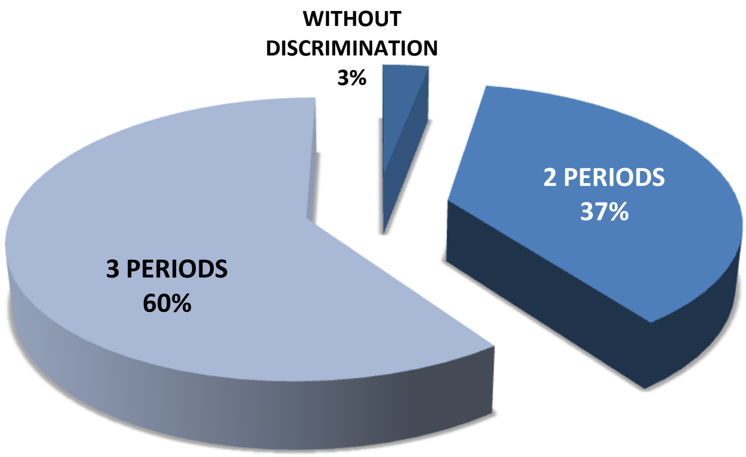
Without Discrimination
0,044027

2 PERIODS	
P1	P2
13-23	0-13 23-24
0,062012	0,002215

3 PERIODS		
P1	P2	P3
13-23	0-1 7-13 23-24	1-7
0,062012	0,002879	0,000886

Using this different numbers it was calculated how much each consumer has to pay for their real consumption depending on the three kinds of tariffs. For each consumer were got 3 different quantities that they have to pay. After this it was chosen the cheapest alternative for the consumer and it was calculated what their maximum safes would be respect to the expensive one.

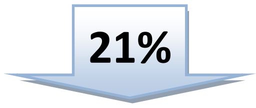
In an Optimal Situation, the percentage of consumers in each tariff would be:



It is going to be considered a hypothetical situation, the less favorable, in which all of the consumers have a tariff without hourly discrimination. The quantity that consumers should pay during this period would be 1396.25€.

Now, implementing the Optimal Situation showed before, total earnings for the system are 1103.30€. It is obvious that there is a reduction of 21% on the quantity paid by the consumers to the system.

Without Discrimination	1396,25895
Optimal Situation	1103,29409
Difference	292,964861



This impact is not trivial. If consumers have more knowledge about their consumption, there could be a modification in their habits optimizing their payments in the electricity bill.

With this analysis we can see that probably a recalculation on tariffs should be done in order to mitigate this huge reduction on incomes for the whole system due to active energy term of the tariffs implemented.

SIMULTANEITY

SIMULTANEITY

Simultaneity Factor is defined in the BOE[3] as the relationship between the total Power installed or planned, for a set of plant or machinery for a period of time, and the sums of the maximum power absorbed by individual facilities or the machines.

The aim of this study is to analyze the influence that relevant demand increments at the household level, could have on the distribution networks, for example the introduction of the Electric Vehicle.

In this part, all of the consumption curves of each costumer are going to be aggregated to see what the maximum power that they consume every day of the study is.

It is obtained a profile in which we can see that the maximum peak of consumption is 104 kW in October, 3rd 2012 at 22:00 coinciding with the final time of a football game:

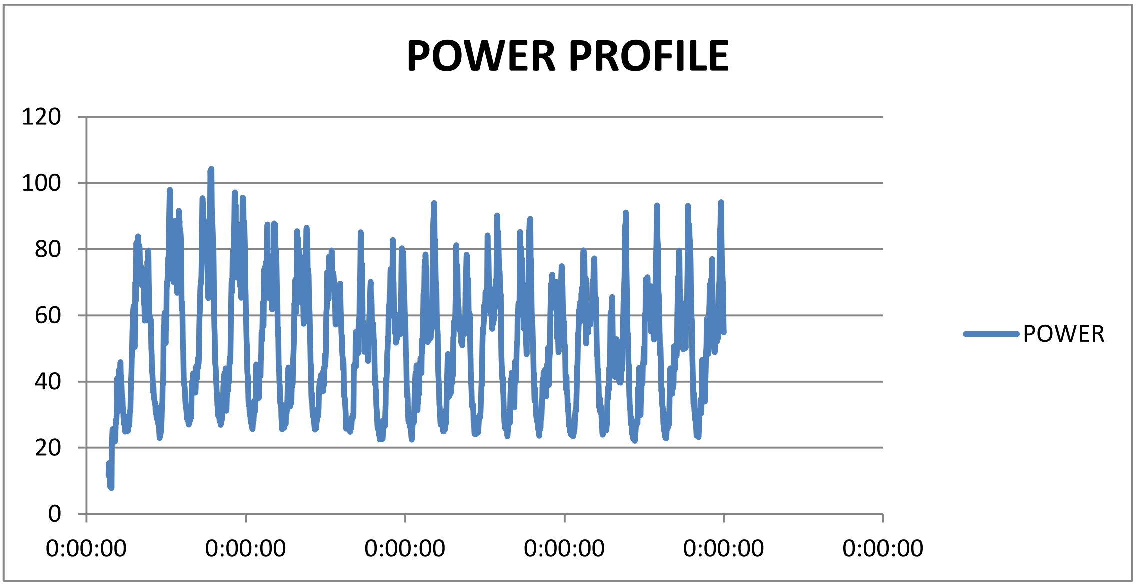


Figure 9: Real power consumption profile

Adding the maximum peak consumption of each client, independently of the day when it was produced, it is obtained a value of 460 kW.

Power Consumption profile and the sum of Maximum Power in the worst situation are represented in the following graph:

[3] REAL DECRETO 842/2002, de2 de agosto, por el que se aprueba el Reglamento electrotécnico para baja tensión. Reglamento electrotécnico para baja tensión e instrucciones técnicas complementarias (ITC) BT 01 a BT 51.

