LOAD PATTERN CLASSIFICATION AND PROFILING FOR A LARGE SUPPLY COMPANY

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ABSTRACT

This paper deals with the analysis of aggregated hourly energy patterns for assisting the introduction of a load profile-based approach within the electricity market regulation. The analysis of the regional energy patterns is carried out for determining a suitable classification of the days with consistent consumption patterns along the year. Numerical applications related to market-validated real data for the distributor and for the supplier of the non-eligible customers in the eight regions in which the electrical distribution in the Romanian territory is partitioned are presented and discussed.

1. INTRODUCTION

In the world-wide evolution of the electricity markets, the liberalisation process has resulted in enhancing the operational flexibility in the electricity sector. Exploiting this increased flexibility requires more accurate knowledge of the shape of the customer consumption during time.

On the supplier side, specific procedures are needed to perform sound customer classification, defining a set of load profiles characterizing the customer groups, with a direct impact on the formulation of tariff structures [1-4].

On the regulatory side, load profiling is needed to represent the aggregated customer consumption at different areas of the electrical system, due to the impossibility of specifically metering every individual customer. In this case, area-based load profiling or other techniques could be adopted, particularly in order to deal with the needs of the day-ahead and balancing markets. The load profiling issue may impact on the determination of market prices and on the management of the load imbalance with respect to the scheduled values [5]. In both cases, although for different purposes, it is needed to create a partitioning between customers subject to hourly measurement and customers for which it is possible to know only the global energy measurement in a specified period (e.g., one month).

In the first phase of application of a load profiling approach, for a large supply company there may be limitations due to restrictions in extensively metering all the customers. As such, the driving factors for load profiling have to be quite simple, but representative, e.g., by using data on average and maximum demand. Successively, more detailed indicators may be adopted for getting a more robust customer classification. In particular, information coming from the market may be included in the procedures for testing and refining the load profiles, e.g., by checking the results on various areas of the electrical system. This aspect of load profiling is particularly critical concerning the relationships between distributors and suppliers.

This paper addresses the salient characteristics of the application of load profiling procedures referred to the distributor and to a large supply company (Electrica) in the eight Romanian regions. The process of formulating and testing sound procedures for load profiling is of utmost relevance since, according to what scheduled by the Romanian Energy Regulatory Authority (ANRE), retail competition will be implemented starting from 1 July 2007. After that date, all customers should become eligible, and the regulation should adopt a load profile-based approach for dealing with the customer consumption in adjusting the electricity market rules. Starting from market-validated real data for the eight Romanian regions in a period of one year, with hourly values for the distributors and for the supplier, the paper reports on the results of the classification of the load patterns, to endeavour meaningful time periods for grouping consistent load patterns.

2. LOAD PATTERN ANALYSIS

A set of hourly energy patterns for the distributor and supplier in the Romanian regions is considered, related to the period from 1 July 2005 to 30 June 2006 (Figure 1). The difference between the patterns at the distributor and supplier sides may be due to the load served to the eligible customers, and to technical and non-technical losses in the distribution system. These losses are relatively difficult to be estimated, due to the lack of metered data related to the scattered loads and of complete modelling of the distribution networks.

The role of the eligible customers in the energy balance of the distribution system is relevant for two types of effects. On one side, the diffusion of the eligible customers is different in the various regions and varies with time as well. On the other side, the shape of the overall hourly energy pattern corresponding to the eligible customers could be significantly different with respect to the shape of the corresponding pattern of the non-eligible customers served by the supplier. These aspects are highlighted by the results presented in Table 1. The diffusion of eligible customers is represented by the degree of market opening, here evaluated only at the distribution system side (excluding the HV customers directly supplied from the transmission system) by using the information on the annual energy. The energy of the eligible customers is metered using interval meters. For the suppliers the amount of energy analyzed is composed of losses and non-eligible customer consumption. The degree of market opening is calculated as the relative amount of energy supplied to the eligible customers, referred to the total energy of the distributor. Table 1 shows the different levels of market opening associable to the regions, as well as the correlation coefficients calculated considering the hourly energy patterns of distributor and supplier, in order to check for possible similarities among these patterns. It appears that the regions with the higher degree of market opening exhibit lower correlation coefficients. More specifically, significant negative correlation (with correlation coefficient -0.818) occurs between the pattern correlation coefficients and the degrees of market opening at the different regions. This is mainly due to the difference between the hourly energy profiles of the eligible customers (mainly large industrial customers) and the corresponding profiles of the regions. From the regulatory viewpoint, it is thus essential to ensure that all the eligible customers are fully metered, in order to subtract the consumption patterns of the eligible customers from the overall hourly energy pattern of the region with the maximum possible accuracy. In order to complete the information, Table 2 provides the correlation matrix between the patterns of the various regions at the distributor side.

