COMPARISON OF LOAD GROWTH PREDICTION METHODS IN DISTRIBUTION NETWORK PLANNING

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ABSTRACT

The distribution network planning is the process of gathering all the available information on the part of the network and, based on this information, creating the plan of constructing the new and reconstructing the existing distribution power system objects. This is a continuous process which should be revised every couple of years in order to include the most recent information on the current and future electricity load.

In order to create a successful distribution electricity network development programme, it is essential to accurately predict electricity consumption in the future for each part of the distribution network. This paper discusses the load growth methods applied on the part of the Croatian distribution network "Elektra Kriz".

INTRODUCTION

Since it often takes a few years to accomplish a distribution network expansion activity, whether it is a construction of a new transformer station, building new lines or reconstructing the existing equipment, the distribution network planning has to be done in advance so the new distribution network elements are available on time. The time it takes to design, obtain permits, document, build, install and test facilities sets the minimum acceptable planning period for any activity. The distribution network planning in Croatia is usually done for a 20 years period. It is considered that longer planning periods would have great deal of uncertainty and are therefore not considered. On the other hand, it is important to have a global development schedule in order to avoid the unprofitable and unnecessary investments.

When planning a distribution system, it is necessary to establish a set of rules which include all the basic system requests. The most common rules are [1]:

1. The part of the network has to maintain a constant balance between supply and demand.
2. All the network components must have a sufficient transmission capacity for all operating scenarios.
3. All network components must be dimensioned according to the short-circuit currents and the forces which occur in these situations.
4. The network has to be as simple as possible for operation.
5. The components must be built in an easy-to-maintain manner.
6. The network has to provide the sufficient supply reliability.
7. The insulation has to match the voltages.
8. The implementation has to comply with all the regulations and legal acts.
9. The proposing of the solution has to be achievable within the given restrictions.
10. Demand-side requests must be taken into consideration.

It is important that the distribution network planning is in accordance with the transmission network planning and development.

Uncertainty in predicting major events is a big concern in long-term planning. It is often very difficult to evaluate the electricity consumption growth rate of the planned small-industry zone, or will it reach the planned electricity consumption.

Load growth of households is much easier to predict. It is usually sufficient to observe the population number and structure in recent years. The population structure is important because it provides the information about the young people – whether they immigrate to or emigrate from the area.

Generally, increase in per capita consumption spread widely over areas with existing facilities already in place is slow. One of the most difficult tasks is to plan the development for these areas because the facilities exist, but they will have to be rearranged, reinforced and upgraded in the future [2].

The electricity demands may occur in areas where no electricity network currently exists. In this case new equipment and facilities must be installed.

LOAD GROWTH PREDICTION METHODS

There are two types of load growth prediction methods, analytical and global. Analytical load growth prediction methods are based on several separate analyses and on investigation of the needs of different types of consumers. The research can be based on statistical data of consumption in the past or it can be based on a survey. It should also include the planning data.

Global methods can be used under the assumption that the future growth will be the same as the growth in the past. The principle of load growth is determined by analyzing the statistical data on the past load growth. All methods are far more accurate in short-term than in the long-term predictions. The period of 20 years which is considered in this paper is valid for prediction using global methods.

The global methods include [3]:

• linear function:

$$w_i = m \cdot t_i + n$$

• square function:

$$w_i = m^2 \cdot t_i^2 + n \cdot t_i + k$$

• exponential function:

$$w_i = e^{m \cdot t_i + n}$$

• logarithmic function:

$$\ln w_i = m^2 \cdot t_i^2 + n \cdot t_i + k$$

• logistic function:

$$w_i = \frac{W_s}{1 + e^{n - m \cdot t_i}}$$

• Gompertz function:

$$w_i = W_z \cdot e^{-n \cdot m^{t_i}}$$

The symbols in the previous equations are defined as follows:

w_i - demand according to the explicit function in the i-th year

W_s - demand which matches the saturation point

t - time in years

m, n, k - parameters

In order to determine the parameters in the mathematical models, the RMS (Root Mean Square) method is used:

$$\min\left(\frac{1}{N}\sum_{i=1}^{N}(W_i - w_i)\right)$$

where are:

N - number of years in the past with available electrical energy consumption information

W_i - electrical energy consumption in the i-th year

Linear function

Linear function is the simplest function used to predict the load growth, and it often provides very accurate results. Therefore, the linear function is often used for load growth predictions, especially for short-term predictions.