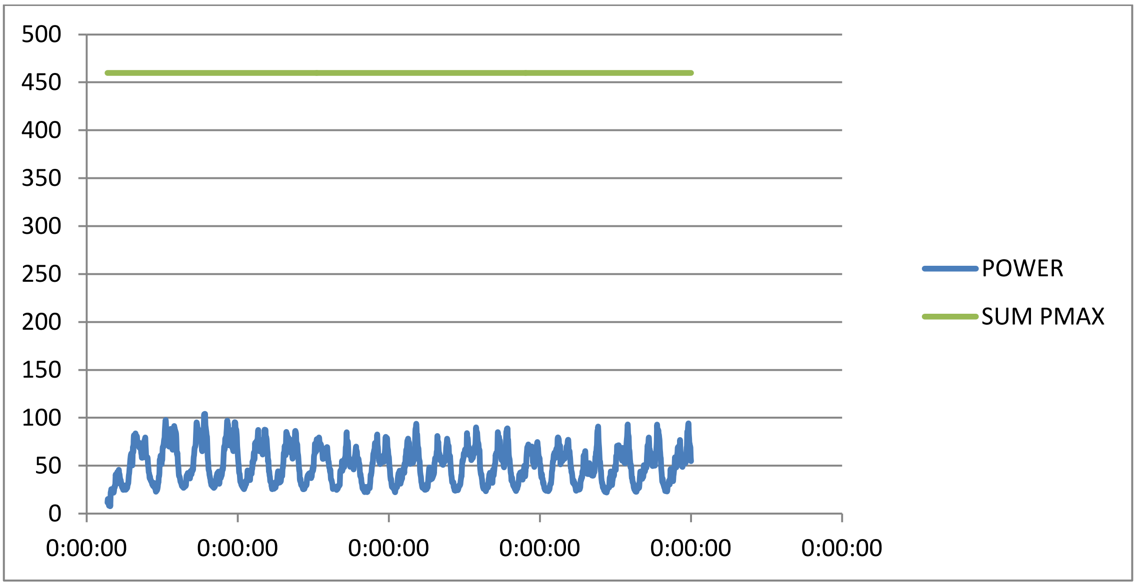
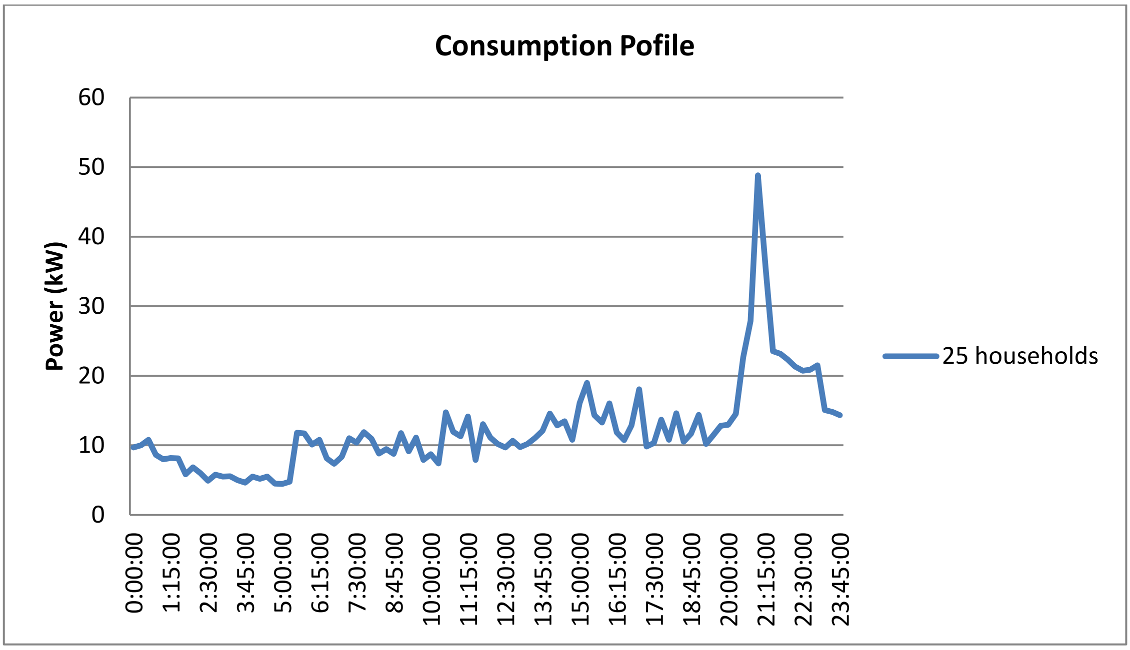


Figure 10: Power consumption and sum of maximum power reached

Now it is interesting to know what the supply connection's power design is (PAcometida). For this, there is going to be selected a block of 25 curves, the 25 most representative during a Thursday with a normal consumption.

The consumption profile of these 25 curves at the chosen day is which follows:



To calculate it is going to be applied the formula from the BOE, where:

$$PAcometida\ (kW) = FS \times PA \times n$$

- Simultaneity Factor (FS):

$$FS = \frac{CS}{n}$$

- Simultaneity Coefficient (CS):

$$CS = 15.3 \times (n - 21) \times 0.5$$

n= number of houses

- Adscript Power (PA):

$$PA\ (kW) = 5.75$$

Respects to these formulas and with the data of this specific case, the following results are obtained:

$$n = 25$$

$$CS = 15.3 \times (25 - 21) \times 0.5 = 17.3$$

$$FS = \frac{94.3}{179} = 0.692$$

$$PA\ (kW) = 5.75$$

$$PAcometida\ (kW) = 0.692 \times 5.75 \times 25 = 99\ kW$$

Plotting the previous results:

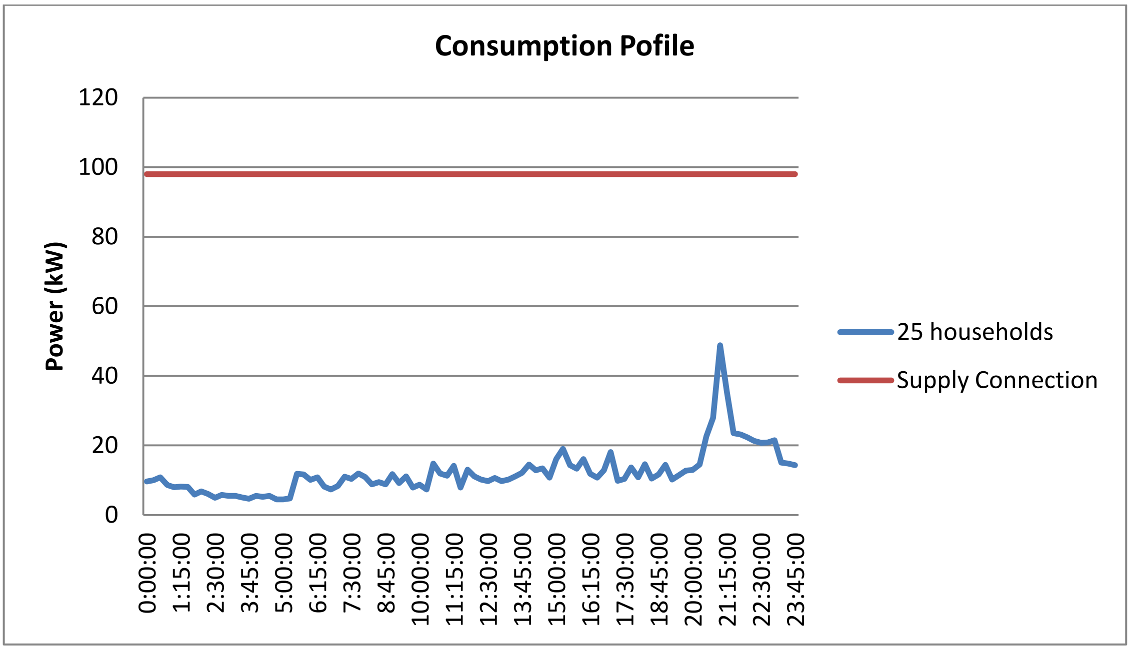


Figure 11: Power consumption and supply connection power.

