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Analysis of Electricity Consumption for Industrial Consumers

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This paper presents a case study regarding the analysis of electricity consumption for a slaughter house as industrial consumer. This analysis takes into consideration the load curves during a whole year time delay. Based on data processing statistical methods within this case study, the author develops a forecasting procedure with time series analysis in order to better estimate the electricity consumption during a year. For the considered consumer, continuous supplied all the day by two power delivery networks of 20kV by means of an electrical transformer, practical results have been considered in order to verify the accuracy of statistical analysis.

Keywords: *industrial power systems, load forecasting, statistics.*

1. Introduction

Generally the load curve is a graph of the load variation observed or expected as a function of time. This definition is in agreement with the standard IEC 60050 [1, 3]. In energy and power delivery, the load curves knowledge is very important because of following main reasons:

- to ensure an equilibrium between supply and demand for electricity,
- to provide information about the change in time of loads in common network points for joining,
- to establish all participants operation within electricity market.

Usually, load curve shapes are expressed as analytical functions and to easy use them, processed measured data are required. Load curves are determined experimentally or by calculation and are drawn after the indication of the measuring apparatus. By calculation are used different methods as statistical, optimizing or aggregation. The author proposes a forecasting procedure with time series analysis in order to better estimate the electricity consumption during a year for a slaughter house as industrial consumer.

2. Industrial consumer configuration

As example, is considered a slaughter house which is continuous supplied (three working turns/day) by two power delivery networks (L_1, L_2) of 20 kV by means of an electrical transformer of 20/0.4 kV, as shown in figure 1.

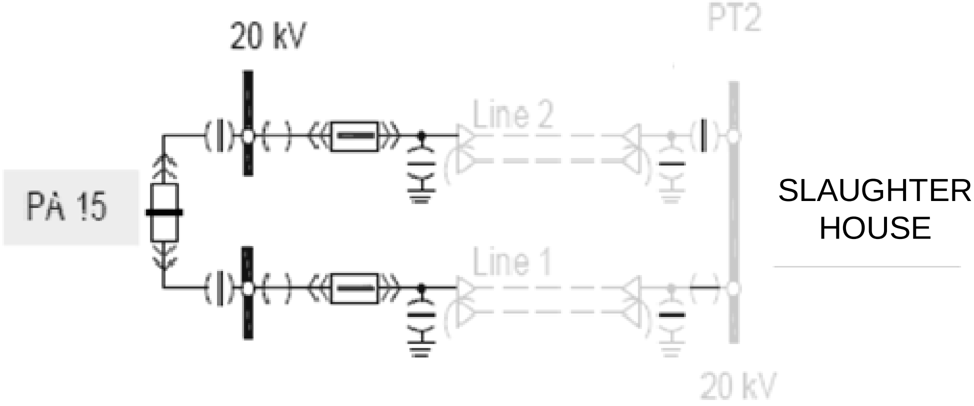

Figure 1. General networking of a slaughter house.

To oversee the industrial consumer, a monitoring and counting in real-time system is used.

This one is able to survey and analyses the electrical power and energy consumption and is based on the data stored in a computer server [1, 2, 3]. In this aim are used electronic ABB counters which are able to data register from 15 to 15 minutes for different time periods (day, month and year).

3. Load curves and statistical analysis

As example, are considered the data sets measured every hour for over a period of one month, during the 2016 year, as follows:

- winter month of February;
- summer month of June.

Measurements were exempted from Sundays.

Data processing was done using the software packages STATISTICA, ORIGIN, GRAF and EXCEL. The hystograms for the present case, are presented in [3].

For timing check series of data, statistical analysis methods are used [2, 3]. To solve this problem, the following formulas are considered:

- load curve $P_{i\ med} = f(t)$, for $i = 1,2,......24$ estimates the average consumption at the time *j* for a monthly analized time period.

- medium power P_{med} estimated at hour i within a considered month M, calculated as:

$$P_{med} = \frac{1}{M}\sum_{j=1}^{M} P_{ij} \ . \qquad (1)$$

- sample variance s calculated as square root of the measurements performed dispersion D_S :

$$s = \sqrt{D_s} \qquad (2)$$

- coefficient of variation C_V calculated in [%] as follows:

$$C_V = \frac{s}{P_{imed}} \cdot 100, \qquad (3)$$

- coefficient of use k_u of installed power P_{ins}, calculated as follows:

$$k_u = \frac{P_{med}}{P_{ins}}, \qquad (4)$$

where P_{med} is the active medium power during a t time range.

