Journal of Business Management and Economics 06: 06 June (2018).

Contents lists available at www.innovativejournal.in

JOURNAL OF BUSINESS MANAGEMENT AND ECONOMICS

Home page: http://innovativejournal.in/index.php/jbme

ISSN: 2347-5471

The Electricity Consumption Forecast with Micro and Macro Analysis

Nuno Domingues, ISEL-ADEM

Rua Conselheiro Emídio Navarro, 1, 1959-007 Lisboa, Portugal

DOI: https://doi.org/10.15520/jbme.v6i06.2190

Abstract: Electricity forecast is a key subject to support decision making. Understand all key factors, the major agent's interaction and the results of the available energy mix are important on the electricity sector.

The present paper presents a method of approach to define a complete top-down and bottom-up hybrid model. This method is a baseline to build a tool to test and analyse the electricity market in a Country to provide results that would allow to make quantitative balance and to eliminate unfeasible options.

The present paper focuses on the behaviour and on the response areas of the electricity markets.

Keywords: electricity forecast; top-down, bottom-up, decision support system, energy mix

CONSUMPTION FORECAST

To understand and foretell the impacts on the system, the evaluation from a macroeconomic model on the several indicators has a key role. The impacts based only in the published national data are not credible because it does not reflect the internal policy actions, the external development and agent's behaviours.

To model the Portuguese electric system, the present paper also includes the consumption forecast. A power system is more or less complex depending on the grid design, type, number, location and capacity of power plants, feeders, number of lines, connections, equipment and type, demand and location of consumers, among others. Medium term management and long term planning seek a balance between economy and reliability.

To forecast the electricity daily consumption curve in Portugal (the load diagram), one has to analyze the various consumer types, according to the typical load diagram available on the historic load diagrams. Each consumer has different inner attributes. This provides, for a certain period of time, the evolution of consumption of that customer. Figure 2.1 Illustrates the load diagrams contour for different group of consumers:

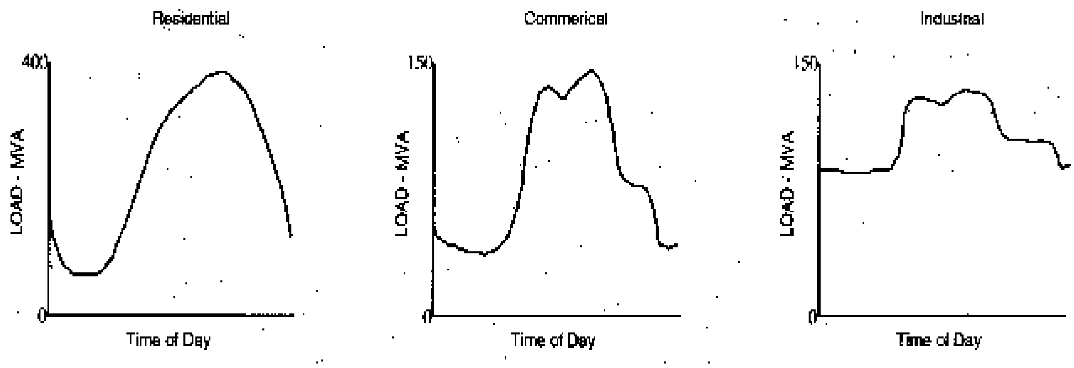

Figure 2.1- Load diagrams for different group of consumers

A load diagram indicates the pair of values (consumption, hours) for a type of consumer for a day of the week. When studying a group of consumers the influence of each in the total decreases, the greater the number of consumer households less individual consumer characteristics appear and less rapid changes in the consumption, as illustrated in Figure 2.2. In the present paper it is considered a large enough group of consumers to "filter out" the load profile. To select the method of load forecasting is necessary to take into account the available data, the computational resources and the desired efficiency (or the admissible error).

