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DETERMINATION OF TYPICAL ELECTRIC POWER LOADS FOR RURAL END USERS

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Summary. The typical load graphs of low voltage distribution network used for common weekdays during the electric power system load peaks were worked out, and on their basis a reduced weekly load ordered graph was obtained. A dispersion analysis was conducted in order to develop typical graphs for electric power load by defining load variability factors, load curve similarity analysis, as well as an analysis of load distributions.

Key words: electric power load, typical load graphs.

INTRODUCTION

Projects within the scope of electric power loads are conducted in order to know the power demand characteristics in time, as well as all the factors shaping those features better. Therefore, it is essential to analyze not only the load curves for the whole power system, but also any particular group of the end users. This knowledge is necessary in making decisions concerned with the maintenance and future development of electric power networks.

Literature refers to many different methods of analyzing the variability of time curves for the power loads [[Bieliński 1998; Dobrzańska 2002; Dudek 2004; Dudek 2009a, 2009b; Misiorek, Weron 2004; Nęcka 2007; Praca zbiorowa 1971; Trojanowska 2003]. One of the more important methods pertains to typical load graphs. The term “typical graph” usually means the load curve which represents significantly well a variability of loads in the analyzed time period. Long research to determine load curves for a particular group of end users has not yet given any satisfactory results [Marzecki 2001], especially with regard to rural end users.

The purpose of the project was to develop typical load graphs for low voltage distribution network used by rural farms.

MATERIAL AND METHODS

A dispersion analysis was conducted in order to develop typical graphs for electric power load of rural distribution networks by defining load variability factors, load curve similarity analysis, as well as the analysis of load distributions.

All calculations and analyses were done on the basis of the authors' research conducted in 41 selected representative 15/0.4 kV transformer stations located in rural areas of the Małopolska Region. The analyses included continuous measurements and recording of average 10 minute long active power loads with the use of a specialized microprocessor equipment.

RESULTS

Dispersion Analysis

Indicators referring to the peak load value were used as measures of electric power load time series, in particular the following [Bieliński 1998]:

− pulse duty factor $$m = \frac{P_{śr}}{P_{szr}}, \quad (1)$$

− non-uniformity factor $$m_o = \frac{P_{\min}}{P_{szr}}, \quad (2)$$

where:

P_{min} – is the minimum value of the mean 10 minute active power during the analyzed time period,

P_{szr} – is the maximum value of the mean 10 minute active power during the analyzed time period,

$P_{śr}$ – is the mean value of the mean 10 minute active power during the analyzed time period.

Variability of load during daily periods is of significant importance for the electric power economy. Table 1 lists both pulse duty and non-uniformity factors for the above- mentioned time intervals as well as corresponding values of those factors related to weekly periods.

Calculation results listed in Table 1 confirm mean uniformity of daily load curves for rural networks, since the closer to unity m_d value is, the more uniform is the load demand curve. A higher value dispersion for both m_d and as m_{do} factors was observed for a summer day consumption in comparison with that of a winter day.

Table 1. Characteristic parameters of daily and weekly load levels in low voltage rural power networks

Value	Winter Season				Summer Season			
	m_d	m_t	m_{do}	m_{to}	m_d	m_t	m_{do}	m_{to}
Mean	0.60	0.50	0.34	0.22	0.57	0.48	0.29	0.15
Minimum	0.25	0.26	0.07	0.05	0.23	0.22	0.02	0.09
Maximum	0.90	0.63	0.72	0.39	0.98	0.92	0.97	0.47
Variability Factor	0.16	0.18	0.33	0.37	0.25	0.32	0.48	0.95

When comparing variability of daily and weekly loads, one can conclude that the mean values of both pulse duty and non-uniformity factors for the daily intervals show higher values at lower variability factors than corresponding values of those factors in reference to weekly periods. This proves a lower pulse duty and higher non-uniformity of the load curve during the weekly intervals than those of the daily intervals.

THE ANALYSIS OF LOAD CURVE SIMILARITIES

Standardized daily curve vectors (daily profiles) which provide information on the shape of characteristics were used for various weekdays for the analysis of power load change similarities. Vector components for the daily profile are calculated on the basis of the following formula [Dudek 2004]:

$$p_i = \frac{P_i - P_{\acute{s}rd}}{\sum_{j=1}^{24}\left(P_j - P_{\acute{s}rd}\right)^2}, \text{ i = 1, 2, …, 24,} \qquad (3)$$

where:
P_i, P_j – load at i (j) hours,
$P_{\acute{s}rd}$ – mean daily load.