When the curves of each consumer are analyzed independently and the maximum peaks of each one of there are selected and added, it is reached a demand of aggregated power of 64.8 kW.

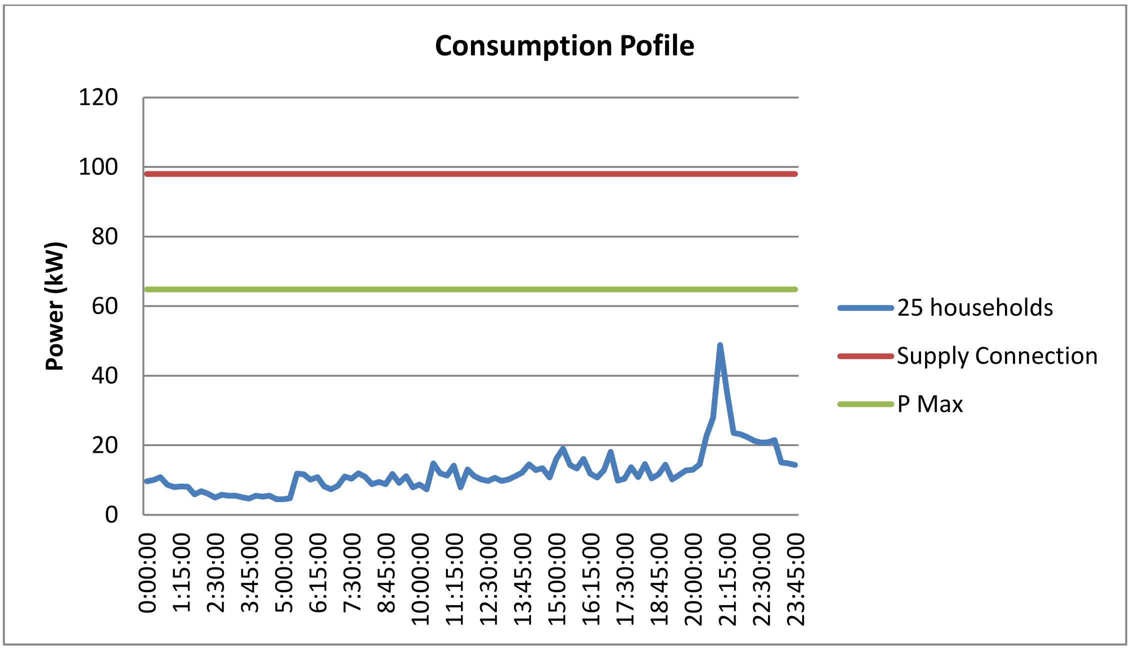


Figure 12: Consumption profile, supply connection capacity and sum of maximum power reached.

On one hand, the data used in this study belongs to the month of October in Sevilla, where there is no significant consumption of air conditioner or heating. Therefore, it is logical to think that in those critical moments, power consumption is going to be higher and this profile would have other peaks.

On the other hand, there is another element very important, the introduction of the electric vehicle, which would increase the electric consumption.

ELECTRIC VEHICLE

In collaboration with Pablo Lobo Roldán

ELECTRIC VEHICLE

The progressively introduction of the Electric Vehicle is a factor that should be taken into account.

Consumers would charge their electric vehicles at night, in the off-peak hours, helping to create the so-called flat curve. This would produce an increase in the power demand at nights, where the most part of the electricity is generated by the wind mills, which implies a reduction on wind spillages as in the case of Spain, where not all of the energy produced with wind is consumed.

Electric vehicle plus wind generation implies dismissing of conventional vehicles and generation, which means a reduction of CO_2 emissions.

Mentioning intermittent generation, it is needed to say that demand response will facilitate the real time balance of security of supply and this would help to this technology's operation. TSO's would find in demand side management a good ally to keep this balance in real time making more efficient the network's operation. It also would help to reduce losses and increase reliability and quality of supply.

Adding the arguments studied in this thesis (consumers reacting to signal prices and the introduction of the electric vehicle) it could be said that in the short term, it would be produced an increase on CO_2 emissions if consumers react to prices changing their power demand behavior. However, in the long term, with a good demand response program, the introduction of the electric vehicle and the proliferation of intermittent generation, CO_2 emissions will not increase. This would help to reach the environmental targets implemented in Europe.

For the study mentioned before, there were selected the 25 most representative consumption curves of the 179 analyzed used in the Simultaneity chapter.

It was made an analysis during 24 hours to study how much energy would be demanded by different levels of penetration of electric vehicles and the need of a system to control the power consumption when it reaches the limit of the supply connection cable.

The consumption profile of the 25 smart meters and the supply connection's capacity are showed below:

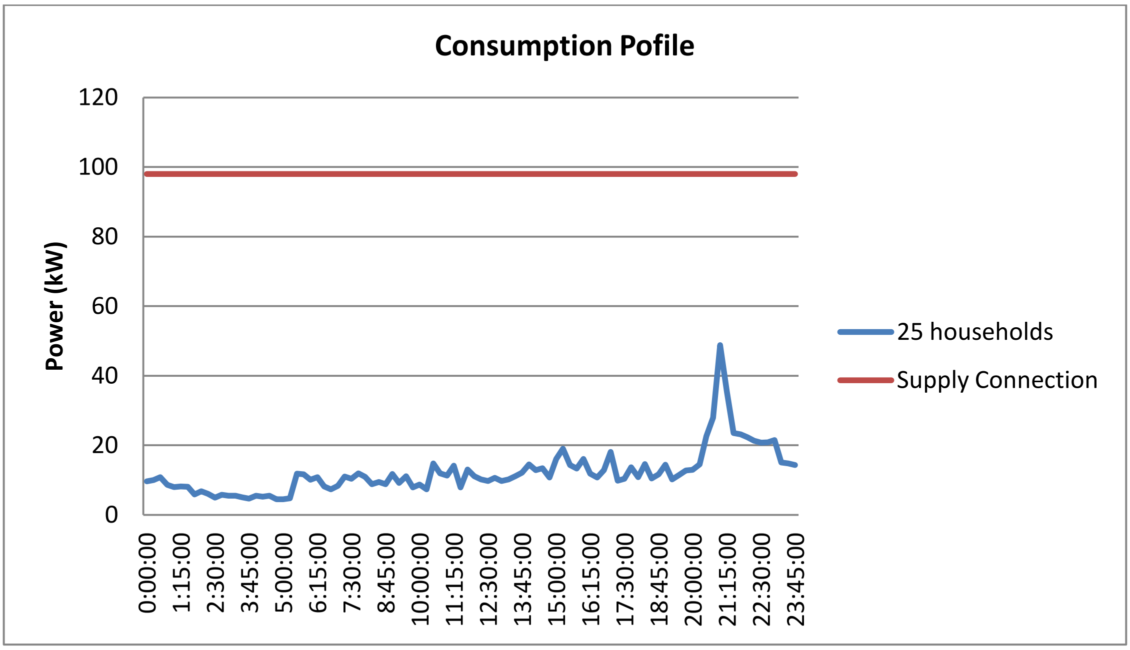


Figure 13: Consumption profile of 25 households.

