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Apart from this, the model has been sufficiently simplified to be able to make the calculations of the algorithm with the greatest speed and simplicity. The unavoidable core is the probabilistic load flow, modified to include the theorem of convolution of probability functions.

The conclusions of the theoretical study and the analysis of real measurements for low voltage systems and customers make it inadvisable to work with parametric density functions, as opposed to the excellent results obtained with Convolutive Aggregation.

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![Figure 1: Uncertainty zone.](image)

The present work focuses on determining this zone, in order to calculate the risk involved in the initial estimation and the time that this lasts. The techniques being tested consider the uncertainty zone, parametrised from the accumulated overall distribution function, previously calculated.

After explaining the results of the bibliographic search the article gives an explanation of the model for forecasting the distribution function, as well as the system for acquiring, purifying and processing data that is at present being applied.

Lastly, after explaining how the estimation of the uncertainty zone is performed, the results from a real case are given.
PEAK LOAD DEMAND FORECASTING BY USING A FUZZY CLASSIFICATION SYSTEM COMBINED WITH THE CONVOLUTIVE AGGREGATION METHOD

Dr. Alfredo Quijano López. Ms. Marta García Pellicer. Dr. Raimundo Criado Calero. Mr. Mikel Irizar Moyua.

INTRODUCTION

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OBJECTIVE OF THE MODEL

In the process of liberalising the electric power market, the optimising of production and investment costs takes on greater importance, guaranteeing sufficient quality of the supply at any time and point in the distribution system. For this reason, probabilistic methods for demand prediction are required, as they provide greater accuracy in the estimation of electrical load and the state of the network.

At low aggregation levels the random variable represented by the electric power demand does not match any parametrisable probability
density function, meaning that it is inconceivable to use conventional demand prediction techniques applicable to greater aggregation levels. There is a clear need to use forecasting techniques independent of the type of probability density function, even able to use numerical expressions.

A calculation algorithm has been calculated to combine the probabilistic load flows and convolutive aggregation for predicting the peak demand in low voltage systems and which allows the density functions of the aggregated demands along the low voltage network to be determined, providing better control of the prediction and better results.

Work is currently being carried out on adapting the model to the prediction of time curves with socio-economic demand patterns.

DESCRIPTION OF THE MODEL

The different stages involved in the model for obtaining the model are: firstly the data on load curves, by a purifying process, and the data on invoicing and socio-economic characteristics are processed to determine the structure, connectivity and characteristics of the distribution system.

Then a classification process is undertaken to obtain uniform groups of individual customers.

After determining uniform groups of individual customers, the behaviour pattern curves of each of these groups are determined. After determining the behaviour pattern groups and the structure of the system, we proceed to determine the aggregated electrical demand from the general protection box to the MV/LV transformer station.

Having obtained the density function of the aggregated electrical demand, its most characteristic statistics are determined: average value, standard deviation and percentiles, proceeding to validate the model and the execution of a sensitivity analysis of the model.

Finally, when the aggregated density function has been found, we proceed to study the uncertainty zone.

Purifying the Data

The data used for the process of developing and later validating the model are the load curves at different aggregation levels, from the individual customers to the MV/LV transformer station, and the invoicing data for the individual customers.

The different types of data undergo an exhaustive purification process until these are used by the model, both in the phase of building this and that of validating it.

The load curves have to be turned into units of power, eliminating all the erroneous records.

The data on invoicing and socio-economic characteristics of individual customers stemming from the databases of the electrical company are purified, obtaining files with two types of information highly relevant for the model. Firstly a matrix is obtained with all the invoicing data and socio-economic characteristics per customer. This matrix will later be used in the classification process, for determining groups with uniform behaviour. Secondly, for each MV/LV Transformer station, a matrix is determined to contain the connectivity of each of the station’s customers, from the General Protection Box to the head of the station, thus determining the number of customers and power contracted, per type of customer and for each General Protection box.

Classification of Customers

The method developed originates from a model which considers, along with the electrical demand, a series of human behaviour variables which have an effect on the electrical demand, a classification process which determines their level of influence being required.

For determining the groups with similar characteristics, data on which similarities can be studied is used, such as the power contracted, the rate, etc., which have an influence on the electrical demand and which are defined for all consumers.

To perform the classification process, three clearly differentiated but fully related stages are involved: Categorising, Factorial Analysis and Classification.

Behaviour patterns

The modelling method involves a process of parametrising the variables, which define human behaviour and have a great influence
on the demand for electrical power, said variables being considered implicitly by a classification process as explained in the previous section.

After determining the uniform groups of individual customers, the characterisation of their consumptions is performed, by determining the behaviour pattern curves for each of the types of customers found.

To determine the behaviour pattern curves, the sampled and purified load curves of the individual customers belonging to each of the groups were used.

The behaviour pattern curves thus obtained are functions of the density of the load curves of the individual customers representing each of the groups. This thus considers all the temporal consumption possibilities, therefore eliminating the influence that the time lag of the load curves implies in traditional point by point aggregation.

