AN ALTERNATIVE METHODOLOGY FOR PEAK LOAD FORECAST IN AN ASSIGNED AREA REGARDING THE EFFECTS OF NEW TARIFF SYSTEM

Vladimir M. SHILJKUT
"Elektrodistribucija Beograd" – Serbia
vladash@edb.eps.co.yu

Slobodan MAKSIMOVICH
"Elektrodistribucija Beograd" – Serbia
smaks@edb.eps.co.yu

ABSTRACT

This paper presents an alternative method for the peak load forecast in an assigned area, created in order to solve some prognostic problems specific for Serbia and its electricity distribution companies. The major one was the fact that the new Tariff System and higher electricity prices, applied and modified/increased since 2001, caused decreasing trend of the peak load value. By its conception, this methodology solves also some widespread prognostic problems, such as load transfers between substations during several years of trend period. The paper explains the conception and principles of this method and illustrates its results on several examples of High (or Medium) Voltage / Medium Voltage (HV/MV) substations operated by "Elektrodistribucija Belgrade", electric power distribution company in Serbian capital. Finally, the forecasts based on this and several other methods are compared in this paper.

INTRODUCTION

For decades in Serbia has been applied one obsolete Tariff System for the electric energy sale. Instead of the daily load chart smoothing, it produced the opposite effect (high daily peak). Finally, in 2001, a modern Tariff System was accepted, bringing many novelties. It also caused the peak load decrease in the whole consumption area of »Elektrodistribucija-Beograd« (in further text: EDB) integraly, as well as in assigned consumption areas of particular substations HV/MV (SHM).
However, it brought the problems to planning engineers, because the classical extrapolation peak load forecast methodologies produce decreasing curves. Beside that, unsolved remains the problem of mutually non-respondent data in the SHMs loading history, caused by the transfers of load between them (different consumption areas in the different years).
As a solution of these problems, an approximate methodology for SHM loading history data simulation has been developed [1]. It simulates permanent application of the new Tariff System, even before it was brought in.
Making peak load forecast and modelling its saturation in the future, however, can not be solved completely by this method, and they remain the problems for themselves. But, due to the fact that the result of the simulation, mentioned above, is always non-decreasing curve, this method makes easier the choices of the relevant trend-period and appropriate extrapolation curve.
These and some other achievements and advantages of this method are illustrated on the real examples, in this paper.

SPECIFIC PROBLEMS

Except the problem of the load transfers and the influence of the new Tariff System on the peak load trend, mentioned above, electricity distribution companies in Serbia are usually confronted with some additional, specific problems:
- Substations MV/LV (SML) still are not connected to company's Remote Control and Measuring System (RCS);
- Also some SHM (35/10 kV in Belgrade), especially in suburban and rural areas, are not connected to RCS. Therefore, the loads of MV feeders in them can not be taken on-line, as well as the loads of their transformers or particular substation itself, if there was more than one SHM supplied from the single HV feeder;
- Measuring data from these substations are taken manually, but the exact moments of such measurements are not known, and – consequently – the consumption areas supplied in those moments are unknown, too;
- Manually taken loads of MV feeders in such SHM are not respondent to SHM's annual maximal (peak) load;
- Even for SHMs on RCS, the loads and consumption areas of their MV feeders in the moment of particular SHM's annual peak load are not given in the Annual Reports, and it is very hard to reach those data. The whole consumption area of the SHM in that moment it very hard to detect, too;
- Only for the moment of the maximal annual load of integral consume of EDB the consumption areas of all SHMs and their MV feeders are known, but the loads in that moment (simultaneous loads) of SHMs not connected to RCS, and their feeders, remain unknown;
- In EDB's Annual Reports before 1998, were given only simultaneous loads (in the moment of maximal annual load of integral consume of EDB) of MV feeders in SHMs on RCS, but data about the consumption areas supplied from those MV feeders were not mentioned.
Concerning these problems, it is obvious that the major inaccuracy in the peak load forecasts origins from the input data, which are usually incompatible or not relevant.
Using methodology described below, some of these problems become solved or avoided, and some propitiated.

