Periodical Load Curves for Procession Data and The Monitoring for Longer Periods

Lidija Korunovic[1] and Marko Vuckovic[2]
[1]Lidija Korunovic is with the Faculty of Electronic Engineering
University of Nis, Aleksandra Medvedeva 14, 18000 Nis, Serbia
lidija.korunovic@elfak.ni.ac.rs

[1]Marko Vuckovic is with electric power distribution company
Jugoistok“ Nis, 46a Bul. Z. Djindjica
Nis 18000, Serbia

ABSTRACT: *The load class exclusion of craft stores but with the presence of the periodical load curves are outlined in the current work. For low voltage consumers, we have presented the procession data for a procession of data. The load requirement and usage are monitored for a longer period including the daily mean consumption including past periods.*

Keywords: Daily Load Curve, Low Voltage Consumer, Commercial Load

Received: 27 October 2022, Revised 8 December 2022, Accepted 17 December 2022

DOI: 10.6025/jet/2023/14/1/17-23

1. Introduction

The knowledge of load characteristics is the base for both exploitation and planning of distribution networks and electric power system. Therefore, it is very important to have reliable information about the load curves. The curves depend on many factors such as load composition, tariffs, influence of seasons, i.e. weather conditions, life habits, economic standard of living and the usage of central heating. Thus, it is not easy to determine statistically reliable load curves, especially at low voltage, because stochastic load variations significantly influence on the shape of load curves on this voltage level. Furthermore, it is expensive to perform measurements at large number of low voltage consumers and technically difficult to transmit and storage large amounts of data.

One of the papers that deal with load curves at low voltage is [1]. This paper presents the methodology for load curve determining on the basis of questionnaires completed by low voltage consumers. However, load curves obtained in this way can be used only for rough estimation, when it is not possible to perform numerous measurements at low voltage consumers. The results of such measurements performed during two years at low voltage consumers that belong to residential, commercial and industrial load class are presented in [2].

However, numerous measurements in long time periods with the possibility to storage huge number of data at one location became the reality with the usage of up to date energy meters and systems for remote energy meter reading. Such meters and the system are installed in electric power distribution company „Jugoistok“ Nis. Thus, data measured by nearly seven thousands energy meters in the area of town Nis are collected. On the basis of the data regarding time period longer than two years statistically reliable daily load curves of two seasons and several load classes are obtained [3]. Therefore, these curves are very applicable. For example, the curves are implemented in the software for energy loss calculation in low voltage distribution network of town Nis, they are used for load factor and loss factor determining of different load classes at low voltage [4], while typical seasonal load duration curves are presented in [5].

This paper is continuation of the research which first results regarding the curves of two seasons and different load classes are presented in [3]. Thus, the paper presents the results of the analysis of daily load curves in different months of one load class at low voltage - commercial load excluding craft stores and shops. The load class includes offices, but also some households that are signed in as commercial load only due to the privilege not to pay a fee for the national television. Tariffs for the commercial load (at low voltage) excluding craft stores and shops and the households are the same. Data for the curves presented in this paper are collected from 259 energy meters using the system for remote energy meter reading. Since the consumers that belong to the same load class have similar load structure, the number of over two hundred and fifty consumers is large enough to form typical, averaged chronological daily load curves. Totally number of measurements of real power performed by these meters installed at commercial load excluding craft stores and shops is even 10 149 556.

In order to process such number of data and to form averaged chronological daily load curves of working day, Saturday and Sunday for every month of concerned time period, adequate computer program is made [6]. Firstly, this program sorts the data that correspond to working day, Saturday and Sunday of every month of concerned time period. After that, it sorts the data in 15 min long time periods of the day (24 hours), i.e. in 96 time periods. Then, the program averages the data and chronological load curves with 96 points for working day, Saturday and Sunday, for every month are formed.

This paper presents and/or describes daily load curves for working day, Saturday and Sunday of different months of one year. Curves of months in winter and summer season and intermediate period are analysed separately and the differences are quantified. The curves of typical month of winter season regarding working day, Saturday and Sunday are mutually compared and compared with corresponding curves of typical summer month. The results are compared with the results of the analysis regarding daily load curves of different months of shops [6, 7].

