CONSUMPTION AREA OF "ELEKTRODISTRIBUCIJA BEOGRAD" PEAK LOAD FORECAST REGARDING THE EFFECTS OF NEW TARIFF SYSTEM

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ABSTRACT

This paper presents an original method for the fitting peak load changes during the several decades in the integral consumption area of "Elektrodistribucija Beograd", as well as fitting changes in the last 5 years, caused by the new Tariff System appliance.The chain index of the annual peak load's change is fitted by decreasing exponential function. That way, the peak load change is fitted by S-curve with saturation slower than saturations of the power or standard S-function. The peak load's value reduction, caused by the Tariff System's changes, is also fitted by decreasing exponential function, with previously done re-calculations for the same weather conditions.

INTRODUCTION

The new Tariff System in Serbia [1] brought whole line of novelties, such as: lower tariff period that existed during weekends and in the afternoon during workingdays has been cancelled; starting time of lower tariff period at night has been moved from 22:00 to 24:00; the block-tariff concerning electric energy for households has been established; the price ratio of lower and higher daily tariffs has been changed from 1:2 to 1:4; prices for electric energy and power have been increased, etc. The aims of these changes were more rational electricity consumption and the peak load's reduction. Due to cancellation of lower tariff period in the afternoon and moving its starting time later at night, peak load value started to decrease, but with delay of one winter season. Peak load value decreased by reallocation of electric energy usage, during the day. This trend lasted until winter 2004/05, when the effect saturated and the influence of new customers connection on distribution network prevailed. This caused that peak load increased again.

Before the new Tariff System, the annual peak load in „Elektrodistribicija Beograd“ (in further text: EDB) was forecasted by the extrapolation of the linear trend of previous 10 years loading history data. Peak load reduction caused a dilema: to procede with usual practice of linear extrapolation or try to model the influence of the new Tariff System. Lit. [2] described an attempt of its modelling with exponential curve. This model was extended in [3] by re-calculation of the peak loads for the same average daily temperature, with keeping the same trend from the last decade of the old Tariff System appliance.

This paper, however, presents another attempt to forecast the saturation effect, based on several decades long historical period, through the peak load chain index forecast.

DATA

Tables 1 and 2 show the dependent and independent variables data, necessary for analysis of integral EDB consumption area's peak load growth. In the tables year means winter season, for example: 2003 = season 2003/04.

Table 1 - Values reached during the old Tariff System

Year (Y)	Peak Load (MW)	Year (Y)	Peak Load (MW)	Year (Y)	Peak Load (MW)
1954	47	1969	328	1984	999
1955	57	1970	379	1985	1059
1956	70	1971	416	1986	1158
1957	81	1972	461	1987	1172
1958	92	1973	463	1988	1144
1959	108	1974	531	1990	1269
1960	118	1975	586	1991	1348
1961	134	1976	638	1992	1453
1962	151	1977	676	1993	1489
1963	183	1978	699	1994	1475
1964	193	1979	754	1995	1479
1965	202	1980	836	1996	1614
1966	230	1981	891	1997	1618
1967	247	1982	897	1998	1645
1968	296	1983	940	1999	1653

Table 2 – Year 2000 and the new Tariff System

Year (Y)	Peak Load (MW)	Average daily temperature (^{o}C)
2000	1649,00	-0,8
2001	1640,55	-6,9
2002	1473,30	-3,3
2003	1376,64	-5,1
2004	1470,20	-9,1
2005	1528,90	-7,5