After the introduction of 5 electric vehicles (green line) starting to charge in the moment when people arrive home from work, about 19:00 hours and finishing when they are completely recharged, it can be seen that the consumption grows between 19:00 and 3:00 in the morning but it keeps on the margins no to overcharge the supply connection.

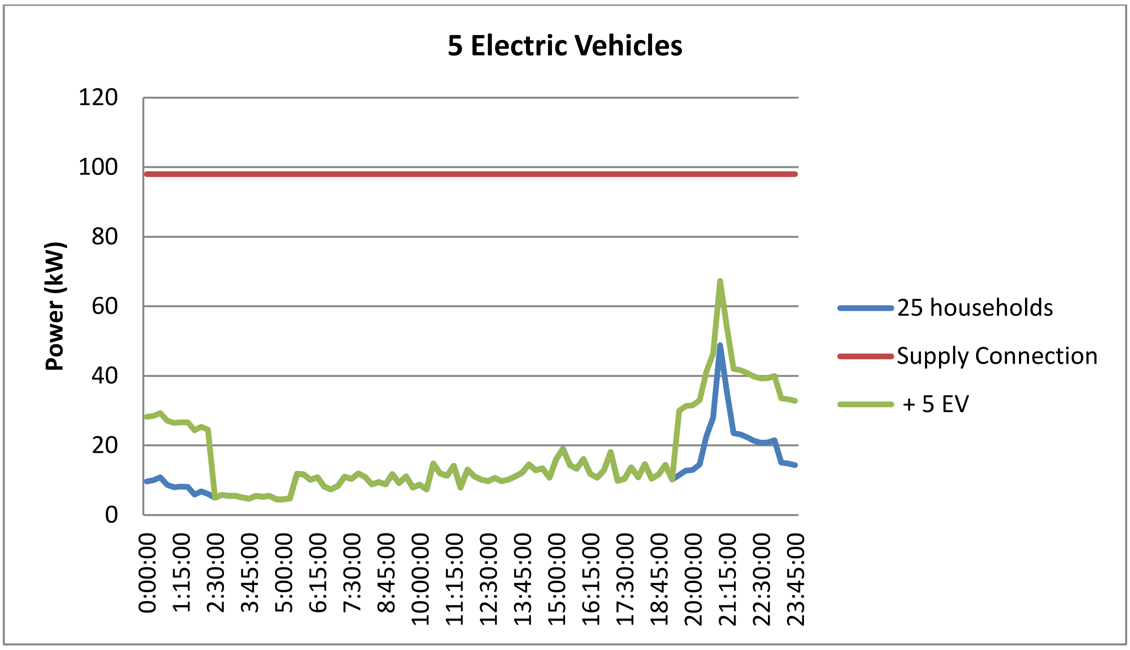


Figure 14: Penetration of 5 EV in 25 households.

When 15 electric vehicles are connected (green line), it is reached the maximum power of the supply connection cable producing an outage. Consumption rises to high levels, therefore it is needed a mechanism to control the quantity of power demanded by the electric vehicles.

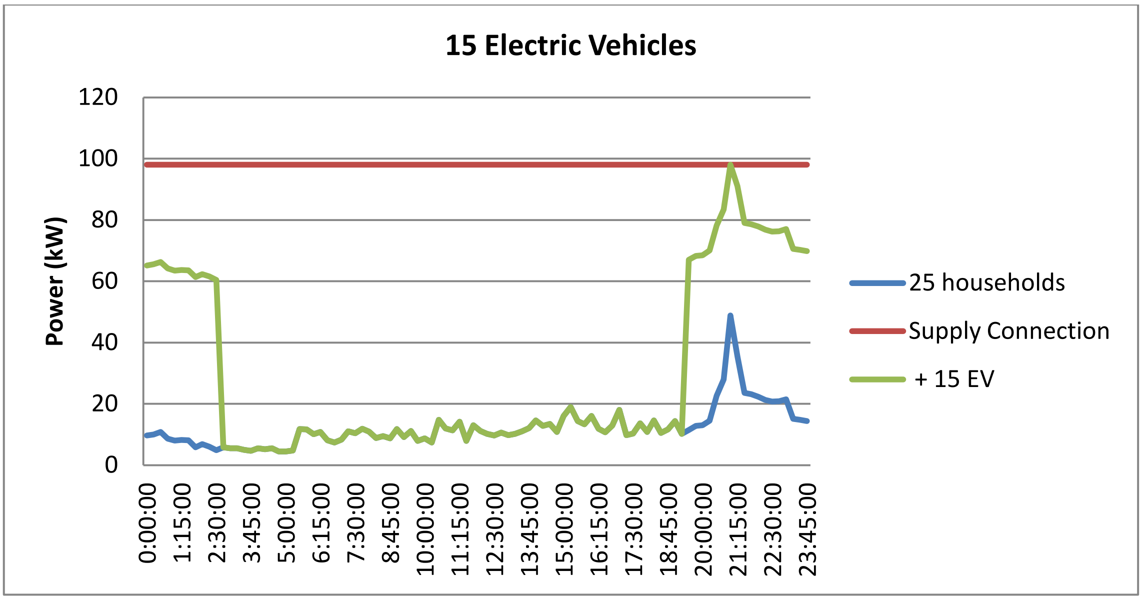


Figure 15: Penetration of 15 EV in 25 households.

Taking into account that for 15 electric vehicles the power demanded reached the levels of the supply connection cable, when 100% of the consumers have an electric vehicle, it is clear that the charging control system has to be implemented. With a control system, the charging period is distributed during the night in order that all of the vehicles have power enough in the morning.