2. Curves of Months in Winter Season

According to electric power system of Serbia, winter season begins on October 15th when distant heating starts and summer season begins on April 15th when the heating stops. Therefore, months in winter season are: November, December, January, February and March, while summer months are: May, June, July, August and September. Since October and April do not fully belong to winter or summer season, in this paper they are called months of intermediate period.

Figure 1 presents averaged daily load curves of working day of four months in winter season - November, March, January and February. The curve of December is missed because it is very close to the curve of March and it will be difficult to distinguish it. The curve of November is the lowest one that indicates that the usage of electricity for heating was limited in concerned month. On the other hand, the highest curve is the curve of February that is higher than the curve of January in significant period of the day. It can be explained by the influence of holidays in January when the offices do not work that effects the result of averaging.

The shape of all curves from Figure 1 is similar. After the midnight the load decreases slowly to the minimum load that is around six o’clock in the morning. The minimum load of the curves is in the range from 1.05 kW in November to 1.58 kW in January. After that, the load increases in three steps approximately every hour that indicates the beginning of the work of certain consumer groups. The pick load of all curves appears at almost same time, in the period from 9:15 am to 10 am. It is 2.41, 2.29, 2.17 and 1.81 kW for the curves of February, January, March and November, respectively. Around 11 am all the curves start to decrease slowly by approximately 4 pm, it can be said they are almost constant from 4 pm to 7 pm or 8 pm, and after that the curves continue to decrease by 6 am.

Although the curves of months in winter season have similar shape, they differ from each other significantly. Thus, maximum

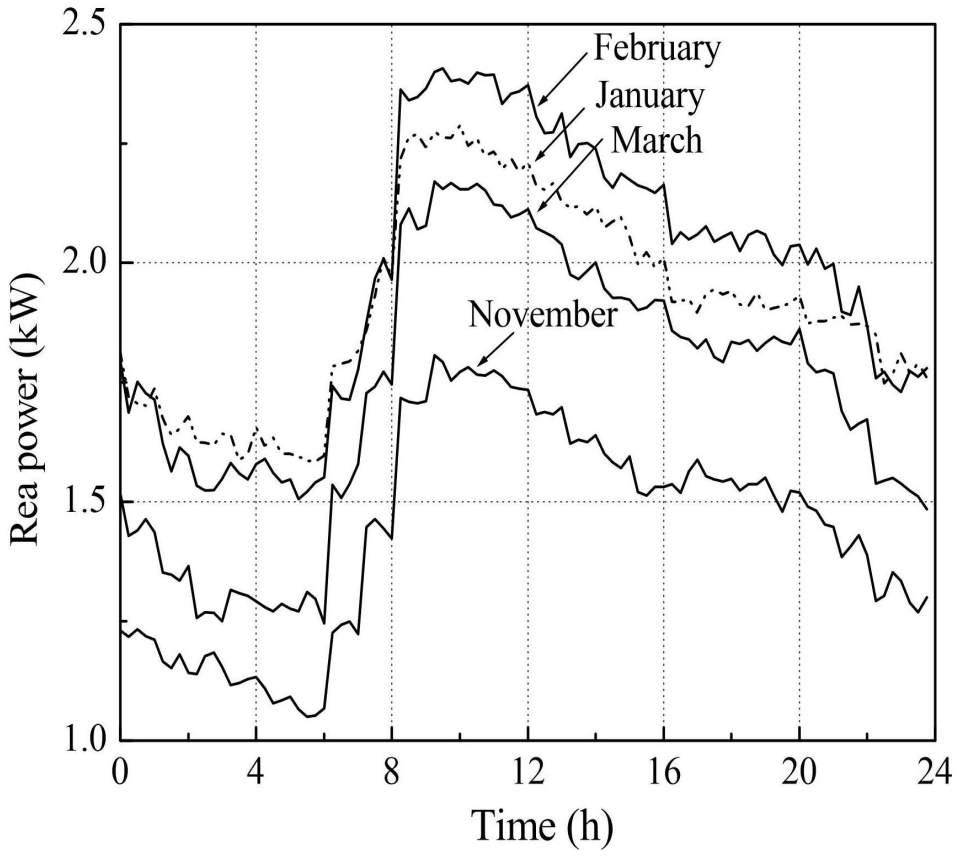

Figure 1. Averaged daily load curves of working day in November, January, February and March.

deviation of the curve of November from the curve of February is even 25.6 % and in all points it is greater than 22.4 %. The deviation of the curve of March from the curve of February is also significant - maximum deviation is 19.7 % and in 81 (of 96) points it is greater than 10 %. Only deviations of the curve of January from the highest curve are less than 10 %, i.e. these are up to 8 %. Therefore, is recommendable to use daily load curves of working days in certain months instead of one representative curve for all working days in winter season.