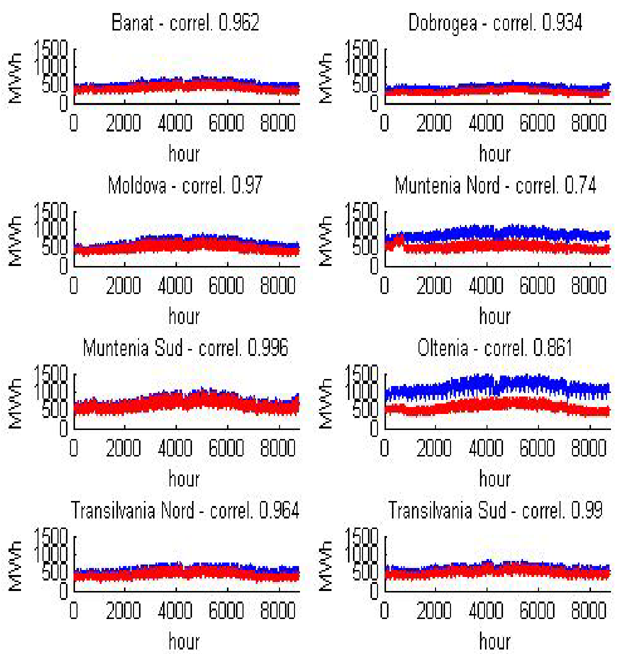

Figure 1. Hourly energy patterns in the eight Romanian regions (blue: distributor; red: supplier).

Another view of the differences among the regions is illustrated for instance by comparing Figure 2, showing a zoomed portion of the hourly energy patterns at the distributor side for three regions, to Figure 3, showing the differences between the patterns at the distributor and supplier sides. It clearly emerges that in the case of the Muntenia Sud region, with very low degree of market opening, the shapes are similar, being the difference mainly due to the effect of the small number of eligible customers, whereas in the other cases the consumption patterns of the eligible customers play a major role due to the increased number, with prevailing demand in the weekdays in the Oltenia region and a more regular pattern in the Muntenia Nord region. The other regions, also shown in Figure 3, correspond to intermediate cases.

Table 1. Correlation among the distributor and supplier hourly energy pattern and estimation of the degree of market opening based on the annual energy in the distribution system.

region	annual energy (TWh)		pattern correlation coefficient	market opening (%)
	distributor	supplier		
Banat	4.39	3.64	0.962	17
Dobrogea	3.65	2.64	0.934	28
Moldova	5.06	4.21	0.970	17
Muntenia Nord	7.34	4.41	0.740	40
Muntenia Sud	6.11	5.69	0.996	7
Oltenia	9.58	4.81	0.861	50
Transilvania Nord	4.72	3.93	0.964	17
Transilvania Sud	5.15	4.40	0.990	15
Total	*46.00*	*33.73*	*0.968*	*27*

Table 2. Correlation matrix among the regions (distributor values). The regions in rows and columns are listed in the same order of Table 1.