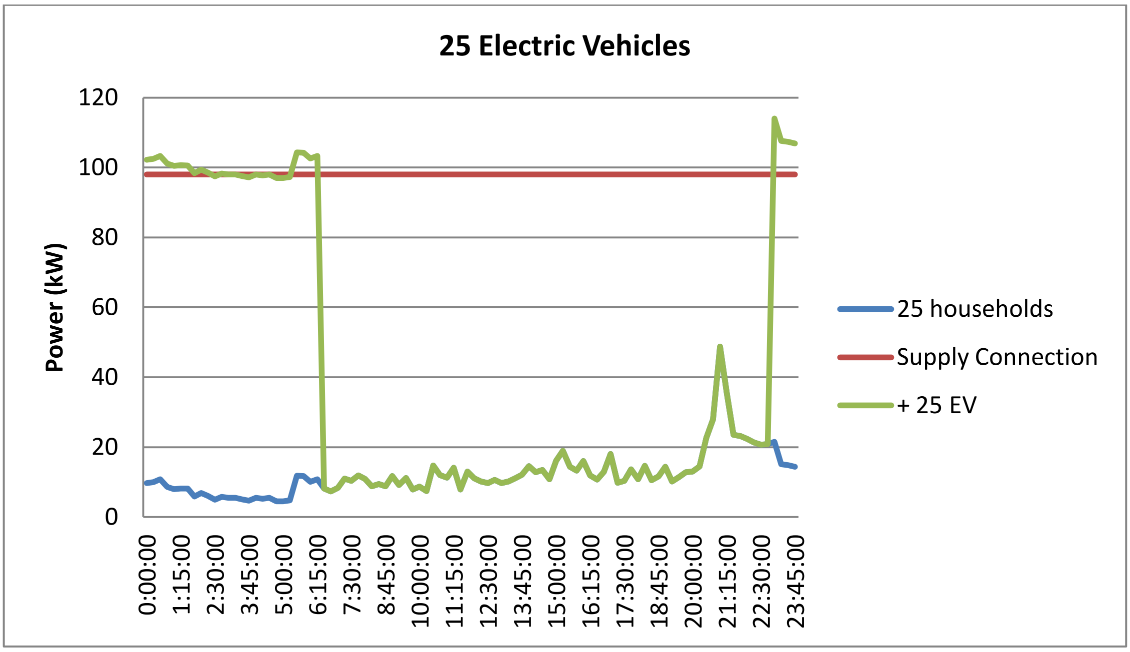


Figure 16: 25 consumers with 25 EV and no control system.

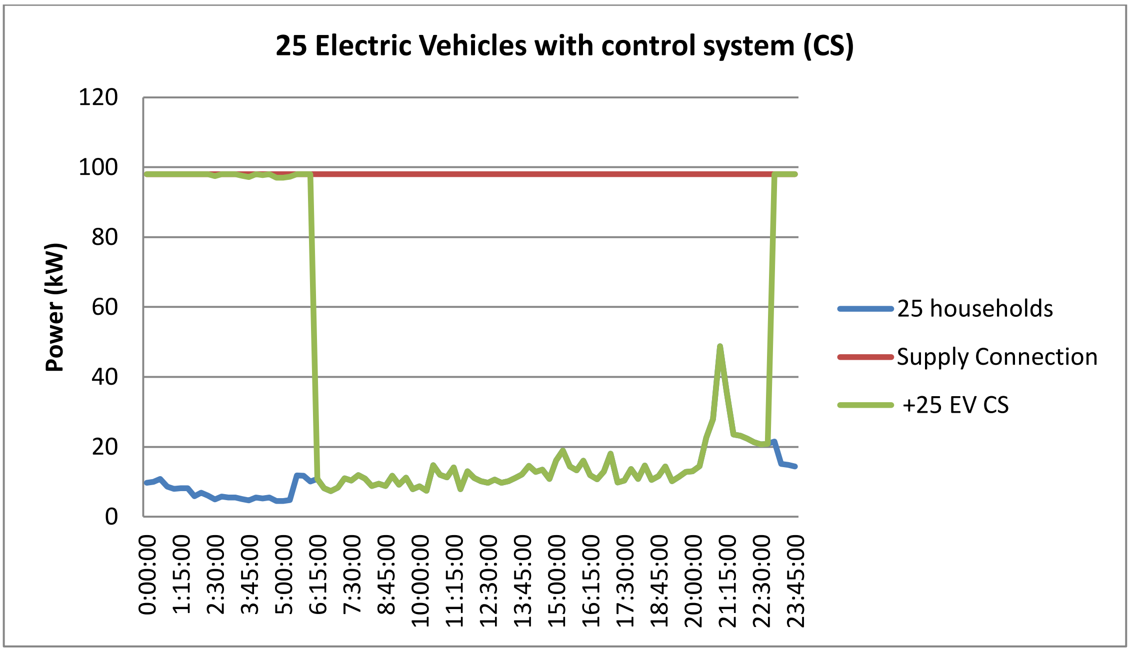


Figure 17: 25 consumers with 25 EV and control system (CS).

After the study of 25 households, this is going to be analyzed for the 175 consumers (7 times the previous study) with and without a system control to limit the power demand until the maximum power support by the supply connection. It was calculated the supply connection capacity, 530kW.

The consumption's profile of 175 consumers in one particular day is the following:

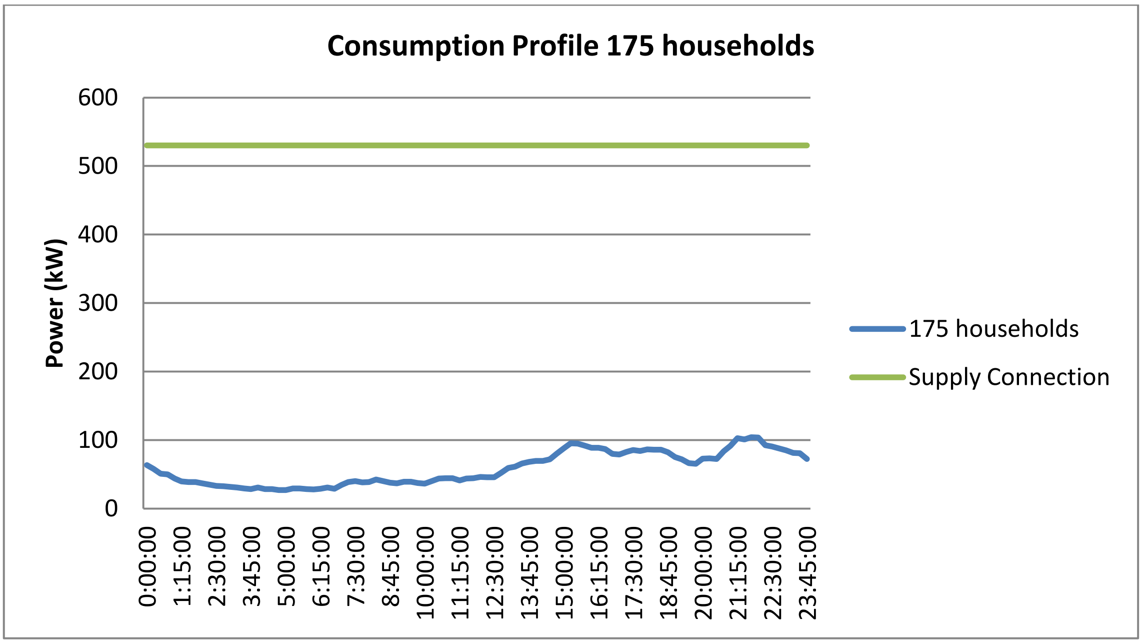


Figure 18: 175 households consumption profile.

