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Electrical consumption forecast using actual data of building end-use decomposition

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ABSTRACT

The calculation of electricity consumption forecast a few days ahead is a complex issue and studies about this matter are continually being performed. Advances in this field enable obtaining consumption forecasts increasingly accurate. These consumption forecasts aim to improve the knowledge of the facilities, the planning and control of consumption and the measurement and verification of energy saving measures, among others. In this study the authors present several advances related to consumption forecast using end-use (EU) approach. In the disaggregation of the total consumption process, the correlation between energy and external variables, such as mean temperature, degree days or daylight, is studied. Additionally, an extrapolation method to obtain a total consumption forecast from forecasted EUs consumption that cover approximately 60% of total consumption is developed. With this procedure, total consumption forecasts with high accuracy can be obtained. The higher accuracy in each end-use, the better results are obtained in the total consumption forecast. For this reason, the study is focused in the end-uses disaggregation and its forecast calculation. The entire methodology is illustrated and contrasted using the consumption of the Universitat Politècnica de València (UPV).

1. Introduction

The energy consumption may be related to the search different benefits. However, quantifying the benefit provided by consuming a certain amount of energy is often difficult. The best way to do this is to divide the consumption into end-uses (EUs) or processes to assign a benefit to each kWh of each process. This will also enable estimating the advantage of achieving a certain energy saving on an EU more accurately. Accurate consumption forecasts are important to measurement and verification as well as to participate in the demand response programmes, as it has been previously discussed in other publications of the authors [1–4]. To sum up, each consumption fraction can be dependent on different external variables and these fractions are what are called EUs.

The consumption of a building or a large and complex facility can be divided, according to this criterion, into different EUs. For each EU, the forecasting process should consist of two phases. The first phase is the process of selecting the most similar days to the day of prevision (DOP), i.e., to find days in which external variables that affect the EU consumption have similar values to the DOP. The second phase is the forecasting calculus. This phase can be accomplished in many different ways. In previous study made by the authors, artificial neural networks to calculate the forecast were used. In this study the selection process is improved and a much easier and faster forecast method that achieves accurate results is developed. This method calculates a forecast for each EU and the total consumption for each hour of the day using the conditions of the DOP and the conditions and consumption of selected days.

As previously discussed in other papers of the authors, the number of selected days must be reduced, 4 days were used [1,2]. So 4 days must be selected for each EU in which the variables that affect the consumption are as close as possible to the DOP.

The division of the total consumption into the different EUs provides several advantages, such as making different fractions of the consumption independent on the external variables that do not affect them. It also enables greater control and understanding of how energy is consumed. In addition, it simplifies the process of purchasing energy in the spot markets [5]. Furthermore, some applications oriented to specific EUs such as measurement and verification of energy efficiency and energy management actions applied on different EUs are enabled [6–8]. In conclusion, the decomposition of consumption into EUs helps the consumption forecast step in the sense that it enables the use of different input variables for the prediction of each EU, providing a series of

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Table 1
Measuring points of EUs.

EU	Description	Number of measuring points	Main external variable that depends
SS	Split systems consumption	25	Temperature
HP	Heat pumps consumption	36	Temperature
OC	Only cold production	2	Temperature
OH	Only heat production	4	Temperature
PL	Public lighting	15	Day number
IL	Internal lighting	18	External light
GA	General appliances	16	Occupancy
TC	Total consumption	1	All

additional benefits already discussed. A possible EUs classification is analysed below.

The paper is organised as follows. Section 2 explains the whole methodology, introducing the necessary concepts and showing the information available related to EUs. Section 3 describes the classification of the end-used performed in this study. Section 4 explains the consumption forecast phase and the extrapolation of the EUs consumption in order to calculate the total consumption forecast for the facility. Section 5 shows the results of applying the methodology to the consumption forecast of the Universitat Politècnica de València (UPV). Finally, in Section 6 some conclusions are drawn.

2. Proposed methodology

The proposed methodology to carry out the forecast consumption of a facility consists of two phases. The first phase is the selection of days similar to the DOP. The second stage is the consumption forecast phase.