- shape factor k_f defined as:

$$k_f = \frac{P_{med,p}}{P_{med}}, \qquad (5)$$

where $P_{med,p}$ is the medium square power during a t time range.

- load curve unevenness coefficient, expressed as:

$$k_{ap} = \frac{P_{\min}}{P_{\max}}, \qquad (6)$$

where P_{min} and P_{max} are the minimum and the maximum active powers.

Based on the formulas (1) - (6) and on practical measurements, a statistical synthesis of the daily load curve values during February and June of 2016 year, are presented in Tables 1 and 2.

Table 1.

Day	P_{med} [kW]	s [kW]	D [kW^2]	P_{min} [kW]	P_{max} [kW]	C_v [%]	k_f	k_u	k_{ap}
15.02.16	281.7	18	323.55	251	317.6	0.012	1.523	0.89	0.8
16.02.16	285.77	29.95	896.6	247.5	366.3	0.032	3.3	0.78	0.67
17.02.16	292.05	9.8	95.85	275.7	312.3	0.003	1.052	0.93	0.89
18.02.16	290.76	36.16	1306.6	234.3	371.4	0.044	4.6	0.78	0.65
19.02.16	286.6	26.88	722.16	235	347.1	0.026	2.71	0.82	0.68
20.02.16	272.8	37.75	1426.5	225	356	0.053	5.33	0.76	0.63
22.02.16	292.5	17.87	320	263.2	326	0.012	1.48	0.89	0.8
23.02.16	292.8	29	841.7	244.3	340.3	0.03	3.044	0.86	0.72
24.02.16	295.96	23.2	537.16	266.5	346.6	0.019	2.072	0.85	0.77
25.02.16	304.9	29.25	855.03	245	350	0.027	2.98	0.87	0.7

Table 2.

Day	P_{med} [kW]	s [kW]	D [kW^2]	P_{min} [kW]	P_{max} [kW]	C_v [%]	k_f	k_u	k_{ap}
13.06.16	342.2	23.9	569.8	278.8	371.6	0.017	1.942	0.92	0.76
14.06.16	359.6	24.9	620.6	284	397	0.018	1.995	0.905	0.71
15.06.16	359	25.7	659.95	313.5	412.5	0.018	2.093	0.88	0.76
16.06.16	360.2	33.8	1141.3	283.5	425	0.033	3.321	0.85	0.67
17.06.16	339.5	25.5	645.7	282.2	390	0.02	2.149	0.875	0.72
18.06.16	335.5	32.77	1072.5	267.5	380	0.032	3.349	0.88	0.71
20.06.16	345	27.25	741.4	289.6	382.2	0.02	2.37	0.905	0.76
21.06.16	363	17.2	295.55	332.5	398	0.009	1.289	0.913	0.83
22.06.16	366.3	25.1	628.5	293.5	403.5	0.016	1.985	0.91	0.73
23.06.16	356.2	46.16	2130.2	223.5	423.3	0.06	6.065	0.842	0.53

Analyzing data from previous tables, the following conclusions are highlighted:

- within the considered time tables, the *s* and *D* factors have quite high values;
- k_f factor values are not quite close to the unitary value, that means the industrial consumer load is not constant;
- C_V factor values are summarized in the range of $0 < C_V < 17\%$, so his sets of values have a high degree of representativeness.

Using the ORIGIN software package, in the figures 2 and 3 are depicted the monthly load curves during February and June of 2016 year.

With formulas (1) – (6), are obtained the estimated curves for hourly consumptions $P_{i\,med} = f(t)$ within winter and summer, as shown in figures 4 and 5.

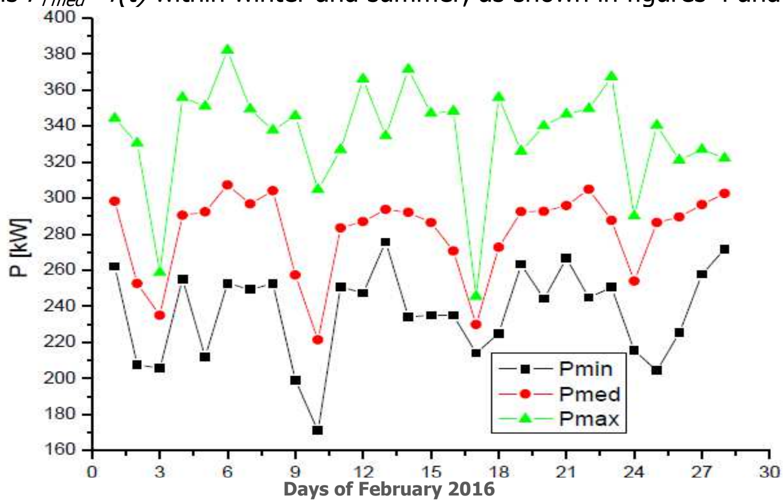

Figure 2. Active power curves of the industrial consumer in February 2016.