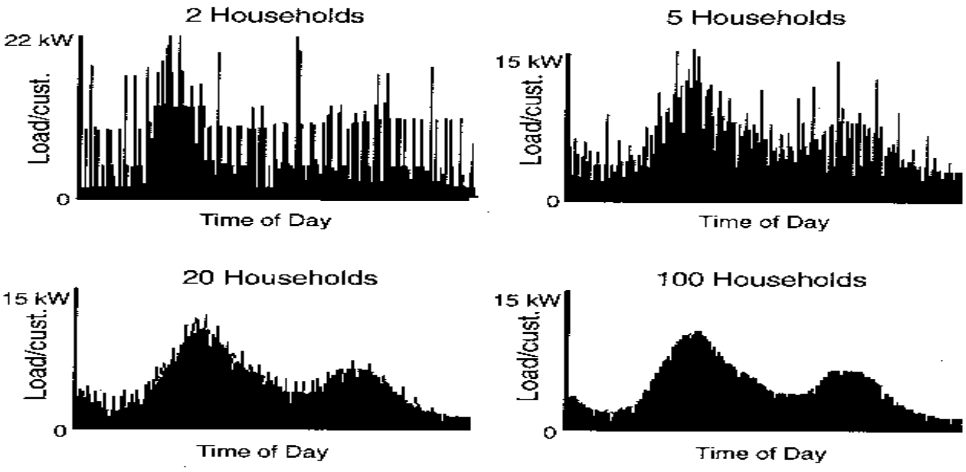

Figure 2.2- Load diagrams for different number of household consumers

The first difficulty faced was the amount of information that was necessary to handle. A daily load diagram has infinite points. Apparently, there is a function that easily portrays the characteristic curve of a given load profile. Thus, there was the need to begin by trying to simplify the load diagram to handle less data but obtain credible information. For the observation of several load curves one realizes that the curve can be "filter out", as illustrated in Figure 2.3

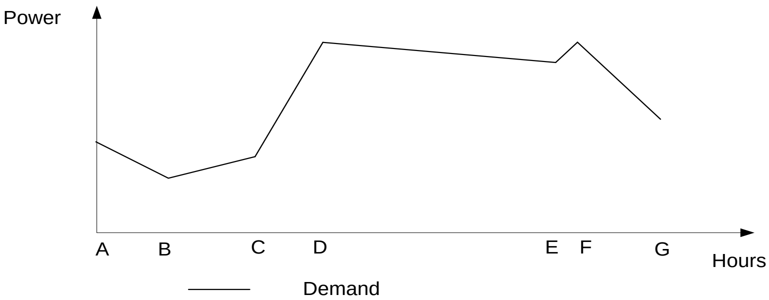

Figure 2.3- Typical load diagram

Where:

A. consumption at 00h00m
B. Minimum super off peak
C. Home consumption growth in the mornings (domestic consumption followed by the start of business activity)
D. Peak daytime
E. End of work and business activity
F. Night Peak
G. Consumption at 24h00m

The approach presented is the trapezium rule (single), which, for a section of the curve, can be illustrated as Figure 2.4, taking in reflection the consumption profile defined by Figure 2.3.

And mathematically by the equation

$$T(f) = \frac{(f(a) + f(b))(b-a)}{2},$$

matching exactly to the value of the area of the trapezoid defined by the interpolating line. If the approximation is fine enough, one can reduce the infinite points of the load diagram to only 7 points. The quality of the approximation depends on the error of this method and the assumed negligible error.

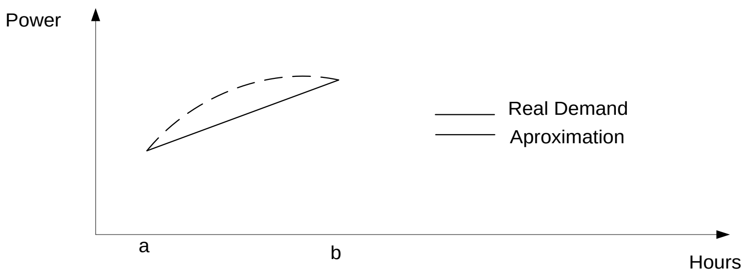

Figure 2.4- Trapezium rule (single)

The next step is to typify the seasonal load curves. In the present paper there was the chose to separate into the following groups: summer, winter, summer holidays, winter holidays, higher energy consumption day, highest peak consumption day and lowest peak consumption day. In addition, the first four groups were divided into weekdays and week-end. Thereby, these 13 days are used to represent all the 365 days (or 366 days every 6 years) of a year.

