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Methodology to "decipher" the electricity bill of a prosumer in Spain: application to practice 4 of the course Generation, Transmission, and Distribution of Electricity

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Abstract

The calculation of the electricity bill components is not an easy task in Spain. Such calculation is even more complex when there is a renewable system in the equation consumer-producer (Prosumer). One of the skills that the student of the course on Generation, transmission, and distribution of electricity, belonging to the master's in industrial engineering at the Polytechnic University of Valencia in Spain, must learn is how to calculate an electricity bill. This paper aims to give the students a tool to learn how to estimate a prosumer electricity bill, employing a methodology that facilitates and makes learning faster. A real prosumer Electricity bill was employed, analyzed, and calculated. Each concept will be segregated and calculated, explaining how it was obtained. The tools used for carrying out the practice are MS excel and the web of i-DE for downloading the hourly data of the invoice. A detailed method to calculate the electricity bill was obtained as a final result.

Keywords: *Electricity bill, prosumer, Lab practice.*

Introduction

The model to calculate the electricity bill in Spain is complex, and it is not easy to calculate its cost. Because a PV system is added to the equation, the calculation is even more complicated when a prosumer is included. Several publications have analyzed the electricity bill and the energy cost, but since the model to estimate the electricity bill changed in June 2021, the information must be updated. (Alcazar-Ortega et al., 2019) explain how to calculate

the electricity bill through the regulation before June 2021. (Roldán-Fernández et al., 2021) explain the impact of the domestic PV system in the Iberian electricity market and the profitability of household PV self-consumption in Spain (Roldán Fernández et al., 2021). An estimation of electricity Bill savings for residential solar PV system owners is analyzed by (Fikru, 2019a). Also, the electricity bill forms the inequality of energy poverty is studied by (Aristondo et al., 2018). Additionally, other authors have estimated the potential to reduce the electricity bill cost (Fikru, 2019b; Javaid et al., 2021). Finally, (International Renewable Energy Agency (IRENA), 2019) analyzes the future of solar PV: Deployment, investment, technology, grid integration and socio-economic aspects.

This paper analyzes how to estimate the electricity bill according to the State Official Gazette BOE-A-2021-7120 (Ministerio de Educación y Formación Profesional et al., 2019). This analysis is applied to one of the practices in the "Generation, Transmission, and Distribution of Electric Power" course belonging to the Master in Industrial Engineering at the Univesitat Politènica de València, Spain. Among the topics to be analyzed by the students are components of an electricity bill and its estimation (Tariff 2.0 TD). The concepts are applied to a real case, obtaining the bill's final cost.

1.Method

In an electricity bill, one part of the total cost goes to the supplying company and the other part (regulated part) goes to the electrical system through the distribution company. A 2.0 TD electricity bill has three periods and includes the following Concepts (Cañas Peñuelas et al., 2020):

- **a)** Payments to the electricity supplier. It is a variable term that depends on energy consumption. The price depends on the agreement consumer-supplier in the liberalized market and the indexed prices in the daily market if the client accepts the Voluntary Price for Small Consumers (known in Spanish as PVPC - Precio Voluntario para el Pequeño Consumidor).
- **b)** Payments to the electricity system for using the electrical grid. It consists of a variable term based on consumption plus a fixed period. The prices of both energy and contracted power are regulated. The payment to the electrical system includes energy (Fixed cost per kWh, the total variable cost depends on the consumed energy), contracted power, payments to the distribution company for meter rental, and Taxes (Electricity tax and VAT).

From June 2021, there is only one option of PVPC corresponding to the 2.0 TD tariff, which replaces the tariff, 2.0 A; 2.0 DHA, and 2.0 DHS. The 2.0 TD tariff is based on hourly discrimination and divided into different daily consumption periods. The tolls and charges applied to the electricity bill vary according to the consumption period, as shown in Fig. 1.