PEAK LOAD'S CHAIN INDEX FORECAST ACCORDING TO THE OLD TARIFF SYSTEM

In [2] and [3] the linear trend of load growth during 1990-2000 period was extrapolated in the future, with corrections related to the influence of the new Tariff System. Such linear trend for integral city area's peak load is usual [4]. Figure 1, however, shows that – based on many years long history of load changes (marked with black squares) – after each period of the intensive load growth, in Belgrade comes a saturation period, with slower growth. Saturation trend is usually modelled by S-curve, which has a general form:

$$P_v = A - \frac{B}{1 + e^{\frac{Y-C}{D}}} \quad , \qquad (1)$$

where A, B, C and D are parameters defined through regression analysis („fitting“), and Y marks the year. Such procedure, done with data from Table 1, as the result gave the following analitic expression:

$$P_v(MW) = 2025{,}9 - \frac{2098}{1 + e^{\frac{Y-1983{,}4}{10{,}175}}} \quad , \qquad (2)$$

also shown in Fig. 1, as a continuous curve. The problem with this curve is its saturation by 2025,9 (MW), which will emerge beyond 2030, estimated as too low value.

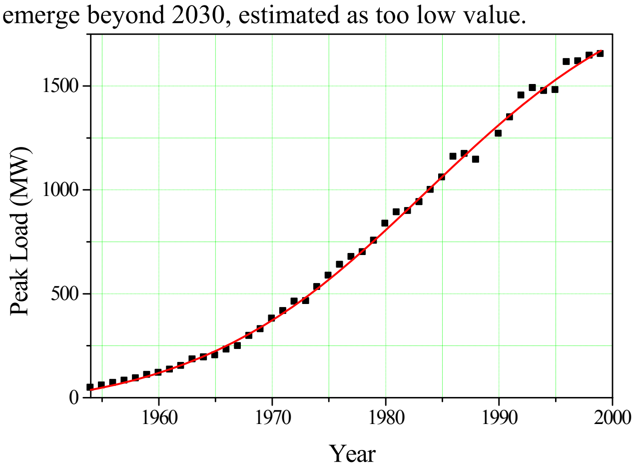

Figure 1 Peak load growth in EDB's area until 2000

That was the reason for making an attempt here – to model chain index the first, and then, through it, to model indirectly an S-curve with slower saturation. Chain index is the percentage of peak load value change, considered in one particular year in relation with its value in the previous one. It is calculated from data given in the Table 1. Figure 2 presents the change of the peak load's chain index since 1954 to 2000 (dark points).

It can be seen that there is a general trend of chain index value's reduction during the time. This trend can be fitted by decreasing exponential curve, which has to fulfill the condition of its asymptotic approach to zero. Its form is

$$i_j = i_{\max} \cdot e^{-\frac{Y-1954}{T}} , \qquad (3)$$

where i_j (%) is the chain index, i_{max} (%) – its maximal value on the modelled curve, and T (in years) – time constant of its reduction, according to the modelled curve. Parameters i_{max} and T were determined during fitting process, done – as usual –by minimization of the sum of square errors between modelled and calculated data. As the result of this numerical procedure, following expression was derived:

$$i_j = 19{,}269 \cdot e^{-\frac{Y-1954}{21{,}88488}} , \qquad (4)$$

which is also shown in the Figure 2, by continuous curve.

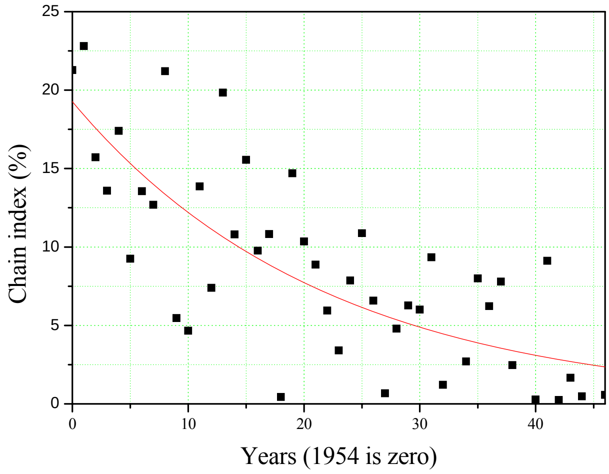

Figure 2 The peak load chain index value until 2000

The peak load in the year *j* is then:

$$P_j = P_{j_0} \cdot \prod_{j=j_0}^{n} \left(1 + \frac{i_j}{100}\right),$$

$$P_j = P_{1954} \cdot \prod_{j=1954}^{n} \left(1 + \frac{1}{100} \cdot 19{,}269 \cdot e^{-\frac{Y_j-1954}{21{,}88488}}\right) \qquad (5)$$

Measured values and peak load values calculated according to the equation (5) are shown in the Figure 3.