The single error is $d_k = f(x_k) - \varphi(x_k)$. Using the quadratic error, $d_k{}^2 = (f(x_k) - \varphi(x_k))^2$, one can avoid the symmetric errors and increase the error sensitivity. For the method, the quadratic error is

$$\sum_{k=1}^{m} d_k{}^2 = \sum_{k=1}^{m} (f(x_k) - \varphi(x_k))^2$$

After the analysis of the historic load diagrams, a demographic and economic forecast is carried and then the forecasting of electricity consumption. An accurate forecast requires precision in both in the economic, the consumer type and the energetic aspects of the electricity consumption.

A forecast can be accomplished through two different methodologies that are predictions by interpolation (causal) and by extrapolation. The main difference is that the extrapolation methods do not take into account the cause of past data but only assume that past trends and patterns continue in the future, so they are not used. There are several factors that influence the natural evolution between consecutive years: demography, use of special equipment (e.g., air conditioning, heat pumps), electricity price, the price of the substituting energies, family income (or budget or their purchasing power) variation, GDP, Government spending, productivity, stock, wages, capital, fiscal balance, trade balance, unemployment, precipitation, high and/ or low temperature, for example. There are factors that influence more than others.
There are three interpolation methods for load forecast:

- Econometric Regression - uses historical energy consumption and other data (such as economic, behaviour, social, environmental and exogenous data) to determine the elasticity of consumers, i.e., a measure of how consumers will change their consumption accordingly to that data. Based on the elasticity of the consumer and assuming they do not vary over time, carried out a forecast of energy. This method is widely applied in predicting the energy consumption.
- Saturation method - performs surveys to determine the number of consumers with a particular appliance (e.g. air conditioning) and the energy consumed by this. Thus, based on the forecast of the number of devices expected in the future, along with the prediction of energy expended annually by each, it is possible to forecast energy consumption. This method is usually used applied to the residential sector.
- Method of the Energy End Use - This method is similar to the previous one except that instead of using an application based on the forecast, the base is an end-use energy. For example, the sales forecast of energy can be developed based on forecast growth in the area of the commercial sector.

When there are historical data from 10 to 15 years, econometric regression methods are the most used ones. That is the case of the present paper. For that, the forecast is based on the assumption that the future electricity consumption per consumer depends on some factors. The way to understand these relations is made by mathematical regressions (simple and multiple) analyses and compare between the estimated values and the real ones for the past years.
The mathematical equations of the forecast are:

$$Y_i = A + B(X_i - \overline{X}) + C(Z_i - \overline{Z}) + ... + \varepsilon_i = \hat{Y}_i + \varepsilon_i$$

Where

i Year

Y_i Actual consumption value

A, B, C, ... factors to be calculated

X, Z, ... correlated data

$\overline{X}$ Medium value of X_i

ε_i Error between the real and the forecast values of electricity consumption

$\hat{Y}_i$ Forecast value of electricity consumption

The medium value of X is:

$$\overline{X} = \frac{1}{n} \cdot \sum_{i=1}^{n} X_i$$

To calculate the values of the factors A, B, ... it is solved the minimisation problem of the quadratic errors, as follows:

$$\min \sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2 \Leftrightarrow \min \sum_{i=1}^{n} (Y_i - A - B \cdot (X_i - \overline{X}) - C \cdot (Z_i - \overline{Z}) - ...)^2$$