3. Curves of Months in Summer Season

Four averaged daily load curves of months in summer season are presented in Fig. 2. The curve of July is not presented because it is between the curves of June and May that are close to each other, and therefore it will not be notable. The shapes of the curves in winter and summer season are similar, but the latter are significantly lower. Thus, the curve of June has the highest pick and it is 1.51 kW, while minimum load of the curves is in the range from 0.72 to 0.84 kW. In general, curves in summer season decrease after the midnight, increase in three steps after 6 o'clock in the morning, they have the pick load during working hours, and start to decrease rapidly in the afternoon, from 3 pm and in the evening, from 9 pm, when the groups of load devices of concerned load class turn off.

The curves of June and May cross each other several times, but the curve of June is the highest one in time period from 9 am to 4 pm. It is due to the large influence of airconditioners used for cooling in summer months, particularly the hottest ones. The curve of September is the lowest one along almost whole its length due to limited usage of airconditions in September. This curve deviates up to 17.9 % from the curve of June. In 81 points the deviations are greater than 10 % that regard to be large. Therefore, for correct distribution network analyses, daily load curves for proper months should be used.

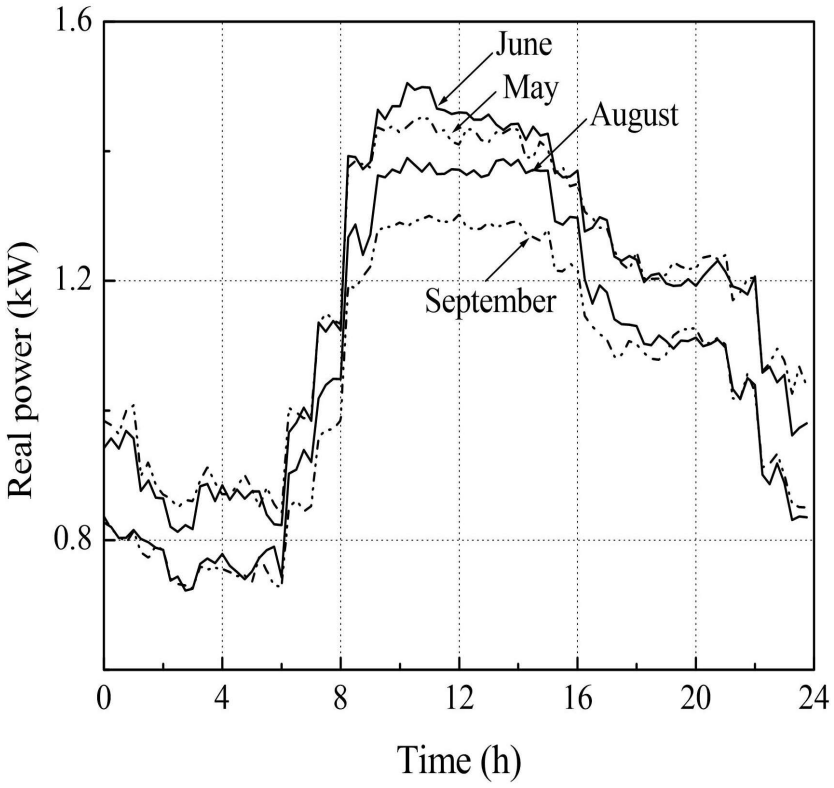

Figure 2. Averaged daily load curves of working day in May, June, August and September

4. Curves in Intermediate Period

Two curves of months in intermediate period, April and October, are presented in Fig. 3. The same figure presents the mean curve obtained by averaging these two curves. The curves are similar and have the similar shapes as the curves in winter season. However, they are significantly lower than the curves of cold winter months due to partial use of electricity for heating in intermediate period. Maximum load of April's and October's curves appears around 9:30 am. It is 1.59 kW and 1.51 kW, respectively, and the latter load is only 5 % less than the former one. Minimum load of both curves is almost the same, approximately 0.9 kW, and appears at 6 am.