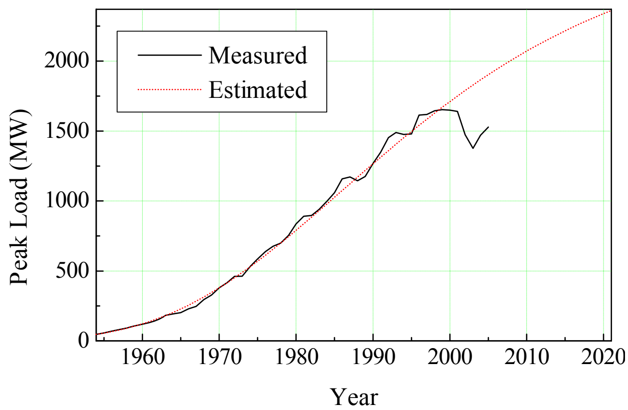

Figure 3 Peak load values in EDB's area until 2021

As it is possible to see in this Figure, regression by forecasted chain indexes approximates relatively well the values of peak load reached during appliance of the old Tariff System, taking into account reduction of growth rate (regression is, by its form, the S-curve with slower saturation). Much remarkable distortion occures since 2000, caused by the new Tariff System practice.

CONSIDERATION OF THE NEW TARIFF SYSTEM

Re-calculation on the same weather conditions

Peak load values were reached by different average daily temperatures. Because of insufficient number of data for comprehending the effects of the new Tariff System, as well as strong relation between the peak load and average daily temperature, the peak load values reached by new Tariff System have to be recalculated on the same metheorological conditions [5].

Resetting on the same average daily temperature is performed in this way: for each of the last six winters during the new Tariff System period, using data for four winter months (November, December, January and February), the linearized relations between temperature and the daily peak loads have to be determined; then, from these relations, the peak load value for each winter season is calculated for desired average daily temperatures. To illustrate this procedure, Figure 4 shows data for winter 2005/06, with the linear regression.

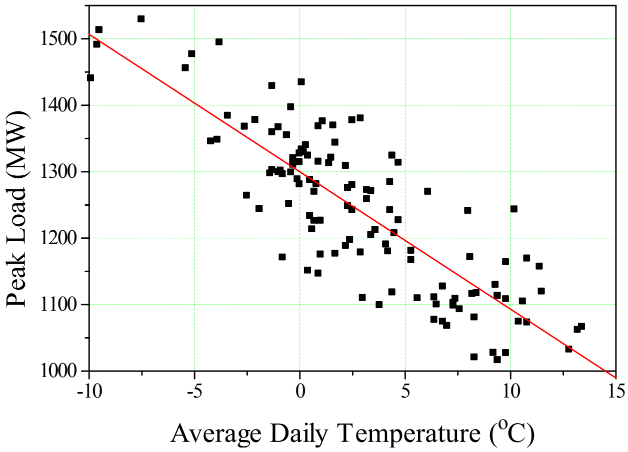

Figure 4 Relation between average daily temperature and peak load values in 2005/06 winter season

Analitic expressions of these relations, for the last season by old Tariff System and following five years by new one, are:

$$P_{2000/2001}(MW) = 1426{,}38 - 17{,}94 \cdot t(^{o}C),$$
$$P_{2001/2002}(MW) = 1365{,}56 - 27{,}82 \cdot t(^{o}C),$$
$$P_{2002/2003}(MW) = 1249{,}88 - 24{,}81 \cdot t(^{o}C), \qquad (6)$$
$$P_{2003/2004}(MW) = 1242{,}89 - 19{,}77 \cdot t(^{o}C),$$
$$P_{2004/2005}(MW) = 1251{,}53 - 20{,}85 \cdot t(^{o}C),$$
$$P_{2005/2006}(MW) = 1299{,}97 - 20{,}68 \cdot t(^{o}C)$$