By derivation in order to each factor and equals to zero:

$$A = \frac{\sum_{i=1}^{n} Y_i}{n}; \qquad B = \frac{\sum_{i=1}^{n} Y_i \cdot (X_i - \overline{X})}{\sum_{i=1}^{n} (X_i - \overline{X})^2};$$

$$C = \frac{\sum_{i=1}^{n} Z_i \cdot (Z_i - \overline{Z})}{\sum_{i=1}^{n} (Z_i - \overline{Z})^2}; ...$$

The distance between point i to the average value of Y is equal to the sum of the distance between i and the regression line with the distance between the regression line and the average value of Y:

$$(Y_i - \overline{Y}) = (Y_i - \hat{Y}_i) + (\hat{Y}_i - \overline{Y})$$

Adding all values and powering them:

$$\sum_{i=1}^{N}(Y_i-\overline{Y})^2=\sum_{i=1}^{N}(Y_i-\hat{Y}_i)^2+\sum_{i=1}^{N}(\hat{Y}_i-\overline{Y})^2+2\cdot\sum_{i=1}^{N}(Y_i-\hat{Y}_i)\cdot(\hat{Y}_i-\overline{Y})=\sum_{i=1}^{N}(Y_i-\hat{Y}_i)^2+\sum_{i=1}^{N}(\hat{Y}_i-\overline{Y})^2$$

The measure that quantifies the quality of the adaptation to the regression of the data is called "explanatory variable: R^2." The explanatory variable is

$$R^2 = \frac{\sum_{i=1}^{N}(\hat{Y}_i - \overline{Y})^2}{\sum_{i=1}^{N}(Y_i - \hat{Y}_i)^2} \in [0,1]$$

The bigger the explanatory variable is, the more accurate is the method.
After the load consumption forecast, one should forecast the energy mix. For that it is used a diagram of load duration, the same used to planning.

The predicted load generally includes forecast annual electricity consumption of energy (kWh) and peak power demand (kW). The annual electricity consumption of energy is given by integration over time of the load during the year.

For planning is common to use the load duration curve, illustrated in Figure 2.5. This curve is obtained from the weekly consumption satisfaction that the net production by type of plant in a given year.

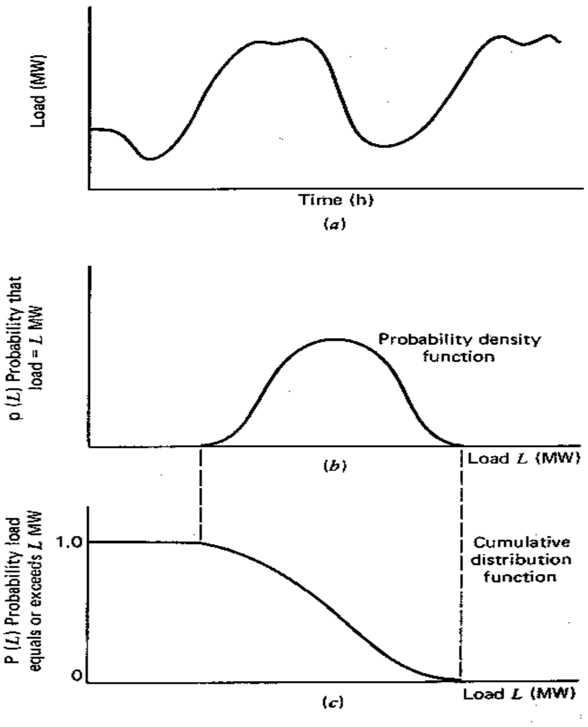

Figure 2.5- Probability curves of load duration

The load duration curve provides the maximum peak, minimum peak and it is possible to obtain the average value from it.
It is important to have a duration curve in order to be able to make predictions about the behaviour of the load in the future.

Mathematically, one has to estimate the slope parameters and work on probability functions:

$$F_x(x) = \int_{\infty}^{x} f_x(x)dx$$

$$F_x(x) = P(X \leq x)$$

Being,

$f_x(x)$ probability density function

$F_x(x)$ probability function

A usual criterion for determining the load duration curve is the "loading". This curve are represented five generating units, whose position is subject to an order of merit (i.e., an order of increasing efficiency), as illustrated in Figure 2.6.