METHODOLOGY ELABORATION

Regarding the nature of the some problems, previously mentioned, this method is based on the following <u>principles</u>:
1) Consumption area of supplying SHM is fixed in the last year of load measuring;

2) Consumers of SHM are SMLs supplied from it;
3) Due to the small SML's consumption area, time chart of its peak load history is typical S-curve [2], (Fig.1);
4) The influence of the new Tariff System is modelled with saturation by lower peak load value, and such S-curve is approximated with a step-function;
5) The maximal value of the step function is the participation of SML in the peak load (annual maximal or simultaneous) of supplying MV feeder (or SHM), in the last year: this value is taken from the feeder's peak load, proportionally to power of transformers installed in that particular SML;
6) Loading history of supplying SHM is modelled by superposition of step-functions of SMLs, in their first operating years. Result is an increasing, S-like curve;
7) To get the peak load forecast for a SHM, on its S-curve classical extrapolation methodologies can be applied.

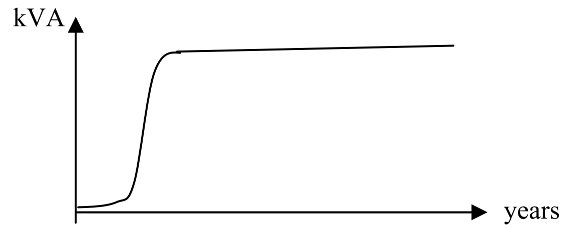

Figure 1 Typical loading dynamism for consumption area of substation MV/LV

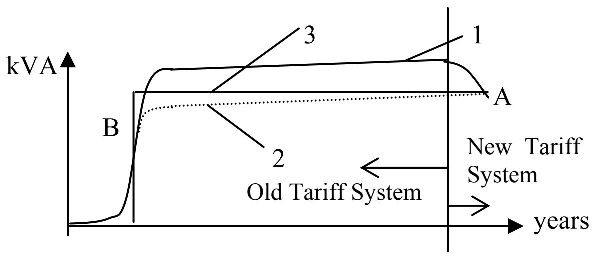

Figure 2 Influence of New Tariff System on peak load value of substation MV/LV

According to the previous, necessary input data are:
a) Peak load value (annual maximal or simultaneous) of MV feeders (or their SHM, at least), in the last year;
b) Power value of the transformers installed in all SML;
c) Data about each SML's first operating year and original power of the installed transformers;
d) Data about each SML's year(s) of the reconstruction and the value(s) of increased power of installed transformers.

Modelling details

New Tariff System caused **the peak load value reduction**, especially in the areas with electrical heating. Therefore, typical S-curve has got descending part at its end (Fig.2, curve 1, right). If new Tariff System was applied during the whole SML's operating period, the peak load curve would probably be changed according to chart 2 in Fig.2. It would be S-curve again, but with saturation at lower peak load.

Based on this logic, the accessible peak load data for each SML's consumption area are points A (present SML's peak load) and B (in the SML's first operating year).
Concerning SHM, if the new Tariff System was applied all the time, its peak load history would be created by the superposition of peak load charts, type 2 in Fig.2, of SMLs supplied in assigned SHM's consumption area.
Depending on SHM's installed power, the number of supplied SMLs can be several dozens. Therefore it is possible to **substitute S-curve** 2 in Fig.2 **with the step-function** (Fig.2, curve 3). The point B presents SML's first operating year (accessible data). The ordinate of point A (and B, too, for step-function) is load quota of particular SML in the peak load value of supplying SHM, measured in the last year.

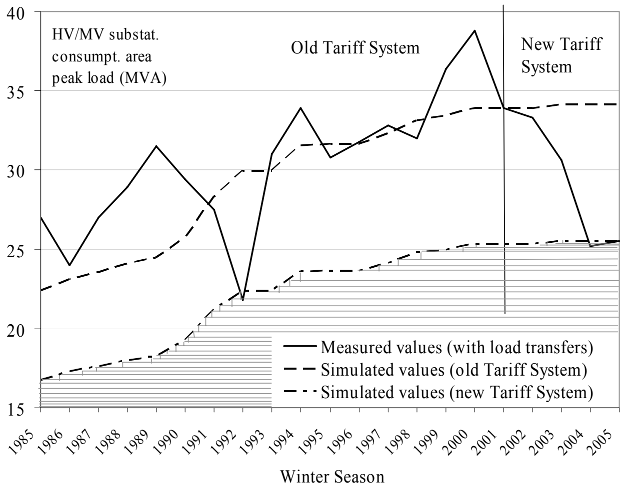

Figure 3 Peak load history of the particular substation HV/MV (35/10 kV „Zeleni Venats“)