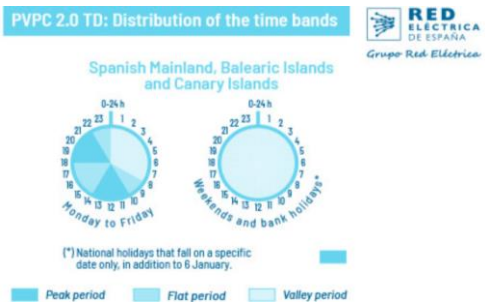

Fig. 1 Consumption periods – Tariff 2.0 TD (Voluntary price for the small consumer (PVPC) | Red Eléctrica, n.d.)

1.1.Estimation of the energy cost (E_{cost})

To estimate the term of the energy or energy cots (E_{cost}) it is used equation 1.

$$E_{cost} = \sum_{h=1}^{hour/month} E_h \cdot E_{cost,h} \quad (1)$$

Where: E_h is the energy consumed in each hour (h); $E_{cost,h}$ is the total energy price each hour, published by the System Operator (It includes tolls, hourly cost of the energy,hourly cost of the losses, and other system costs).

1.2.Cost of the power (P_{cost})

Regarding the cost of the power, it is estimated through equation 2.

$$P_{cost} = T_{cost} + C_{cost} + S_{cost} \quad (2)$$

Where: T_{cost} is the power term for the transmission and distribution tolls; C_{cost} is the power term of the charges and S_{cost} is the economic supplier benefit. To estimate the transmission and distribution cost (T_{cost}) and the charge cost (C_{cost}), equations 3 y 4 are used.

$$T_{cost} = T_{cost,P1} \cdot P_{contra,P1} + T_{cost,P2} \cdot P_{contra,P2} \quad (3)$$

$$C_{cost} = C_{cost,P1} \cdot P_{contra,P1} + C_{cost,P2} \cdot P_{contra,P2} \quad (4)$$

Where: $T_{cost,P1}$ and $T_{cost,P2}$ are the transmission and distribution toll prices for periods P1 (peak and standard) and P2 (off-peak); $C_{cost,P1}$ and $C_{cost,P2}$ are the prices of charges of the periods P1 (peak and standard) and P2 (off-peak); $P_{contra,P1}$ and $P_{contra,P1}$ are the powers contracted during the periods P1 and P2. The supplier benefit is calculated through equation 5.

$$S_{cost} = S_{cost,€/kW} \cdot P_{c\_P1} \quad (5)$$

Where: $S_{cost,€/kW}$ is the suplier's margin, expressed in €/kW. This value is periodically updated in the state's official gazette (In Spanish it is know as BOE). The current value is €3.11/kW per year. P_{c_P1} is the power contracted by the consumer in the peak period (P1) and S_{cost} term is prorated based on the number of days in the billing period.

2.Case study

The previous concepts have been applied to a real case. It is a single-family house that has a 4.2 kW PV system. General information about the electricity bill is given in Table 1. Detailed information on the real electricity bill is given in Table 2. It must be considered that due to a substantial increase in the electricity bill because of rising gas prices, the Spanish government decided to reduce during a limited and undefined period (included the period of the analyzed invoice) the VAT from 21 to 10% and the electricity tax from 5.11% to 0.1%. Also the toll and charge were significantly reduced for every period.

Table 1 Information about the electricity bill (January 1 to 31, 2022)

Total kWh – Tariff 2.0 TD		
Tariff	2.0 TD	
Contrated power (kW)	4	
Period	Jan 2022	
%P1	73.7	25%
%P2	31.4	10%
%P3	195.4	65%
Total kWh	300.5	100%
Cost of the bill	41,11€	

Table 2 Real electricity bill (January 1 to 31, 2022)