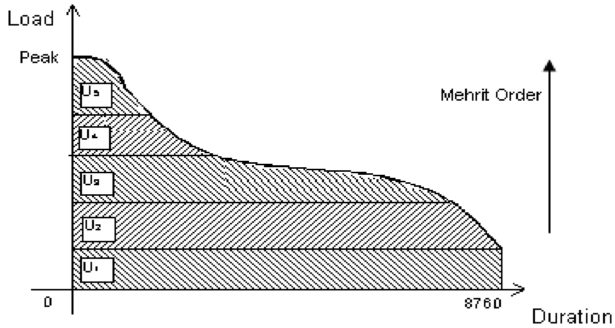

Figure 2.6- Diagram of load duration by loading criterion

The merit order is based on the average cost at full load. The unit System Management takes into account the total costs, not only the marginal. Each area in the figure represents the total energy produced by the unit U_i in a year. For a determined number of hours worked annually, h, the unit annual energy generated the power P. If it worked 8760h year, then one can calculate the relative power to h by:

$$P_{Rel} = \frac{P.h}{8760}$$

In this method the only parameter that remains is the exact energy. This is not truthful for a prediction because it doesn't reflect a change that can occur whether in power level or in the number of hours.

To calculate the price of energy, in order to estimate its evolution, it becomes necessary to use a weighted average cost:

$$C_{med} = C_{medPRO} + C_{medPRE} + C_{med\,\mathrm{Im}} \Leftrightarrow$$

$$C_{med} = (\frac{Q_{hydro}}{Q} C_{hydro} + \frac{Q_{Coal}}{Q} C_{Coal} + \frac{Q_{NG}}{Q} C_{NG}) + \frac{Q_{PRE}}{Q} C_{PRE} + \frac{Q_{\mathrm{Im}}}{Q} C_{\mathrm{Im}}$$

where

- *PRO*- Ordinary production
- *PRE*- Special production
- *Im*- Import/ export of electricity balance
- C are the different costs
- Q are the different production quantities

Then it's necessary to add the allowed surplus defined every year by ERSE.

CONCLUSIONS

It is not sufficient to apply bottom-up or top-down approaches alone when the goal is to develop a simple and complete model of a complex and wide problem. Some variables could be directly insignificant but influence variables that have a crucial role on the system should be modelled.

An interactive and self learning tool is important in decision making in the electricity sector. Thereby, an appropriate background study that combines top-down and bottom-up approaches is crucial. Also, this tool should pay attention to the generation and to the consumption behaviours.

REFERENCE

[1] Sprague, Ralph H. e Hugh J. Watson, 1991, Sistemas de Apoio à Decisão, Campus, ISBN : 85-7001-649-2

[2] João J. E. Santana e Maria José Resende, 2006, Reflectir Energia, ETEP - Edições Técnicas e Profissionais, ISBN 9789728480141

[3] H . Lee Willis, Power Distribution Planning Reference Book, 2004, CRC Press ISBN: 978-0-8247-4875-3

[4] Allen J., Bruce F. Wollenberg, 1996, Power Generation, Operation, and Control, Wiley-Interscience, ISBN: 0471586994

[5] Richard C. Dorf, 1997, The Electrical Engineering Handbook, CRC Press, ISBN: 978-0-8493-8574-2

[6] Caracterização da procura 2018, ERSE, available online http://www.erse.pt/pt/electricidade/tarifaseprecos/2018/Documents/Caracteriza%C3%A7%C3%A3o%20Procura%20EE%202018.pdf

[7] ADENE, Guia da eficiência Energética, ISBN 978-972-8646-17-2

[8] REN- Redes Energéticas Nacionais, www.ren.pt

[9] Pordata- Base de dados de Portugal Contemporâneo, www.pordata.pt

[10] EDP- Energias de Portugal, www.edp.pt

[11] DGEG- Direcção Geral de Energia e Geologia, www.dgge.pt

[12] INE- Instituto Nacional de Estatística, www.ine.pt