To carry out the day selection, a thorough analysis of the EUs of the facility is first performed. All variables that influence the consumption profile of each EU are analysed. Then, individual weights are assigned to each variable that affects the consumption of each EU. This will establish how each criterion affects each EU. This is necessary in order to decide which days are more similar to the DOP. The process consists of assigning qualifications to each criterion of each day depending on the similarity of each variable with the value it has for the DOP. Then, using the weights assigned to the criteria, a mark is given to each day calculated as a weighted average of the criteria qualifications. This enables ordering the days by a mark to carry out the selection of 4 days among those which obtained the highest mark. All the days whose consumption or whose variables are considered anomalous must be removed before the days selection is made.

The criteria to be considered are external variables that affect consumption. For each EU a unique relationship between consumption and external variables can be studied. That is the reason why the study of this relationship must be first done and different weights must be assigned to each criterion for each EU. There is a common criterion to all EUs, proximity to the DOP. It has been proven over time the need to choose days surrounding the DOP to calculate an accurate consumption forecast, so this criterion must always have a significant weight.

To carry out the prevision of EUs, the heuristic method (average of 4 similar days) described in [1] is used. Finally, an algorithm to obtain the total consumption forecast using the EUs consumption on selected days and the EUs forecast previously obtained for the DOP is applied. This algorithm performs a linear interpolation (or extrapolation if applicable) to obtain the total consumption forecast of the DOP.

The entire forecasting process is outlined in Fig. 1.

The average temperature (T_{avg}), the Cooling Degree Days (CDD), the Heating Degree Days (HDD), the maximum temperature (T_{max}), minimum temperature (T_{min}), the proximity to the DOP (n), the light factor (light), a parameter that quantifies the need for artificial light of a day from its cloudiness are the variables used in this study that consumption depend on and the labour activity parameter (LAP) used to represent the activity of each type of day (weekdays, weekend, holidays, etc.) [1].

Table 1 shows the number of measuring points that make up each EU and the main external variable that affects the consumption of each EU.

The UPV has an Energy Management and Control System (EMCS) which has a total of 300 measuring points distributed along its 90 buildings. With these measuring points, consumption is measured every 15 min and it is stored in a database since 2005. To classify the EUs of these facilities some of these measuring points have been classified into groups according to the type of loads fed and the behaviour in relation to external variables. Therefore, the EUs consumption curves in the UPV are the result of adding a large amount of consumption measuring points, providing a reasonably high stability to the daily consumption of each EU.

The consumption formed by the addition of the identified EUs is what is called the end-uses consumption (EUC), which represents around 60% of the UPV's total consumption (TC). This percentage is being constantly revised and improved by identifying and classifying the type of consumption measured by new measurement points installed in the UPV. An accurate prediction of the EUC results in a good prediction of the TC simply by using a fast and easy extrapolation method explained below. Therefore, it is important to improve the selection and classification of EUs so as to get a reliable and strict relationship between consumption and external variables. This will permit finding a good days selection, similar to the DOP, in both the input variables and consumption for each EU, improving the forecast accuracy.

3. End-uses study

First, the temperature-dependent consumption end-uses are classified into four groups, the consumption that has a unique behaviour for all seasons, split systems end-use (SS). This is because this EU includes machines whose operation mode is automatically selected depending on the desired temperature and the external temperature. Secondly, processes with seasonal behaviour, such as heat pumps (HP), which operate differently depending on whether they are in heating or cooling mode and that mode switching occurs manually at a certain moment of the year. Different from the previous ones are those machines that produce cold at any time of year, the only chillers systems (OC). Thus, this is a refrigeration consumption, which is only affected by high temperatures, but for low values this consumption remains at a small value (residual consumption). Finally, the last temperature-dependent consumption is the consumption of radiators, heaters, etc., that is the only heat systems (OH). This type of process is always producing heat, so it is only affected by temperatures lower than a certain value, and above this thermal limit the consumption of this EU is a low consumption.

Besides temperature-dependent EUs, there are other EUs, such us lighting consumption that can be separated in public lighting (PL), which is dependent on the length of the daylight hours and