Synthesis of SHM's peak load chart is illustrated in the Figure 3 (lower curve – for new Tariff System). It is done going backwards: the last data is measured in the last year (here: 2005 = 2004/05); previous data are got by subtracting the load quotas of SMLs (or new transformers installed in them) put into operation in that particular year; the procedure repeats until the first operating year of the oldest SML, when the peak load of area supplied by SHM become zero. Fig.3 presents characteristic example of SHM in the city centre. It is obvious that the result of this simulation looks like S-curve, which is always increasing. That fact makes forecasting easier, because the load transfers in historical trend period are eliminated by fixing consumption area in one particular year (usually the last one).
The same backwards procedure can be made starting from the last year of the old Tariff System, based on the load value reached by it and for the correspondent consumption area supplied then by the same SHM. In that case, for the new Tariff System's period additional calculation has to be done, taking into account new SMLs, put into operation in that area, in the meantime. The result is represented by upper S-curve, in the Figure 3.

APPLIANCE POSSIBILITIES - EXAMPLES

This methodology can be applied either using SHM's annual maximal or simultaneous load (in the moment of EDB's integral peak load). Instead of some SHM and its consumption area, a free-defined, particular area, supplied by MV feeders from several SHMs, can be analysed and treated by this methodology (example in Fig. 4, 5). Using simultaneous loads, forecasts of SHM's/area contribution in the global peak load of one electricity distribution company, can be made. Such example is shown in the Figure 5.

This method can be used for the analysis of the new Tariff System's effects on the peak load values in the one assigned area, by fixing it, re-calculating and using its peak load from some year during old Tariff System appliance, too. Peak load value re-calculation for that year is necessary only if area supplied then was not the same as the area in the last year. Anyway, it is necessary to make also another additional analysis – which SMLs were in operation that year in the past in assigned area, and from which feeders and SHMs they were supplied. Similar procedure can also be made for any year during new Tariff System, different from the last.

For example of Altina, still expanding suburban settlement on the west edge of Belgrade, Figure 4 shows the difference between the simulations based on data from one year in the old Tariff System period and two years in the new one.

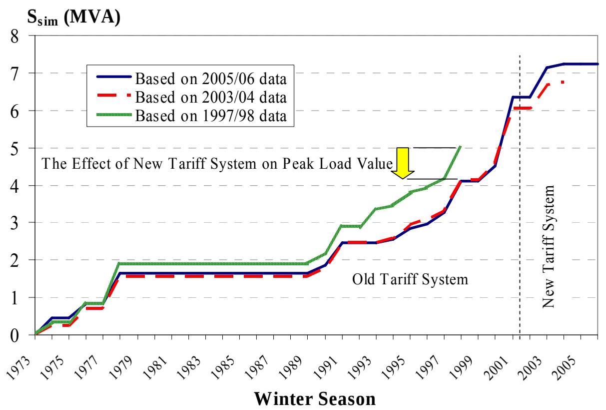

Figure 4 Simulated loading history in Altina suburb

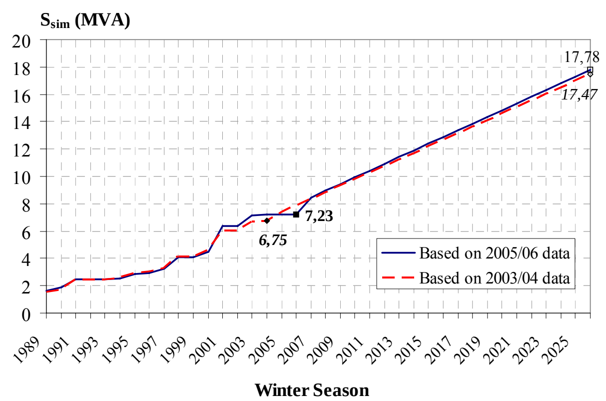

Figure 5 Forecast for Altina suburb, linear extrapolation based on 10 years history data trend

Validity and reliability of the method can be self-checked, by conducting the same procedure, based on data in two years chosen from the same Tariff System appliance period. After simulation procedure done for the first chosen year, a forecast can be made and compared with values really reached in another year. Additionally, forecasts can be made based on the both simulations, respectively, and compared in the horizon year (like Fig.5 for Altina).