Maximum deviation of October's curve from April's curve is above 10 %, it is 12.3%. However, the usage of mean curve instead of two curves of months in intermediate period can be treated as correct enough, because the maximum deviation of the curves of April and October from mean curve is 6.6 %, and in only 14 points it is greater that 5 %.

5. Load Curves of Weekend Days

For comparison, Fig. 4 presents averaged daily load curves of working day, Saturday and Sunday for winter month with highest load, February, and for summer month with lowest load, September. The curves of Saturday in February differs notable from working day curve in February in almost all day periods, except early morning hours and late at night, indicating that some of the offices do not work during Saturdays. The maximum deviation of Saturday load curve from working day curve is 11.7 % and in more than half of the points, deviations are greater than 5 % that regards to be considerable.

The curve of Sunday in February is considerably low in comparison with the curves of working day and Saturday. It varies in relatively narrow range, from 1.34 kW to 1.89 kW. Sunday daily load curve deviates from working day's and Saturday's curve very much, up to 32.4 % and 28.6 %, respectively, while in almost all points these deviations are greater than 5 %.

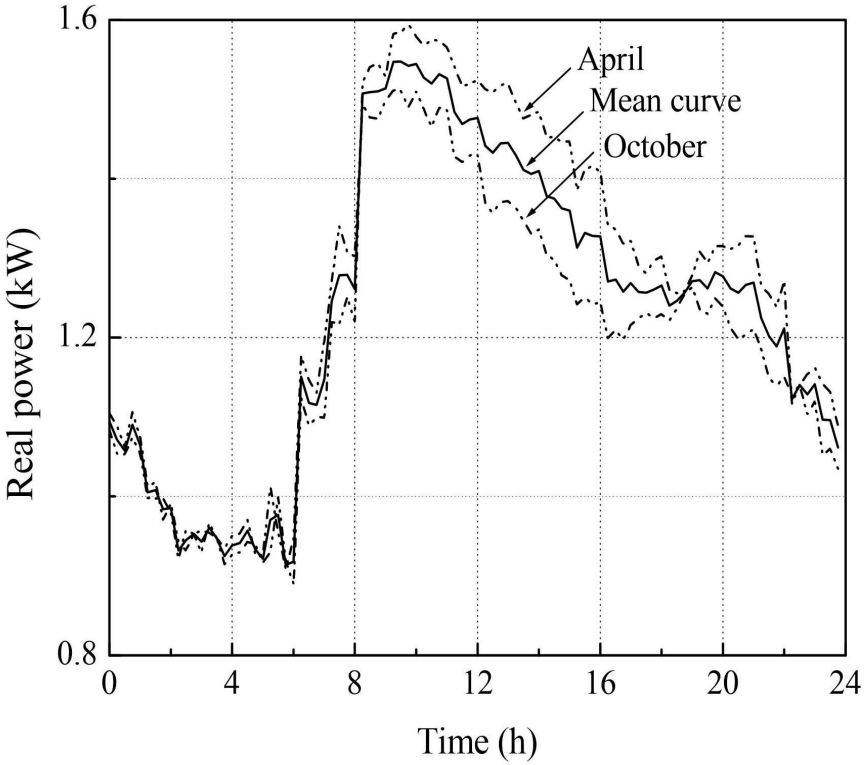

Figure 3. Averaged daily load curves of working day in April and October and mean curve