With the introduction of a 100% of electric vehicles, that means 175 households with 175 electric vehicles and without a charge control system, the result for one day is:

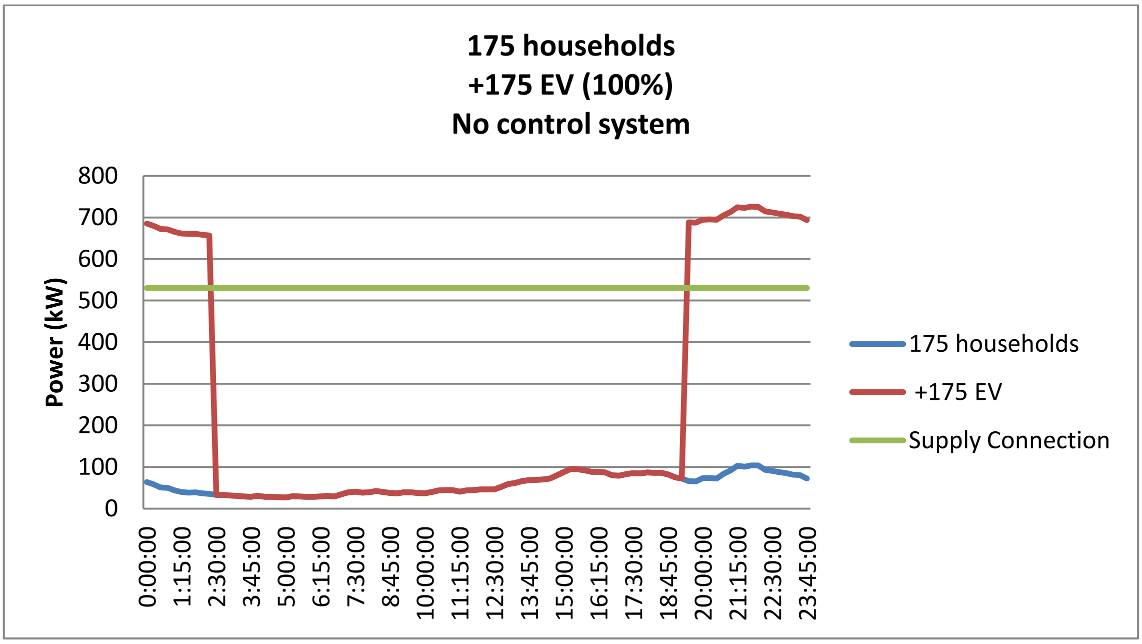


Figure 19: 175 households + 175 EV + No control system

The power supported by the supply connection when electric vehicles are plugged and charging is over its capacity. A control system is needed in order not to overload the connections. If this control system is implemented, the curves remind as follows:

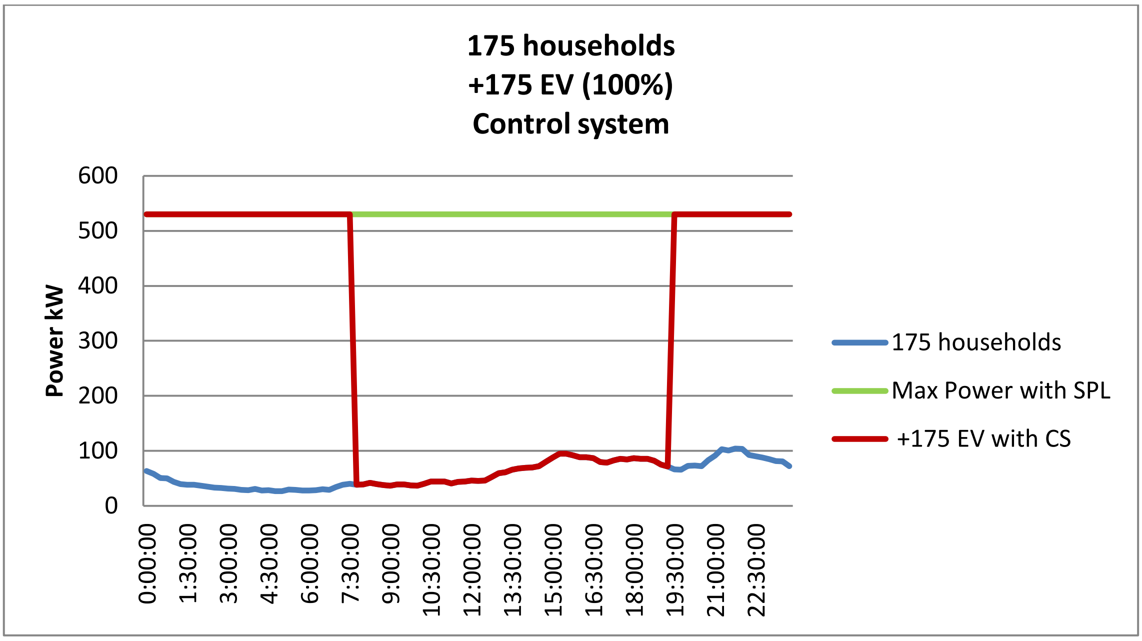


Figure 20: 175 households +175 EV + Control System

The energy consumed by the electric vehicle is going to take advantage of the wind production at nights, avoiding the actual spillages of this generation technology.

If control systems are implemented there is no need of reinforcement in the networks because of the implementation of the Electric Vehicle.

IMPACT ON THE POWER SYSTEM

IMPACT ON THE POWER SYSTEM

Smart meters are going to have an important impact on the Power System.

Different factors studied in this thesis are crucial for determining these impacts:

- Contracted power adaptability.
- Switching to tariffs better adapted to the consumption profile.
- Penetration of the Electric Vehicle.

Contracted power adaptability

Consumers are able to know how much power they need each moment; therefore if they do not use all of the capacity they have contracted, they would change it. In this specific study, the tendency is to reduce it, which means an important reduction on the retribution for the whole system.

In order to mitigate such effect, it is recommended to increase the fix term related to power contracted in the access tariffs.

Switching tariffs

Another consequence of the information available is that consumers can be now an active agent of the system. For instance, they can adapt their consumption responding to correct price signals, starting for optimize their electric tariff.

Consumers would choose the tariff which fist better with their consumption pattern, reducing their bills and also reducing the incomes for the energy term in the access tariffs.

Taking into account the previous point where consumers reduce their power contracted lowering at the same time the power term in the access tariffs, if the energy term is also reduce, there would be a considerable reduction for the incomes with access tariffs. These tariffs represent the remuneration of the system, if they are reduced, the impact on the system would be serious.