Due to its principles, this methodology also allows making the forecasts for the new SHMs (without real load history), which is just put into operation, or even before – while analyzing variants of their incorporation in existing MV grid. The difference between an old SHM and a newer one can be seen in Figures 6 and 7. In the first one, this method was applied on the substation 35/10 kV "Bozhdarevats" and its results compared with the real measured values of SHM's maximal annual load. It is obvious that the real values oscillate around simulated S-curve and represent load transfers with other SHMs. In the case of newer substation 35/10 kV "Shiljakovats", shown in Fig.7, real measured loads are much lower below the middle part of the correspondent S-curve (simulated by the last value of its maximal load), during the period of putting this SHM into operation and its incorporation in existing MV network. Both SHMs, however, supply the similar, neighbouring areas, predominantly rural.

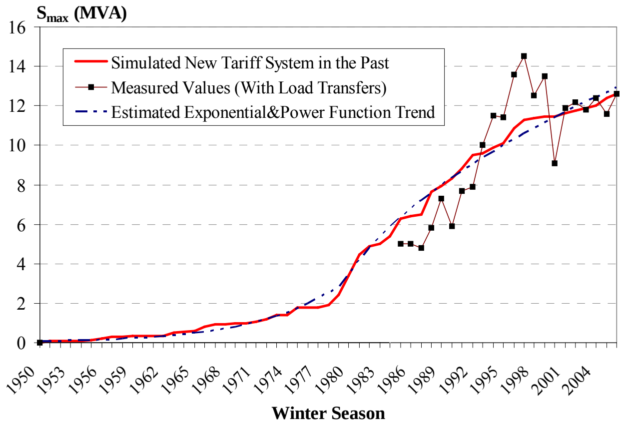

Figure 6 Substation 35/10 kV "Bozhdarevats" load growth

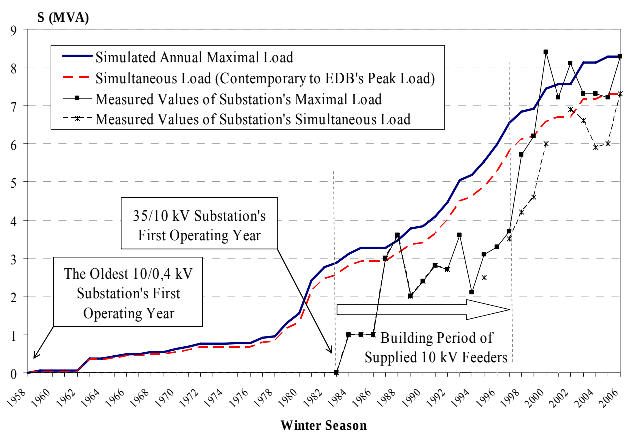

Figure 7 Substation 35/10 kV "Shiljakovats" load growth

Beside any case of the changed Tariff System, similar to described one, this method could be useful also in the case of some other – sudden and intensive – influence which could reduce the peak load value in an area or region, like: gasification, remote heating introduction, organized installation of solar systems for water heating or similar energy efficiency projects; but even for some tragic consumption reductions, caused by natural disasters or war. As input data become better (like SMLs on RCS and – consequently – their accurate loads measured and available on-line), described method becomes more precise, and its appliance much easier, faster and more efficient.

Anyway, it is also recommended to do an additional analysis and re-calculation of the load value measured in the year basic for the backwards simulation, for the worst weather conditions ever recorded [3]. Measured values from Fig. 6 and 7 can also be re-calculated for the same weather conditions. In that case, their oscillation around re-calculated S-curve will represent precise load transfers.