1.000	0.819	0.930	0.926	0.928	0.908	0.938	0.907
0.819	1.000	0.822	0.828	0.873	0.799	0.780	0.741
0.930	0.822	1.000	0.933	0.928	0.898	0.906	0.896
0.927	0.828	0.933	1.000	0.932	0.910	0.925	0.900
0.928	0.873	0.928	0.932	1.000	0.871	0.927	0.914
0.908	0.799	0.898	0.910	0.871	1.000	0.878	0.857
0.938	0.780	0.906	0.925	0.927	0.878	1.000	0.950
0.907	0.741	0.896	0.900	0.914	0.857	0.950	1.000

3. CLASSIFICATION OF THE AGGREGATED DAILY CONSUMPTION PATTERNS

Load profiling at the aggregated level is needed for settlement between distributor and supplier. On the way towards the adoption of a load profile-based regulation, one of the first steps refers to the identification of possible regularities among the daily patterns around the year. The objective is to find out a relatively reduced number of consistent time periods (days), grouping together the patterns within these periods. The resulting information is relevant to the aggregated load pattern analysis and forecasting purposes. In Romania, a categorization of the days of the year including 48 day types was operated for a period (2002-2003) with 4 typical days every month (1=Sundays; 2=Mondays and Fridays; 3=Tuesdays, Wednesdays, Thursdays; 4=Saturdays). Such a classification, applied to the hourly energy data for the eight Romanian regions used in this paper, would produce results such as those illustrated in Figure 4 for the Banat region. It is apparent that this classification, although very detailed in terms of number of time periods, could be poorly efficient in many cases (especially for day type #2), leading to the need for endeavouring better alternatives.

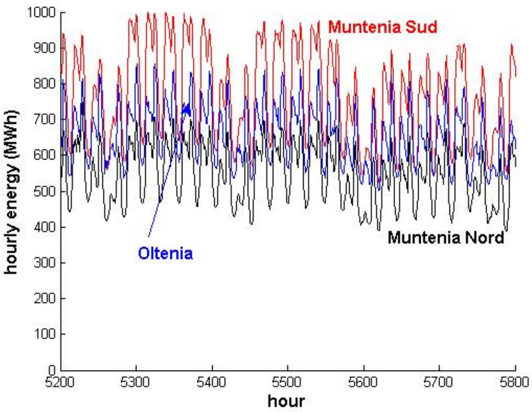

Figure 2. Hourly energy patterns for three regions at the distribution side.

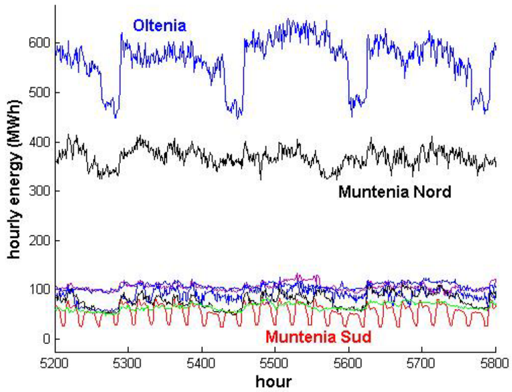

Figure 3. Hourly energy patterns for the consumption of the eligible customers .

A comprehensive analysis of the hourly energy patterns at the distributor and supplier sides has then been carried out to endeavour a useful subset of day types, based on the real shape of the patterns. First, a set of anomalous weekdays has been identified on the basis of the calendar, for instance 1 December 2005 (Thursday), 26 December 2005 (Monday), 2 January 2006 (Monday), and 24 April 2006 (Monday). These days have been specifically observed during the analysis, in order to avoid mixing the patterns at these days to the ones referred to the ordinary weekdays.

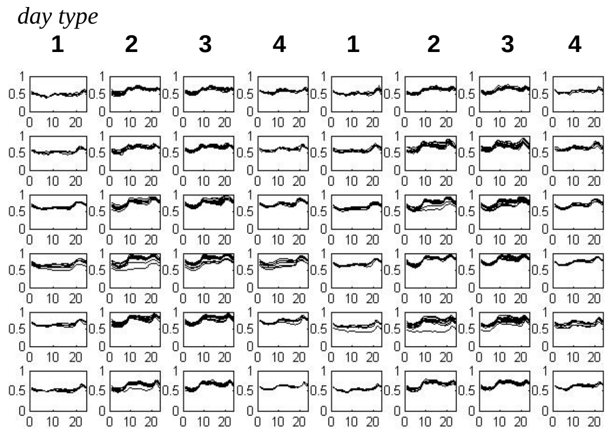

Figure 4. Composition of the day classes for the 48 day-type categorization (example for the Banat region). Horizontal axis: hour; vertical axis: normalized power.