As can be deduced from what has been stated so far, the sampling of the load curves of the individual customers must be consistent and meet the following conditions: 1) the customers sampled must be representative of each of the uniform groups, 2) the number of customers sampled must be representative from the statistical standpoint, 3) the sampling period must be consistent with the model application period.

Aggregation

Having found out the participation of each type of client in the aggregated demand of the general protection box, the estimator of said demand is calculated. To do this, for each of the General Protection Boxes in the System, statistical aggregation is performed by convolution, obtaining the electrical demand density function aggregated at the level of the General Protection Box.

Once the electrical demand aggregated at the general protection box level has been determined, and knowing the connectivity between these in the distribution system, we proceed to perform the statistical aggregation, by convolution, up to the MV/LV transformer station, thus obtaining the function of electrical demand distribution aggregated on the MV/LV transformer station level. This means that its most representative statistics can be determined: average demand, standard deviation, maximum demand at different percentiles. From the development of the process not only the statistics representative of the aggregated electrical curve, but also those of the decreasing monotone curve are obtained.

Having obtained the function of distribution of aggregated demand and its statistics, a sensitivity analysis has to be carried out providing the model's level of accuracy.

In this process a contrasting is performed between the estimations of electrical demand and the values measured at the transformer station level, both the distribution functions and statistics.

Characterisation of the Uncertainty Zone

This phase means a greater approximation to the predictions required for optimising the use of the electrical power supply networks, also optimising the use of transformers, by better knowing the risk of prediction error.

A method for approximation to the characterisation of marginal distribution which is undefined from the estimated percentile, is developed, with statistical calculation alternatives and based on geometrical concepts.

Two mathematical functions: one which allows the low voltage demand points to be obtained, and the other providing information as to its repetition frequency, are determined, both variables defining the uncertainty zone.

NUMERICAL APPLICATION

To illustrate the application of the convolutive aggregation model, a MV/LV Transformer station belonging to the Iberdrola network was chosen, for which the most important aspects of the method are displayed together with the results obtained.

The Transformer Station studied is a 630 kVA station and total contracted power of 1,766.2 kW, supplying power to 354 customers, spread over twelve distribution lines and 19 general protection boxes (CGP).

After processing the data and performing the classification process, the functions representative of the behaviour patterns are determined as shown in graphs 2, 3 and 4:
After determining the behaviour patterns, convolutive aggregation is applied to obtain the aggregated electric power demand at the head level, whose density function is shown in Figure 5 and whose representative statistics are indicated in the adjoined table:

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average (kW)</td>
<td>185.02</td>
</tr>
<tr>
<td>Typical deviation (kW)</td>
<td>75.14</td>
</tr>
<tr>
<td>Percentile 95% (kW)</td>
<td>321.6</td>
</tr>
<tr>
<td>Percentile 99% (kW)</td>
<td>362.4</td>
</tr>
<tr>
<td>Percentile 99.5% (kW)</td>
<td>372.8</td>
</tr>
</tbody>
</table>

Table 1: Estimations for head.

From the previous results, we can deduced that the sample of measurements is more dispersive than the estimated density function, giving good results in respect to the average and for different percentiles.

One of the essential aspects of the model applied is the estimation not only of the statistics describing the electrical demand, but also of the density function representative of aggregated demand. Hence, one of the important feasibility studies is the comparison of both density functions, approached from two positions: 1) discrete distribution functions, 2) as analytical distribution functions. There are different hypothesis tests for comparison of samples, based on the samples being compared following a Normal distribution function, but there is a lack of knowledge on the form of the sample distribution function, as is the case of the electrical demand at low voltage, because, as the aggregation level is low, the Central Theorem of the Limit is not satisfied and the aggregated demand does not follow a Normal distribution function. It is in these situations that the “Non-parametric Tests” based on other statistics, are applied. The next graph shows the monotone rising curves both estimated and measured, at the head level:

Table 2: Errors.

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average (kW)</td>
<td>7.9</td>
</tr>
<tr>
<td>Typical deviation (kW)</td>
<td>31.2</td>
</tr>
<tr>
<td>Percentile 95% (kW)</td>
<td>6.8</td>
</tr>
<tr>
<td>Percentile 99% (kW)</td>
<td>4.5</td>
</tr>
<tr>
<td>Percentile 99.5% (kW)</td>
<td>2.8</td>
</tr>
</tbody>
</table>

CONCLUSIONS

A method for modelising loads usable at low aggregation levels has been obtained, from aggregated groups of individual customers to the head of the MV/LV transformer station,
starting from behaviour patterns for uniform groups of consumers of electrical power.

The method which has been called Convolutive Aggregation is applicable to real cases, with data that can be obtained from the databases of the electric company themselves, i.e., it is able to generate different mathematical models of electrical demand as a function of the initial data and the MV/LV transformer station being studied.

ACKNOWLEDGEMENTS

Our thanks to the electricity company Iberdrola S.A., without which it would not have been possible to obtain real data allowing the development and validation of the model.

REFERENCES