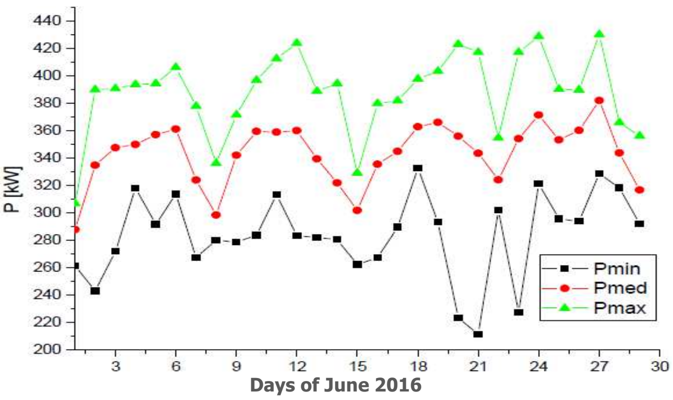

Figure 3. Active power curves of the industrial consumer in June 2016.

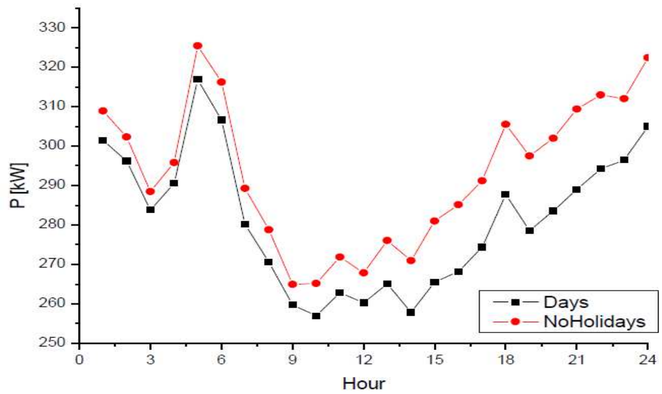

Figure 4. Load daily mean curves of the industrial consumer in February 2016.

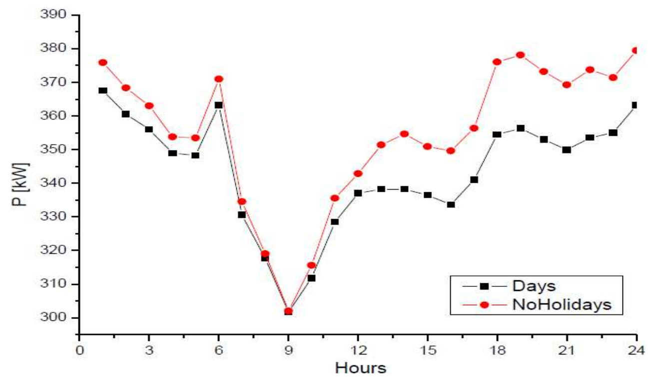

Figure 5. Load daily mean curves of the industrial consumer in June 2016

The load daily average curves for winter and summer indicate that exist maximum charging points between 5 - 7 and 18 - 23 hours. Based of these data, a load standard curve may be proposed. So, is useful to forecast power/energy consumption. The author also developed a second method to forecast the consumption of electrical energy for industrial consumers. This one represents a procedure which uses all the data more than 5 years old. This one is built in order to establish the trend of consumption during a medium/long time period [3].

4. Conclusion

Load curve analysis has been carried out within an industrial consumer using statistical mathematical methods. With STATISTICA software has been checked the normality of distribution series of data. To obtain a real-time load curve analysis must be carried out some software solutions with access into the on-line environment. To draw the load curves for industrial consumers, are presented specific indicators and methods/techniques. In this aim the author develops an algorithm based on time series method. For this industrial consumer load is variable in time and the Smart Metering for it, requires a dedicated software to interface with software packages applied within the concept of Smart Grids.

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