Electric Vehicle

The penetration of the Electric Vehicle originates congestions in the networks, which leads to a need reinforcement.

From the study done in this thesis it is appreciated that with an adequate control system to limit and spare the power demanded by plug-in vehicles, the actual capacity of the supply connections is enough.

The average kilometers that an electric vehicle is estimated to road on the streets during a day are about 40 – 50 km, and with a battery of 3.7 kW, 7 hours charging at night are enough.

Distributed Generation

This topic was not study in this thesis but also is related to Smart Meters and has the same consequences as the penetration of electric vehicles.

Smart meters and active demand response enables a higher penetration of intermittent generation (distributed generation, RES) helping to the reduction of CO_2 emissions. The grid becomes more complex, which implicates the reinforcement of networks at the distribution level. This would lead into an increase of the investment for distributors because more grid capacity is needed.

On the other hand, DG increases the capacity of Distributors to emergency and damage control. (Ecorys, 2014).

IMPACT ON THE AGENTS OF THE SYSTEM

IMPACT ON THE AGENTS OF THE SYSTEM

IMPACT ON TSO

With all of the information available, the Transmission System Operator has new tools which allow having a better image of the network. Real-time data helps TSO to keep the security of supply, more manage flexibility and better coordination among distributors referred to pacification and network operation.

Forecasting and capacity allocation would also be facilitated and with this the balancing deviations would also be reduced.

On the one hand, demand response would help to reduce network investments at transmission level because of the possible reduction in capacity reserves at the generation side and to do them efficiently.

Losses would be reduced and the quality of service and security of supply would reach high levels.

IMPACT ON DISTRIBUTORS

The introduction of Smart Meters and an active demand response would make more efficient the operation of the networks by distributors. At the same time, security of supply would be increased.

Having more control over the networks and an optimal operation, technical and non-technical (theft) losses would be reduced. Also Smart Meters can facilitate the automatic connection and reconnection of consumers to the system. A good quality of energy efficiency would be reached.

Due to the technological advances, as it is happening with the Electric Vehicle or the Distributed Generation, networks at medium- to low-voltage levels require some reinforcements, which mean investment on the networks.

As it was shown in this study, regulated incomes through access tariffs could suppose an important risk for distributors if they are not well adapted to the future situation, avoiding the recover from the network investments.

IMPACT ON GENERATORS

Consumers would be empowered to manage their consumption. They would do it in the best way in order to save as much as possible.

If consumers play an active role switching their demand, generators would reduce energy production in peak hours and increase it in off-peak hours. A positive consequence for them would be to avoid investment on peak generation units. In the short term this would lead to an increase in the CO_2 emissions, but they would be mitigated in the long term because of the penetration of intermittent generation.

In short, energy mix would change. A reduction in fuel and fossil fuel generation would lead their space to distributed generation, closer to the demand and with much less environmental impact.

With the smart meters and the real time balance of demand and generation, requirements for capacity reserve in order to assure a certain level of security of supply would suffer a reduction. That means that generators would need lower levels of investment.

IMPACT ON RETAILERS

From the retail perspective, the advantages are more oriented to the satisfaction of the consumer, increasing the quality of the service because they can offer to the clients those tariffs that fit better with their real consumption profile. Also, management of imbalances would be reduced. Real needs are going to be known so energy purchases in the market would be more precise and also volatility of prices would be mitigated.

Smart meters would allow the retail market to respond to real-time prices from the wholesale market. (Navigant Consulting, 2005)

Costumers would have pricing information that they can use to determine the desired consumption profile for the end-uses that can be scheduled one day before energy is delivered. This will be better enable load shifting and conservation and consumers to make good decisions regarding how schedule their energy consumption. (Navigant Consulting, 2005)

Retailer competition would be another impact which benefits consumers. Retailers can compete to offer different electricity tariffs depending on the consumption real profile. Together with the easier way to switch from supplier are the important innovations promoted by smart meters.

It is expected too that there will be less complains about the billing because them are going to be directly related to the real consumption. In this sense, profiles forecasting would not be a problem. Also automatic switching of tariffs is an advantage of smart meters.

Theft would be also detected easily. As it was sawn in the studies carried out in this thesis, about an 8% of the consumers analyzed were in fraud. With smart meters retailers can automatically disconnect these consumers and not incurred in more debt.

An important quantity of transaction costs can be saved.

IMPACT ON CONSUMERS

Consumers will have more information about their real consumption and about the real cost of the energy at each moment. Now they have the opportunity to be part of the electrical system and to control their power demand.

This would help to increase the efficiency at home and also, as it was said in previous points, to reduce the environmental impact. Demand response makes easier the penetration of renewable energy and could help to increase the implementation of micro-generation systems at home.

This last idea could increase the implementation of net meters. This billing equipment is actually working in the United States and it has really good results. When consumers have generation at home (like solar) if they have an excess of production, they can input this energy into the grid. At the end they are going to be billed for their net energy used. Reliability of the systems would increase in terms of security of supply, because in case of energy scarcity, consumers could help to inject energy into the system.

As mentioned before, consumers would be aware of their consumption and about the price that they pay every moment. If they change their behavior to save in their bill, this does not mean just cost savings, it means to better use of energy. Unconsciously consumers would be increasing their energy efficiency at home. Energy wastes and bad use could be reduced.

CONCLUSIONS

CONCLUSIONS

The agents of the Power System are going be highly affected due to the introduction of smart meters and new technologies as the electric vehicle or de distributed generation, mainly renewable energy sources.

Smart meters implementation would lead to operational, managing and planning benefits for the system but also it would have some drawbacks to be aware of.

As the results of this study confirm, the main impacts are going to be at the Distribution level. With all of the information available thanks to the smart meters, consumers would be an active agent and demand response would be a consequence.

In this study and with the data provided it was seen that consumers would be able to use the information mentioned above and react to it. On the one hand, they would adapt their power contracted to the real necessities. In the majority of the cases studies, the power contracted was reduced, which means a reduction in the fix part of the access tariff. The sample studied was small and can not be considered representative for it, but it can be appreciated that the reduction on incomes for the system is considerable. On the other hand, consumers would react to price signals. They would choose the tariff that fits better with their consumption profile, in most of the cases this would be tariff 2.0 DHS and 2.0 DHA. They also could shift their consumption from peak hours to valley hours where the price of the energy is lower. These last options are going to affect to the energy part of the access tariff, which added to the reduction on the fix part lead into a notable reduction on the retribution for the whole system.

In this study it was seen that the supply connection's capacity for the households are capable of supporting the actual demand, but it should be taken into account that the data used belongs to the month of October, which is not representative of the maximum consumption. In October is not needed air-conditioned neither heating. Even though, assuming the actual capacity of the lines, with the recent and future penetration of the electric vehicle, this capacity is fully needed to cover de demand of this new technology. Also, it is going to be needed a control system in order not to overcharge the capacity of the lines, due to the fact that this plug-in vehicles are charged mainly at nights and the supply connection's capacity would be overloaded without it.