Contracted power ("Fixed term"):	
Amount for transmission and distribution tolls power:	
P1 (peak): 4 kW x 31 days x €0.062982/kW day	7.81
P2 (Off-peak): 4 kW x 31 days x 0.002572 €/kW day	0.32
Amount for power charges:	
P1 (peak): 4 kW x 31 days x €0.013618/kW day	1.69
P2 (Off-peak): 4 kW x 31 days x 0.000876 €/kW day	0.11
Fixed marketing margin:	
4 kW x 31 days x 0.008529 €/kW day	1.06
Energy consumed ("VARIABLE TERM"):	
Amount for energy transmission and distribution tolls:	
P1 (peak): 73.7 kWh x €0.027787/kWh	2.05

P2 (Standard): 31.36 kWh x €0.019146/kWh	0.6
P3 (Off-peak): 195.43 kWh x €0.000703/kWh	0.14
Amount for energy charges:	
P1 (peak): 73.7 kWh x €0.072969/kWh	5.38
P2 (Standard): 31.36 kWh x €0.014594/kWh	0.46
P3 (Off-peak): 195.43 kWh x €0.003648/kWh	0.71
Energy cost	82.69
Compensation of surpluses	
-344.07kWh x €0.194083/kWh	-66.78
Electricity tax	
300.49 kWh x €0.001/kWh	0.3
Subtotal	36.54
Meter rental: 31 days x €0.02663/day	0.83
Total	37.37
Application tax: Reduced VAT (*) 10% S/37.37€	3.74
Total amount invoice (€)	**41.11**

3.Results

The obtained results give detailed information about every concept explained in point 2: cost of the contracted power (Table 4) and energy cost (Table 3). Also, a summary of the electricity bill costs is shown in Table 5. The cost of the real bill is 41,11 €, while de cost calculated using the methodology is 41,09€. Considering that there may be minor discrepancies due to the number of decimal places used, the result is reasonable. It is important to remark that, according to (Ministerio para la transición ecológica, 2019) the maximum revenue for exporting electricity is the cost of the energy. In this case, it is 82.69€ (Table 5)

Table 3 Summary of the cost for energy cost (Variable term)

Summary of the cost for energy cost (Variable term)		
P1	kWh	73.7
	Toll c€/kWh	2.78
	Toll €	2.05
	Charges c€/kWh	7.30
	Charges €	5.38
	Commercialization c€/kWh	27.52
	Commercialization cost €	20.28
	Total P1 €	27.71
P2	kWh	31.4

	Toll c€/kWh	1.91
	Toll €	0.60
	Charges c€/kWh	1.4594
	Charges €	0.46
	Commercialization c€/kWh	27.5184
	Commercialization cost €	8.63
	Total P2 €	9.69
P3	kWh	195.4
	Toll c€/kWh	0.070
	Toll €	0.14
	Charges c€/kWh	0.365
	Charges €	0.71
	Commercialization c€/kWh	27.5184
	Commercialization cost €	53.78
	Total P3 €	54.63
	Toll total TD €	2.79
	Total charges €	6.55
	Cost of the energy (Max to be compensated) €	82.69
Solar energy	Surplus electricity kWh	344.07
	Selling cost c€/kWh	19.408
	Selling cost €	66.78
Summary	Total P1+P2+P3 €	92.02
	Total electricity compensated €	66.78
	Total cost of the electricity €	25.25

Table 4. Summary of the cost for contracted power (fixed term)

Summary of the cost for Contracted power (fixed term)		
Contracted power	4	kW
Days	31	
P1 tolls TD	0.0630	€/(kW*day)
	7.81	€
P1 charges	0.0026	€/(kW*day)
	0.32	€
Total P1	8.13	€
P2 tolls TD	0.01362	€/(kW*day)
	1.69	€
P2 charges	0.00088	€/(kW*day)
	0.11	€

Total P2	1.80	€
Commercialization	0.0085	€/(kW*day)
	1.06	€
Total	10.98	€

Table 5 Summary of the electricity bill costs (€)