These relations are graphically presented in Figure 5. It is possible to see there that by changing the Tariff System, the linear correlation of peak load and average daily temperature has been translated more and more lower, year after year, with gentle movement upwards, during the last two seasons. The inclination of the line increased rapidly first, and then started slowly to approach to the value reached by old Tariff System. Translation of linear functionality downwards can be explaned by replacing electrical heating with some other heating system. Increasing inclination can be explained by the electric power savings during the days with higher temperatures.

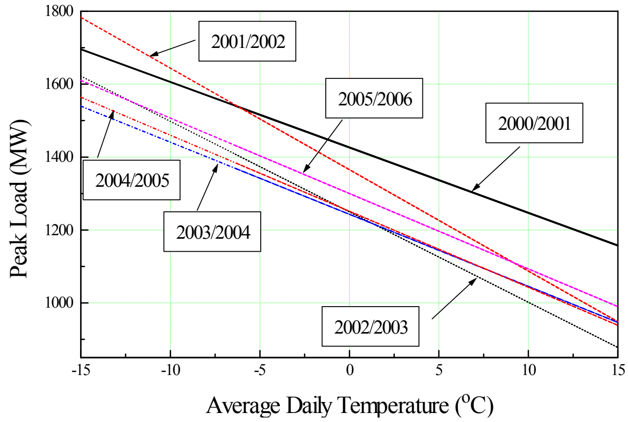

Figure 5 Relations between peak load and temperature in the last six winter seasons in Belgrade

Re-calculations are done for average value (-6,38 °C) of average daily temperature in the moment of EDB integral consumption area's peak load. This value was calculated from the last 15 years period, during which these data were accesible. Results for the last 6 years are shown in Table 3.

Table 3 – Measured values and the calculation results

Year (Y)	P_m (MW)	$P_{m, eq (5)}$ (MW)	$\Delta P_{m, 2\text{-}3}$ (MW)	$P_{m, a.t.}$ (MW)	$\Delta P_{v,2\text{-}5}$ (MW)
1	2	3	4	5	6
00	1649,0	1710,1	-61,1	1540,8	-169,3
01	1640,6	1750,4	-109,8	1543,1	-207,3
02	1473,3	1789,7	-316,4	1408,2	-381,6
03	1376,7	1828,2	-451,6	1369,0	-459,2
04	1470,2	1865,8	-395,6	1384,6	-481,2
05	1528,9	1902,4	373,5	1431,9	-470,5

Marks in Table 3 are: P_m – measured values of peak load; $P_{m, eq (5)}$ – peak load forecast, in the supposed case of the old Tariff System remained active, calculated according to equation (5); $\Delta P_{m, 2\text{-}3}$ – the difference which occured due to the new Tariff System's appliance; $P_{m, a.t}$ – peak loads which would be reached if average daily temperature was -6,38 °C; $\Delta P_{v, 2\text{-}5}$ – the difference which would exist by t_{av}= -6,38 °C, due to the new Tariff System's appliance.

Modelling of the new Tariff System's influence

Regarding the fact that the expected effects (concerning the peak load value reduction) of the new Tariff System's appliance, appeared with delay, an idea imposed itself – convenient for modelling such a phenomenon is exponential function, as the curve typical for the presentation of delays. Namely, the new Tariff System has

been understood as an impulse command and the effects (modelled by exponential function) – as delayed response of the system.
The general form of this function is:

$$\Delta P = P_1 - P_2 e^{-\frac{Y-2000}{T_P}} \quad , \ Y \geq 2001 \qquad (7)$$