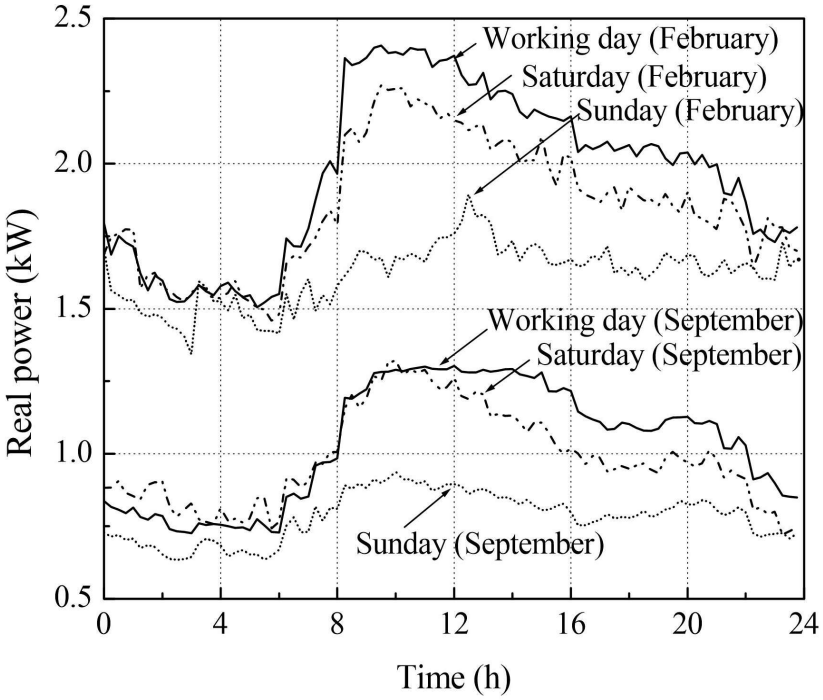

Figure 4. Averaged daily load curves of working day, Saturday and Sunday in February and September

Pick load in September working day is 1.30 kW and it is almost twice smaller than the pick of February working day curve. September Sunday's curve is the lowest curve from Fig. 4 and its minimum (0.63 kW) is nearly four times smaller than the pick in February working day. Comparison of the curves in September yields that deviations of Saturday curve from the curve of working day are up to 18.5 %, while the curve of Sunday deviates from working day and Saturday load curves even more, maximum deviations are greater than 30 %.

Similar deviations of Saturday and Sunday daily load curves from corresponding working day curves are obtained for other months of the year. Therefore, it is recommendable to consider load curves during weekend days separately, in both winter and summer season.

Furthermore, the analyses of the curves of weekend days, Saturday and Sunday, regarding all months in winter season, all months in summer season and two months in intermediate period are performed separately. It is found that maximum deviation of the lowest Saturday's curve in winter season (of November) from the highest Saturday's curve in the same season (of February) is 37.7 % that is even greater than deviation found for corresponding curves of working days. Notable deviations are also found for lowest Saturday's curve of summer season (of September) from the highest Saturday's curve of the same season (of June). These are up to 21.8 % and greater than 10 % in approximately 70 % of points (68 points). On the other hand, Saturday's curves of April and October can be represented by mean curve, since all deviations are less than 10 % and in almost two thirds of points deviations are less than 5 %. It regards to be small.

Similar conclusions are drawn for Sunday curves. It is found that all deviations of the lowest curve in winter season from the highest curve in the same season are greater than 30 % (maximum deviation is even 42.6 %), that deviations of the lowest curve in summer season from the highest curve in summer season are greater then 10 % in all points (maximum deviation is 26.9 %), while the curves of intermediate period deviates less than 5 % in almost all points from the mean curve.

6. Comparison with the Results for Shops

This section deals with the comparison of some characteristics of daily load curves of commercial load excluding craft stores and shops considered in the paper with previously published curves of the load class of shops. Working day curves of different months of shops are depicted in [6], while [7] mostly deals with the analysis of Saturday's and Sunday's load curves of the same load class. The main difference between the curves presented in this paper and the curves of shops is that the first ones are significantly higher.

For example, pick of working day daily load curve in February is 2.41 kW, but the pick of the highest curve among working day curves in winter months is almost two times smaller (1.33 kW). Also, for working day in September, the maximum load of the curve is 1.51 kW, but minimum load of the lowest curve of working day for shops is nearly two times smaller, 0.72 kW. On the other hand, maximum to minimum ratio of most of daily load curves for both load classes is around two. Further comparison of the curves of these load classes will be the subject of some other paper.

Maximum deviation between curves of working day in different months of winter season, presented in this paper, is 25.6 %, and it is almost the same as corresponding deviation found for shops. Maximum deviation for both weekend days, Saturday and Sunday, in months of winter season is around 40% for commercial load excluding craft stores and shops. It is also large for shops, but given in pu, 0.4pu and 0.44pu, since the curves of Saturday in [7] are normalized with maximum load among all Saturday's curves in months of winter season and Sunday's curves are normalized with maximum load among all Sunday's curves in winter months.