FORECASTING PRINCIPLES AND VARIANTS

Classical extrapolation methods can be applied on S-curves created by methodology described in the previous Chapter. Its main achievements and advantages are elimination of the load transfers problem from the historical trending period, relevant for the forecast (and also from the whole loading history) and taking into account reduction of the peak load value. By this method, possible negative trend for extrapolation has been avoided. Mistakes in extrapolation function's form, caused by real existence of load transfers in the past, are also eliminated (or at least – reduced).

However, the choice of the most appropriate extrapolation function and – connected with that – modelling of peak load value saturation, still remain problematic. This paper therefore checks some principles and functions used in practice and literature, and recommend some new.

Figure 5 already presented prognostic result of the practice usual for EDB: linearization and extrapolation of 10 years history period. By the method described here, it gives much better results than with real measured values (with load transfers or their re-calculation) during the same period.

In the Fig.6 is also shown the estimation of simulated curve with exponential function in its first part, and with power function in the second. The last is extrapolated in the Fig.8 and compared there with other functions suggested here.

Figure 8 clearly shows, for example, the difference in forecasts done by the same function (power), if different history periods were taken into account. For linear trend, the 6 years history period was used here. Multiple regression curve fitting a cubic log polynomial, recommended by Lit. [2], was applied too, based on 6 years of historical data and one horizon year (with supposed load value); load transfer coupling (LTC) approach is not necessary by this method.

Fig.8 shows the best mutual match of the results of cubic log polynomial and function suggested by this paper: in the last peak load value, y_l (on which the simulation was based), translated tangent of Sigmoidal (Boltzmann) function (S-curve in Fig.8, derived from the simulated loading history).

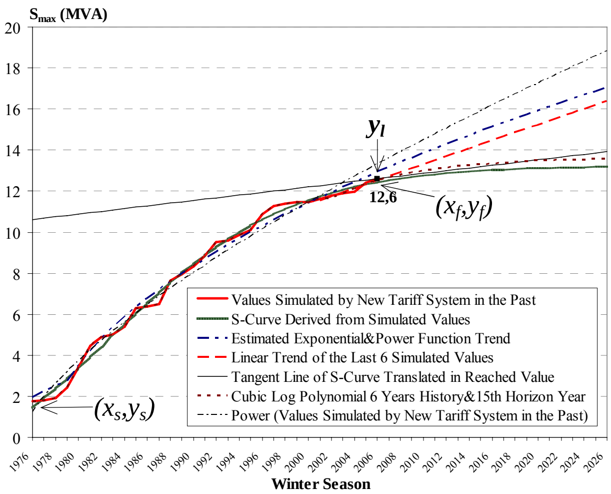

Figure 8 Forecast variants for SHM "Bozhdarevats"

Translation of tangent is necessary, because the last peak load value – for majority of tested cases – is not the point on derived S-curve. Therefore, such line's equation is:

$$y_t(x) = y_l + \frac{(y_f - y_s)\cdot e^{\frac{x_f - x_0}{\Delta x}}}{(1 + e^{\frac{x_f - x_0}{\Delta x}})^2} \cdot \frac{(x - x_f)}{\Delta x}, \text{ where}$$

x_0, Δx are S-curve parameters, and (x_f, y_f), (x_s, y_s) points on it. For the areas which still have the expanding opportunities, forecast/saturation modelling is complicated [1], due to the emerging possibility of some new, smaller S-curve. Such historical examples are already shown in Figures 4 and 7.

CONCLUSION

The method presented in this paper allows easier peak load forecast in an assigned area, by eliminations of the load transfer problems during the historical loading period and possible negative trend, which could be result of some sudden and intensive influence, like Tariff System changes. This method can be applied even with insufficient data, using only the necessary and the most usual one. The paper also proposed one new forecasting function.

REFERENCES

[1] S.Maksimović, V.M.Šiljkut, 2005, "Prognoza vršne snage TS X/10 kV uz uvažavanje efekata novog Tarifnog sistema", *Juko CIGRE 27th Conference*.

[2] H.L.Willis, 1996, *Spatial Electric Load Forecasting,* Marcel Dekker, Inc., New York – Basel – Hong Kong, USA–Switzerland–China, 144-184.

[3] S.Maksimović, 2005, "Zavisnost vršne snage konzumnog područja EDB od meteoroloških parametara", *Juko CIGRE 27th Conference.*