Peak load by the new Tariff System will be modelled as the difference of two functions – the first one defined with the equation (5), by the old Tariff System, and the second – with exponential curve (effects of new Tariff System), according to equation (7). Therefore, final function for the new Tariff System period has the following form:

$$P_n = P_0 \cdot \prod_{i=0}^{n}\left(1+\frac{i_i}{100}\right) - \left(P_1 - P_2 e^{-\frac{Y-2000}{T_P}}\right), Y \geq 2001 \quad (8)$$

Parameters P_1, P_2 and T_P will be determined by „fitting“ for average value (-6,38 ^{o}C) of average daily temperature (column 6 in Table 3) and for non re-calculated data (column 4 in Table 3). As the result, there are the following equations:

$$\Delta P_{tav} = P_{1954} \cdot \prod_{i=0}^{n}\left(1+\frac{1}{100}\cdot 19{,}269\cdot e^{-\frac{Y_i-1954}{21{,}88488}}\right) -$$
$$-576{,}04 + 431{,}03\cdot e^{-\frac{Y-2000}{2{,}88355}} \quad , \ Y \geq 2001 \qquad (9)$$

$$\Delta P_{nrc} = P_{1954} \cdot \prod_{i=0}^{n}\left(1+\frac{1}{100}\cdot 19{,}269\cdot e^{-\frac{Y_i-1954}{21{,}88488}}\right) -$$
$$-460 + 429{,}013\cdot e^{-\frac{Y-2000}{2{,}05}} \quad , \ Y \geq 2001 \qquad (10)$$

From the equation (9) is obvious that the summary effect of the new Tariff System was the reduction of peak load value in average ammount of 576,04 MW (almost 35 % of apsolute peak) on the level of EDB’s integral consumption area, which is remarkable. Concerning the value of delay time constant, T_p, however, this influence will still be noticeable in 8,5 years ($3\cdot T_p$) after new Tariff System’s introduction. Alongside, the load grows as the time passes – due to the connections of new customers to distribution system – and the summary effect is therefore the superposition of two previously described.
Forecast results for the next 15 years are given in Figure 6. It shows that the peak load will reach its maximal (in 1999) measured value around 2010-2013, which means that the new Tariff System delayed investments in new electricity distribution's facilities for 10-13 years. Further stagnation of the peak load is expected by increase of electricity price, which is now – with cca 0,04 EUR/kWh – the lowest in the region.

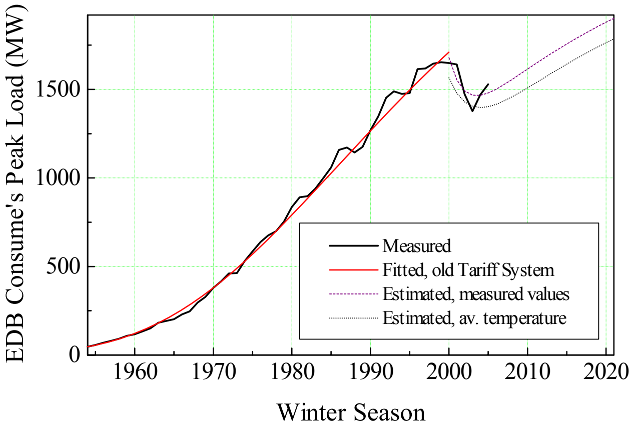

Figure 6 EDB area's peak load forecast until 2021

CONCLUSIONS

By fitting the peak load growth index, using an exponential function, it is possible to model the obvious »saturation« of the peak load growth in EDB's integral consumption area. This modelling is evaluated as more realistic then modelling by ordinary S-curve (Sigmoidal, Boltzmann function).
The effects of the peak load reduction, caused by new Tariff System appliance in 2000-2006 period, can be modelled successfully also by exponential function.
New Tariff System caused the peak load reduction of more than 500 MW, which is cca 30 % of absolute peak, ever recorded. By the new Tariff System influence capital investmets in EDB are delayed for 10-13 years.

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