Summary of the electricity bill costs (€)	
1. Contracted power ("FIXED TERM")	10.98
2. Energy consumed	92.02
3. Electricity compensated (Due to PV system)	-66.78
4. Electricity tax (0,001 €/kWh * 300 kWh)	0.30
5. Meter rental (0.02663 €/day*31 days)	0.83
Total (Without VAT)	37.35
TOTAL AMOUNT INVOICE (Reduced VAT 10%)	41.09

On the other hand, the bill was also estimated without considering the PV system. In such a case, the cost of the bill would be 152,71€, as is shown in Table 6. Consequently, there was a saving of €111,62 due to the PV system, equivalent to 73%.

Table 6 Electricity bill without PV

Power term	**10.98**
Total actual consumption (kWh)	416.9
Consumption P1 (kWh)	102.3
Consumption P2 (kWh)	43.5
Consumption P3 (kWh)	271.2
Cost P1 (c€/kWh)	37.6
Cost P2 (c€/kWh)	30.9
Cost P3 (c€/kWh)	28.0
Cost P1 (€)	38.44
Cost P2 (€)	13.44
Cost P3 (€)	75.80
Energy term (€)	127.68
Total Energy + power (€)	138.66

Total with electricity tax (€)	138.80
Meter (€)	0.83
Total tax base (€)	139.63
Total invoice with VAT (€)	**153.59**
Total savings (€)	112.50

Table 7 shows the energy balance. The PV system produced 461 kWh, 344 of which were exported to the grid, 116 for self-consumption, and 300 kWh were imported from the grid. Finally, a Sankey graphic with the bill components is shown in Fig. 2.

Table 7 Energy balance

Power generation - PV Production (kWh)	**460.5**	**100%**
Exported (kWh)	344.1	74,7%
Self-consumption (kWh)	116.4	25,3%
Power consumption - Total consumption (kWh)	**416.9**	**100%**
Imported (kWh)	300.5	72,1
Self-consumption (kWh)	116.4	27,9%

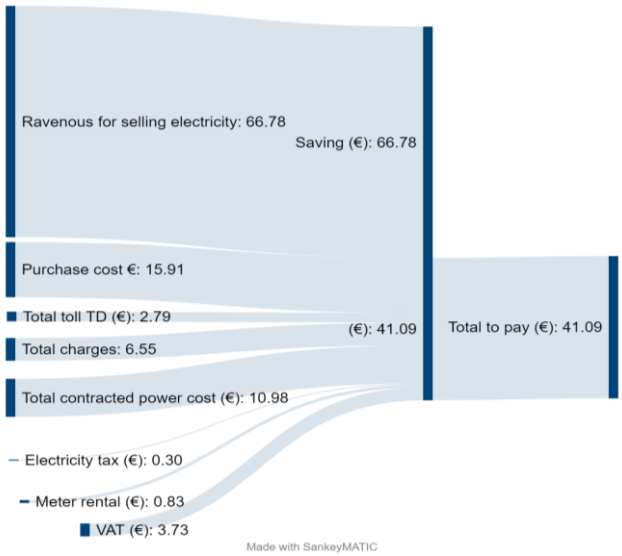

Fig. 2 Sankey diagram of the analyzed electricity bill.

Conclusions

The calculation of the electricity bill costs is a challenge. Nevertheless, it is possible when the regulation is well known. This work estimated the cost of the electricity bill for a prosumer (A single familiar household). The given information in the bill by the supplier is not enough to understand how every bill component is found. One point to improve in a current bill is the information regarding the energy term to pay to the supplier company. There is no information about how this value is obtained and the cost paid in every period; this point must be corrected to give clear information to the customer. Also, a saving of 112.50€ is estimated due to the PV system, equivalent to 73% of the electricity bill. Finally, the students must acquire all the mentioned techniques and knowledge during the practice. As a limitation of the work, it can be said that the methodology is applied to a three-period domestic electricity bill. Future work could include industrial bills with 3-6 periods.

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