Euclidean distance (*d*) of the curve from the averaged mean profile and its distribution was assumed as a measure of daily characteristics similarity and rendered with the use of box plot graphs for particular days of the week (see Fig. 1).

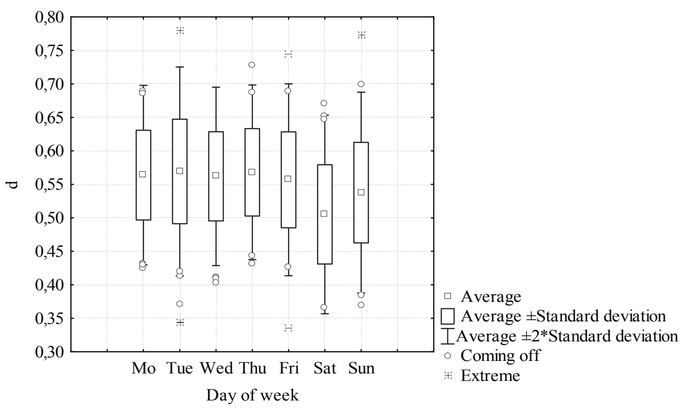

Fig. 1. Box plot graphs showing distributions of profile distances from averaged profiles

Figure 1 shows that the curves for daily loads during weekdays are highly similar in shape. Euclidean curve profile value distance from the average mean profile is approximately 0.56 and differs significantly from the remaining two days of the week. The conducted analysis also shows significant differences between mean values of *d* indicator for Saturday and Sunday.

A cluster analysis was also used for the same analysis by agglomeration method (see Fig. 2) and k-means method in particular. All the above-mentioned methods rendered the same results, allowing to distinguish three typical days of week in terms of daily load variations; i.e. weekdays, Saturdays and holidays.

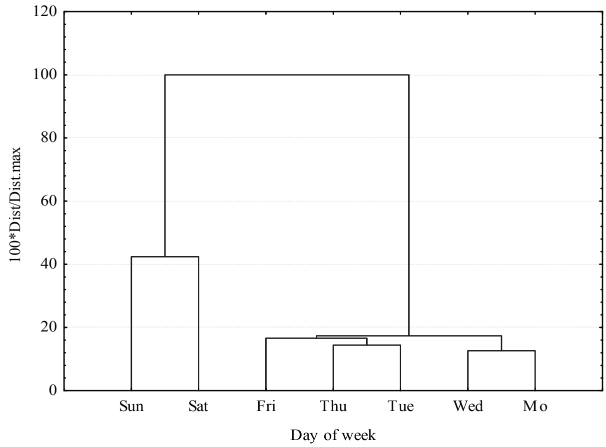

Fig. 2. Agglomeration of similarities between standardized daily curve vectors for particular days of week

ANALYSIS OF LOAD DISTRIBUTIONS

Therefore, the box plot graphs (see Fig. 3) were separately developed for all types of daily load after a previous standardization of the daily curves according to formula 3. The length of the box itself as well as the lengths of whiskers point out to the dispersion of a feature which is reduced on a low side in comparison to a load peak. In the case of holidays, the dispersion for the whole day shows a similar level and features a lower number of non-typical observations than on other days. The majority of odd observations, unrelated to the type of the day, were recorded in the morning hours.

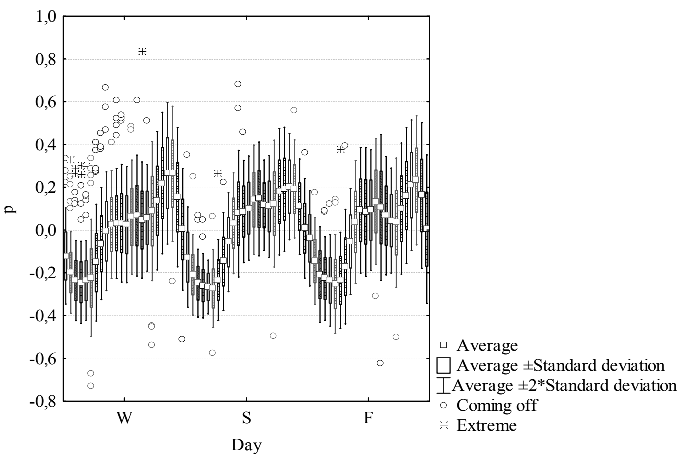

Fig. 3. Box plot graph showing distribution of standardized hourly loads for particular days of week