With the introduction of these new technologies and the new Distributed Generation, lines should be reinforced at the distribution level, which means high inversions in the connections for the Distributors.

As these agents would be the more affected in the near future situation, regulation should help to reduce the negative effect on it. The main recommendation in order to avoid this effect is to review the tariff configuration. It is obvious that if incomes could be reduced through the access tariffs, their elements should be recalculated. From the study done, the best solution would be to increment the quantity paid by power contracted. Taking this measure, the reduction on incomes for the access tariffs would be partially mitigated.

With the introduction of the Electric Vehicle and the Distributed Generation, another recommendation should be to review the network remuneration for Distributors in order to compensate the network investment that should be carried out to support the new distributed energy sources.

From this study it is clear that regulatory actions should take place during the following years in order to mitigate the negative economic effects that new technologies will have on the Power System.

REFERENCES

REFERENCES

Affonso, C.M., L.C.P. da Silva, W. Freitas (2006). *Demand-side management to improve power security.*

Batlle, C., M. Rivier (2012). *Redefining the new role and procedures of power network operators for an efficient exploitation of demand side response.* IIT working paper. Submited to Energy Policy. December 2012.

Brattle (2007). *Quantifying demand response benefits in PJM.* Prepared for: PJM Interconnection, LLC and the Mid-Atlantic Distributed Resources Initiative (MADRI), Cambridge, Massachusetts: The Brattle Group.

CNE (2011). *Informe sobre el estado de cumplimiento del plan de sustitución de contadores finalizado el primer período de los establecidos en la Orden ITC/3860/2007.* December 2011.

CNE (2011). *Normativa en España sobre contadores con capacidad para telegestión: Requisitos y Planes de sustitución. January 20th, 2011.*

CNE (2012). *Contadores Inteligentes y Telegestión.* Reunión nº5. April 2012.

CNE (2012). *Propuestas relativas a la Gestión de la Demanda.* Reunión nº7. May 2012.

CNE (2012). *Conclusiones del grupo de trabajo sobre Smart Grids. Análisis regulatorio para el desarrollo de las redes inteligentes y la integración eficiente de recursos distribuídos. Vehículo Eléctrico y generación de pequeña potencia.* December 2012.

Conchado A., P. Linares (2012). *The economic impact of demand response programs on power systems. A survey of the state of the art.* In: Sorokin, A., S. Rebennack, N. Iliadis, M. Pereira, P. Pardalos, eds. *Handbook of Networks in Power Systems.* Springer.

Conchado A., P. Linares (2013). *How much should we pay for a DR program? An estimation of network and generation system benefits.*

Directive 2009/72/EC. *Of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC.*

Directive 2009/73/EC. *Of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in natural gas and repealing Directive 2003/55/EC.*

Directive 2009/28/EC. *Of the European Parliament and of the Council on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.*

ECORYS (2014). *The role of DSOs in a Smart Grid environment.* Prepared for: European Commission, DG ENER. Final Report. April 2014.

European Commission (2014). *Report from the Commission. Benchmarking smart metering deployement in the EU-27 with a focus on electricity.* June 2014.

EPRI (2011). *Estimating the cost and benefits of the Smart Grid: A preliminary estimate of the investment requirements and the resultant benefits of a fully functioning smart grid.* Technical report 1022519, March 2011.

ERGEG (2007). *Smart metering with a focus on electricity regulation. European Regulators' Group for Electricity and Gas.*

Haney, A. B., T. Jamasb, M. Pollit (2009). *Smart metering and electricity demand. Technology economics and international experience.* EPRG working paper 0903 – Cambridge working paper in economics 0905. Cambridge: University of Cambridge – Electricity Policy Research Group.

Navigant Consulting (2005). *Benefits of smart metering for Ontario.* Discussion draft, April 2005. Prepared for: Ontario Ministry of Energy. Toronto: Navigant Consulting.

Orden IET/107/2014. *Por la que se revisan los peajes de acceso de energía eléctrica para 2014.* Boletín Oficial del Estado. January 31st, 2014.

Orden IET/290/2012. *Por la que se modifica la Orden ICT/3860/2007, de 28 de Diciembre, por la que se revisan las tarifas eléctricas a partir del 1 de Enero de 2008 en lo relativo al plan de sustitución de contadores.* Boletín Oficial del Estado. February 16th, 2012.

Orden ITC/1659/2009. *Por la que se establece el mecanismo de traspaso de clientes del Mercado a tarifa al suministro de último recurso de energía eléctrica y el procedimiento de cálculo y estructura de las tarifas de último recurso de energía eléctrica.* Boletín Oficial del Estado. 22 de Junio de 2009.

Pérez-Arriaga I. et al. (2013). *From Distribution Networks to Smart Distribution Systems: Rethinking the Regulation of European Electricity DSOs.* THINK Project. June 2013.

Real Decreto 1164/2001. *Por el que se establecen tarifas de acceso a las redes de transporte y distribución de energía eléctrica.* Boletín Oficial del Estado. October 26th, 2001.

Real Decreto 842/2002. *Por el que se aprueba el Reglamento electrotécnico para baja tensión. Reglamento electrotécnico para baja tensión e instrucciones técnicas complementarias (ITC) BT 01 a BT 51. August 2nd, 2002.*

Real Decreto 216/2014. *Por el que se establece la metodología de cálculo de los precios voluntarios para el pequeño consumidor de energía eléctrica y su régimen jurídico de contratación.* Boletín Oficial del Estado. March 28th, 2014.

Real Decreto 1110/2007. *Por el que se aprueba el Reglamento unificado de puntos de medida del sistema eléctrico.* Boletín Oficial del Estado. August 24th, 2007.

Real Decreto 10 de Febrero de 2014. *Por el que se establece la metodología de cálculo de los precios voluntarios para el pequeño consumidor y su régimen jurídico de contratación.* Ministerio de Industria, Energía y Turismo.

Resolución del 31 de Enero de 2014. *Por la que se revisa el coste de producción de energía eléctrica y los precios voluntarios para el pequeño consumidor.* Dirección General de Política Energética y Minas. Boletín Oficial del Estado.

Resolución de 8 de Septiembre de 2006. *Por la que se modifica la Resolución de 4 de Marzo de 2006, por la que se establece la tabla de potencias normalizadas para todos los suministros en baja tensión.* Dirección General de Política Energética y Minas. Boletín Oficial del Estado.

Raso, C. (2014). *Article in El Economista journal. Así son los nuevos contadores inteligentes que medirán el consumo de la luz.* April 4th, 2014.

Siderius, H. P., A. Dijkstra (2006). *Smart metering for households: cost and benefits for the Netherlands.* SenterNovem.