The classification of the days has been assisted by a classification tool based on a clustering procedure with the modified follow-the-leader algorithm, effectively used for load pattern classification in [1]. For this purpose, the hourly energy data of each region have been normalized with respect to the maximum value of the pattern, before being forwarded to the classification tool.

The procedure followed for classifying the days is summarized as follows. The clustering algorithm has been run several times for each region, with different numbers of clusters N. The result in each case has been verified both representing the cluster composition, as indicated for instance for the Transilvania Sud region in Figure 5 (with N = 20 clusters) and in Figure 6 (with N = 8 clusters), and extracting other information from the shape of the cluster centroids, e.g., as in Figure 7, where the curve parameter is the cluster number.

From the clustering results in Figure 7 , it clearly emerges that the centroids number 2, 3 and 7 exhibit a consistent behaviour, associable to a scale factor. From Figure 6, the clusters 2, 3 and 7 are mainly formed by regularly scaled groups of days, including Saturdays and Sundays throughout the year. In particular, cluster #3 contains practically all the Sundays from 23 April to 18 September, whereas cluster #7 includes mainly Saturdays from 20 April to 15 September, and the “intermediate” cluster #2 has a mixed composition. The same reasoning applies to the weekdays.

By performing the same type of analysis for larger numbers of clusters, the similarities among the classes of hourly energy patterns continue to emerge. From Figure 5, again, there are various clusters whose days are regularly scaled, and this refers to groups of Saturdays and Sundays. Hence, as intuitively expected, the Saturday and Sunday patterns have to be considered separately with respect to the other days and from each other. Thus, several types of classifications among the days can be formulated by determining a suitable inner partitioning among the set of consistent days, by running the clustering algorithm on a reduced set of data. The overall comparison of the outcomes is carried out by taking into account that the same day partitioning has to be effective for every region.

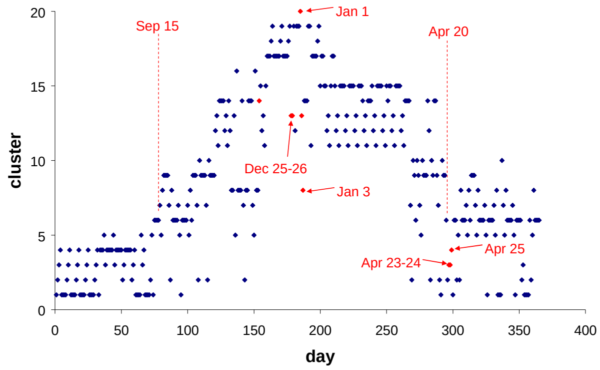

Figure 5. Example with N = 20 clusters for the Transilvania Sud region (initial day 1 July 2005).

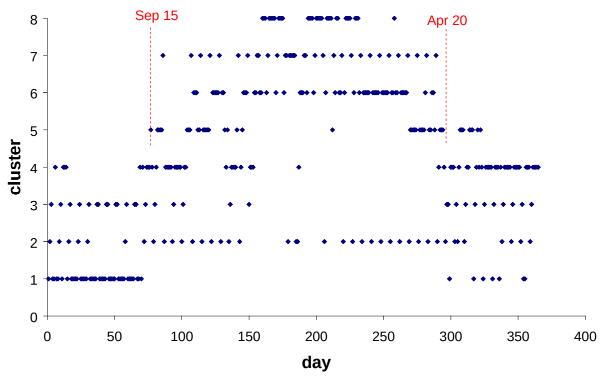

Figure 6. Example with N = 8 clusters for the Transilvania Sud region (initial day 1 July 2005).