The typical reduced load graphs for common weekdays during the electric power system load peaks were developed on the basis of the conducted analysis of the time series for rural end user electric power loads during both daily and weekly periods. They were interpreted as the corrected curves as well as the averaged mean curves (see Fig. 4) and a reduced weekly load ordered graph was obtained (see Fig. 5).

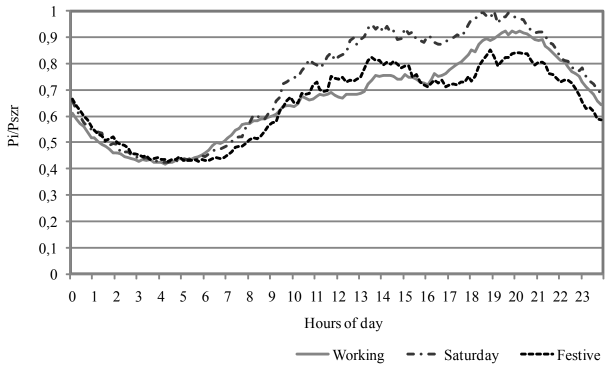

Fig. 4. Typical load curves for rural end users during the days of the system peak loads

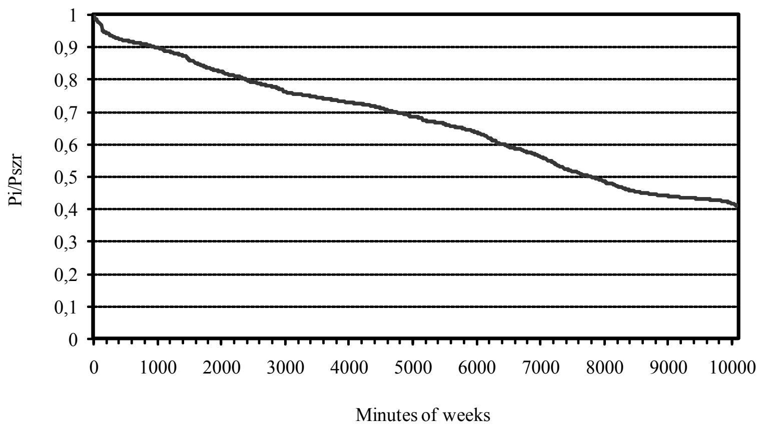

Fig. 5. Reduced ordered graph for rural end users during the week of the system peak load

Figure 4 shows the existence of an unfavourable phenomenon proving that the load peak within low voltage rural power systems coincides with the load peak for the whole electric power system, independently on the type of day.

CONCLUSIONS

The knowledge of typical load graphs allows to determine power demand in each of the weekly 10-minute intervals; therefore, this information comprises the basic data for both the maintenance and planning of electric power infrastructure development. Moreover, it supports the initiation of activities to rationalize electric power networks in terms of shaping the most favourable load characteristics, as well as signing contracts defining the specific load curve features between the power providers and the end users. It is also possible to issue warnings to the power provider service departments about any possible deviations from any usage considered to be typical.

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WYZNACZANIE TYPOWYCH WYKRESÓW OBCIĄŻEŃ ELEKTROENERGETYCZNYCH ODBIORCÓW WIEJSKICH

Streszczenie. Opracowano typowe wykresy obciążeń wiejskiej sieci rozdzielczej dla charakterystycznych dni tygodnia w szczycie obciążenia systemu elektroenergetycznego, a na ich podstawie zredukowany, uporządkowany wykres obciążeń tygodniowych. Dla potrzeb opracowania grafików obciążeń przeprowadzono analizę dyspersji, wyznaczając współczynniki zmienności obciążeń, analizę podobieństwa przebiegów obciążeń oraz analizę rozkładów obciążeń.

Słowa kluczowe: obciążenie elektroenergetyczne, typowy wykres obciążeń.