Square Function

Square function provides good load prediction results for areas with expansive load growth and areas in which the load growth rate is reducing, as shown in fig. 1.

Exponential Function

The exponential function provides good results in areas with a propulsive growth rate.

Logarithmic Function

Logarithmic function may provide favourable results in short periods, but in long-term prediction it may result with absurd load growth curve.

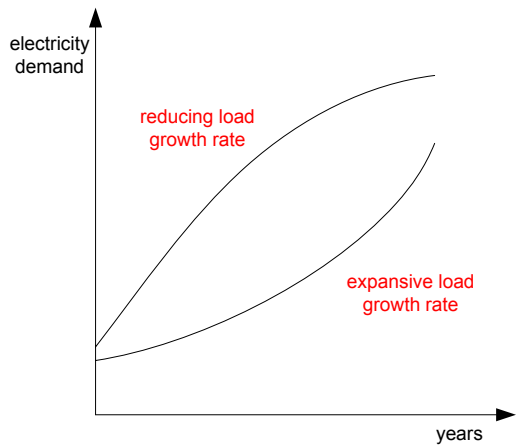

Fig. 1. Square function for areas with expansive and areas with reducing load growth rate

Logistic and Gompertz Functions

Generally, logistic and Gompertz functions are the "*S*" shaped curves, as shown in fig. 2, which have three characteristic phases:

• dormant phase,

• growth ramp, and

• saturated phase.

Among many small areas in a large distribution network the timing of the growth ramps varies the most. Therefore, the growth ramp does not occur in all areas of the distribution network simultaneously, even if all areas have the same load growth capacity.

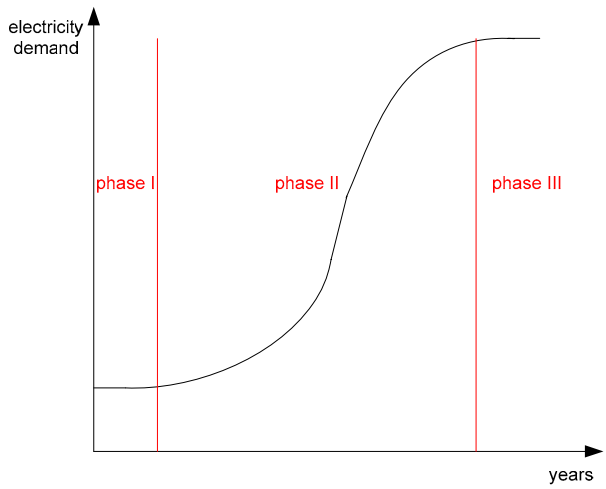

Fig. 2. Three phases of the "*S*" shaped curve

The Dormant Phase

The dormant phase is the initial period with almost no or very small load growth rate. The areas in this phase are usually developing very slowly.

The Growth Ramp

The growth ramp is usually triggered by a major investment, such as big a factory or a commerce zone. In this phase the growth rate is intensive and major investments in distribution network should be set on-line in order to fulfil the raging electricity demand.

The Saturated Phase

This phase is characterised by attenuated growth rate. Load growth may continue, but at much lower level compared to the one during the growth ramp.

GROWTH PREDICTION FOR THE "ELEKTRA KRIZ" DISTRIBUTION NETWORK

The part of the Croatian power grid which is discussed in this paper is specific in two ways. First, most of the industrial facilities had to be shut down because of the raging war during the last decade of the previous century. Secondly, an important national motor highway passes through this area. A very good traffic infrastructure in recent years caused an intensive construction works and, therefore, the increased load demand because of the rising small industrial facilities, as well as the settlements along the highway.

The load growth predictions were made for the entire distribution network "Elektra Kriz" for the time period until the year 2026.

The load prediction curves obtained by linear, square, exponential, logarithmic, logistic, and Gompertz functions are shown in figures 3 – 8.