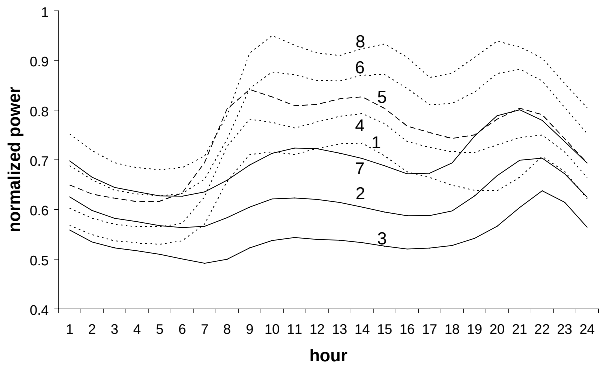

Figure 7. Example of cluster centroids with N = 8 clusters for the Transilvania Sud region (centroid labels are the cluster numbers).

Other inputs could come from exploiting the information on the market prices. The authors have checked for the possible use of the market price information for the purpose of load profiling in the system under analysis. However, at present the price information cannot be used in a straightforward way in this system, due to the relatively reduced electricity market opening, to the variability of the market rules occurred during time, to the presence of active caps on the price components, and to the variation of these cap values during time. For instance, Figure 8 shows the evolution of the exceeding and deficit prices in the Romanian balancing energy market.

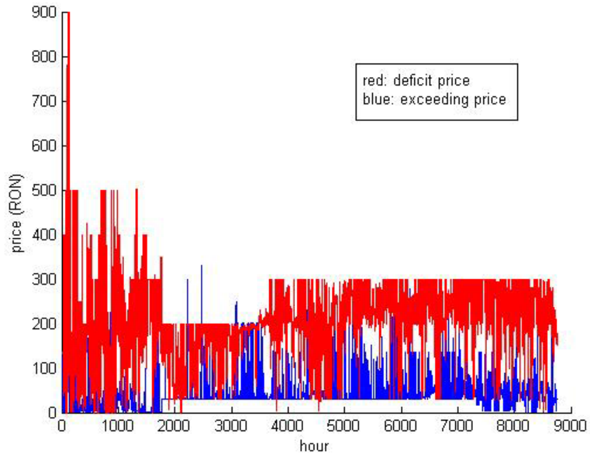

Figure 8. Evolution of the balancing market prices in the time period under test.

4. CONCLUSIONS

A specific investigation has been carried out on a set of real data covering the electrical distribution side in Romania, in order to provide useful information for assisting the interactions between the distributor and the supply company concerning the application of a load profile-based regulation at the aggregated regional level. Interesting results have been obtained concerning the feasibility of the classification of the time periods with consistent aggregated consumption by using a clustering tool. The effects of the eligible customers in the various regions on the aggregated load patterns have been discussed. On the basis of several types of clustering-based classifications, the operators are enabled to formulate proposals for setting up new rules for partitioning the time periods. The details of such rules have to be negotiated with the regulatory authority.

5. REFERENCES

[1] G.Chicco, R.Napoli, P.Postolache, M.Scutariu and C.Toader, 2003, "Customer Characterisation Options for Improving the Tariff Offer", *IEEE Trans. on Power Systems*, Vol.18, No.1, 381-387.

[2] D.Gerbec, S.Gasperic, I.Smon and F.Gubina, 2004, "Determining the load profiles of consumers based on fuzzy logic and probability neural networks", *IEE Proc. Gen. Trans Distr*., Vol. 151, No.3, 395-400.

[3] G.Chicco, R.Napoli, F.Piglione, M.Scutariu, P.Postolache and C.Toader, 2005, "Emergent Electricity Customer Classification", *IEE Proc. Gen. Trans. Distr.*, Vol.152, No.2, 164-172.

[4] G.Chicco, R.Napoli, F.Piglione, M.Scutariu, P.Postolache and C.Toader, 2005, "Application of clustering techniques to load pattern-based electricity customer classification", *Proc. 18th CIRED*, Torino, Italy, June 6-9, 2005, Session 5, paper No.467.

[5] G.Chicco, 2005, "Comparing load profiling techniques for revenue and load deviation assessment", *Proc. IEEE Power Tech*, St. Petersburg, Russia, June 27-30, 2005, paper No.242.