Smaller deviations of the curves are found in this paper for the months in summer season: 17.9 % for working day curves, 21.8 % for Saturday's curves and 26.9 % for Sunday's curves. Corresponding deviations are very large for shops: 0.27 pu, 0.51 pu and 0.48 pu, respectively (1 pu is maximum load in summer season of the highest curve among the curves of working day, of Saturday, and of Sunday, respectively).

For commercial load excluding craft stores and shops, maximum deviation of the curves of October's and April's working day from mean curve is relatively small, 6.6 %. Corresponding deviation for shops is 0.12 pu, where 1 pu is maximum load of October's and April's curve. October's and April's curves of Saturday and Sunday deviate from corresponding mean curves of commercial

load excluding craft stores and shops up to 8.4 %. These deviations for shops are large [7]. They are given in pu, 0.32 pu and 0.41 pu, since the curves are normalized with maximum load of October's and April's curve, separately for Saturday and for Sunday.

7. Conclusion

The analysis of averaged working day curves for different months in winter season of commercial load excluding craft stores and shops showed that the load in cold winter month, February, is around two times higher than the load in the month of summer season with the lowest load. This month is September due to limited usage of air-conditions. Saturday's and Sunday's load curves in all months significantly differ from corresponding curves of working days.

Deviations between the curves of working day in the months of winter season are greater than 20 %, and corresponding deviations between the curves of Saturday and Sunday are also significant. For summer months, deviations are greater than 10 % in most of the points for working day and Saturday and in all points for Sunday. On the other hand, deviations of October's and April's curve from the mean curve are relatively small and in most of the points are less than 5 %.

Regarding all mentioned facts, for correct analysis of distribution networks, it is recommendable to use load curves of particular months of winter and summer season, for working day, Saturday and Sunday. It regards both commercial load excluding craft stores and shops, and the load class of shops. For the load class concerned in this paper, mean curve can be used instead of October's and April's load curves. Further research will include the analysis of curves of different load classes from several years, the influence on weather conditions on the shape of the curves, maximum load, minimum load and energy consumption, and load forecasting.

Acknowledgement

The work presented here was supported by the Serbian Ministry of Education and Science (projects III44004 and III44006).

References

[1] Geric, Lj., Konjovic, P., Djapic, P. & Sindjelic, M. (1994). (in Serbian) *Modeling of residential load shapes using method of questionnaire*. XXXVIII Konferencija ETRAN-a [Conference proceedings], Vol. I. Nis, Yugoslavia, pp. 251–252.

[2] Jardini, J.A., Tahan, C.M.V., Gouvea, M.R., Ahn, S.U. & Figueiredo, F.M. (2000) Daily load profiles for residential, commercial and industrial low voltage consumers. *IEEE Transactions on Power Delivery*, 15, 375–380 [DOI: 10.1109/61.847276].

[3] Korunovic, L., Stojanovic, M., Tasic, D., Stoimenov, L. & Krstic, A. Analysis of load diagrams at low voltage of distribution network of Nis Conference on Electricity Distribution in Serbia and Montenegro, R-6.02, Vrnjacka Banja, Serbia, 2010. (in Serbian), Vol. 7.

[4] Korunovic, L., Stojanovic, M., Vuckovic, M., Tasic, D. & Krstic, A. (2011). (in Serbian) Faktor opterecenja i faktor gubitaka razlicitih kategorija potrošnje na niskom naponu, 30. Savetovanje Cigre Srbija [Conference proceedings], R C6 13. Srbija: Zlatibor, Solomon Islands.

[5] Korunovic, L., Vuckovic, M., Stojanovic, M. & Tasic, D. (2011) The analysis of typical seasonal load duration curves of low voltage consumers, ICEST 2011 [Conference proceedings]. Srbija: Niš, 4, 469–472.

[6] Vuckovic, M. (2011). (in Serbian) Averaged daily load curves of different months of shops in wide consumption category. Proceedings, *4th IEEESTEC Student's Projects Conference,* Conference. Srbija: Niš, pp. 19–21.

[7] Korunovic, L. & Vuckovic, M. (2012) The analysis of averaged chronological daily load curves for different months of shops. SAUM 2012 [Conference proceedings]. Niš, Serbia, pp. 410–413.