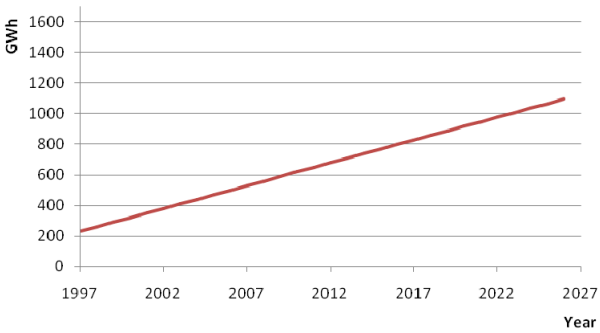

Fig. 3. Load prediction curve obtained by linear function method

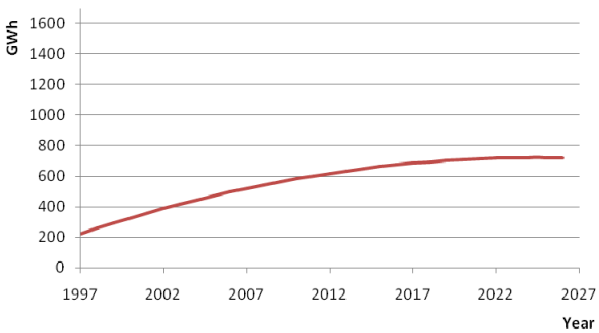

Fig. 4. Load prediction curve obtained by square function method

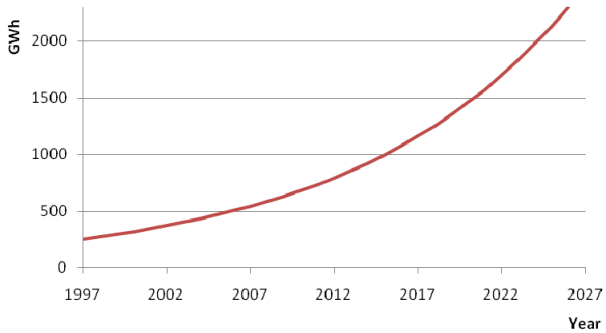

Fig. 5. Load prediction curve obtained by exponential function method

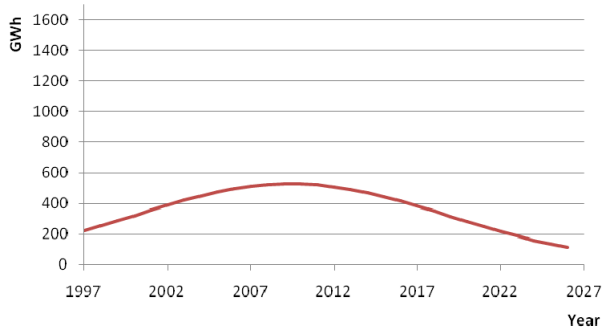

Fig. 6. Load prediction curve obtained by logarithmic function method

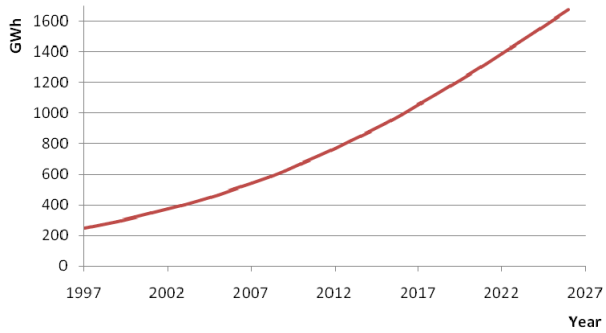

Fig. 7. Load prediction curve obtained by logistic function method

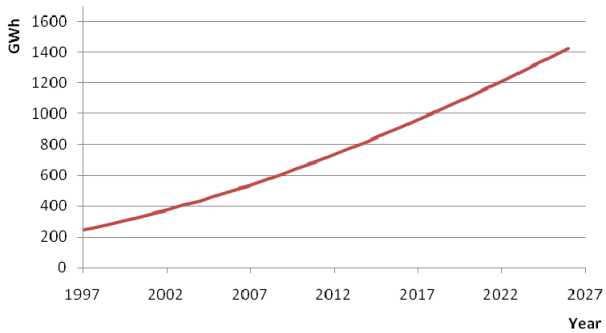

Fig. 8. Load prediction curve obtained by Gompertz function method

CONCLUSIONS

The results obtained by the logistic and Gompertz methods are quite similar. They both faithfully depict the electricity demand behaviour. The linear function is very similar to logistic and Gompertz, but it has slower growth rate.

The square function method predicts reduction in electricity demand growth rate in the "Elektra Kriz" distribution network, which is highly unlikely to happen. On the other hand, the tremendous growth rate predicted by the exponential function is also highly unexpected.

The logarithmic curve provided absurd results in long-term planning.

To conclude, the accuracy and efficiency of each load growth prediction method is highly dependent on the development level of the distribution network area (the point on the "*S*" curve), its features and the prediction period.

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