Using the Analytic Hierarchy Process in Load Growth Forecast

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Abstract – **The load growth is the most important uncertainties in power system planning process. The application of the classical long-term load forecasting methods applied to utilities in transition economy are insufficient and may produce a incorrect decisions in power system planning process. This paper discusses using the method of analytic hierarchy process to calculate the probability distribution of load growth obtained previously by standard load forecasting methods.**

Keywords – **long-term load forecasting, analytic hierarchy process, probability, uncertainties.**

I. Introduction

The basic objective of power system planning is to determine an investment schedule for the construction of generation plants and interconnection links which ensure an economic and reliable supply to the predicted demand over a planning horizon. The criteria are to minimize the total cost and maximize the reliability with different type of constraints.

Several sources of uncertainty have an important impact on this planning process: load growth rates; economic growth, cost and availability of fuels and technologies; financial constraints; environmental constraints; interest rate; construction time, public opinion etc [2].

One of the most important elements and primary tasks of a least cost power system planning is to accurately predict load requirements. Many factors affect electric load including population, income, electric tariffs, economic activity, governmental energy and environmental policies. In addition, random factor such as weather affect demand. As a result, there is significant degree of uncertainty and variability around demand forecasts. Results obtained from load forecasting process are used in different areas. Long-term load forecasting is applied to expansion problem and long-term capital investment return problem.

Accurate models for long term forecasting are essential and help electric utility, financial institutions and other participants in energy system planning to make important decisions. With the deregulation of the energy industries, decision on capital expenditures based on long-term forecasting is also more important.

Long-term load forecasting represents the first step in developing future generation, transmission, and distribution facilities. Any substantial deviation in forecast, particularly under the new market structure, will result in either overbuilding of supply facilities, or curtailment of customer demand.

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Many classic approaches have been proposed and applied to long-term load forecasting to estimate model parameters, including static and dynamic state estimation techniques (least error squares technique), methods based on artificial intelligence such as artificial neural network and expert systems. Genetic algorithms have recently received much attention as robust stochastic search algorithms for various problems.

The confidence levels associated with classical forecasting techniques are unlikely to be similar to those utilities in transition country. This is attributed to the differences in the nature of growth, socio-economics conditions, occurrence of special events. Under such condition, these forecasting techniques are insufficient to establish demand forecast for long-term power system planning. Consequently, this case requires separate consideration either by pursuing the search for more improvement in the existing forecasting techniques or establishing another approach to address the forecasting problem of such systems. Standard approach in this case is to establish several scenarios, mostly three scenarios (low, base and high scenario) with tree different supposed future demand condition [5].

In this paper, the results obtained by classical forecasting method are added in order to obtain probability distribution of load growth. The method of analytic hierarchy process is used for this purpose.

II. Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) is multiple-criteria decision-making approach and was introduced by Saaty [1]. The AHP has attracted the interest due to the nice mathematical properties of the method and the fact that the required data are easy to obtain. The AHP is a decision support tool which can be used to solve complex decision problems. It uses a multi-level hierarchical structure of objectives, criteria, sub criteria and alternatives. The pertinent data are derived by using a set of pair wise comparisons. These comparisons are used to obtain the weights of importance of the relative performance measures of alternatives in terms of each individual decision criterion. If the comparisons are not perfectly consistent, then it provides a mechanism for improving consistency. The AHP is process that consists of several steps:

1. Decide upon the criteria for selection.
2. Create a judgment matrix by pair-wise comparing the entire factor at one level of the hierarchy with respects to each factor in immediately preceding level.
3. Compute the eigenvector of the judgment matrix for the largest eigenvalue.
4. Calculate the composite priority vector from the local priorities associated with each judgment matrix.

One of the most crucial steps in many decision-making methods is the accurate estimation of the pertinent data. Often qualitative data cannot be known in terms of absolute values. For instance, questions like “what is the worth of regulators authority on load growth”. Although information about this questions are vital in making the correct decision, it is very difficult, if not impossible, to quantify them correct. Therefore, many decision making methods attempt to determine the relative importance, or weight, of the alternatives in terms of each criterion involved in given decision-making problem [3].

In approach based on pair wise comparisons, which was proposed by Saaty, the decision-maker has to express his opinion about the value of one single pair wise comparison at a time. Each choices is a linguistic phrase like “A is more important than B”, or “A is of the same importance as B”, or “A is a little more important than B” and so on. The main problem with pair wise comparisons is how to quantify the linguistic choices selected by the decision maker during their evaluation. According to scale proposed by Saaty, the decision-maker has to choose his answer among 17 possible discrete choices as a set of integer numbers [1].

The decision problem is broken up into layers, each layer influencing the entities in the level immediately above it. Beginning from the second level of the hierarchy, each entity is given a weight by pair wise comparison of factors in that level respect to every factor in the upper level. This process will create, for decision problem with n-layer hierarchy, a set of judgment matrices [**A**] generated for each of (n-1) evaluation levels. To create a judgment matrix with m factors, at least (m-1) ratio questions need to be asked. If denote the relative importance of i-th factor with respect to j-th factor by a_{ij} , than the relative importance of j-th factor with respect to i-th factor would be $1/a_{ij}$ and the importance of every factor with itself (a_{ii}) is equal to one. The matrix obtained in this way is called “reciprocal judgment matrix” or “pair-wise comparison matrix”.

The next step is creation of a judgment matrix and extract the relative importances implied by the previous comparisons. Saaty asserts that to answer this question one has to estimate the right principal eigenvector of the obtained judgment matrix. The eigenvector analysis is a unique technique to determine the relative ranking of factors with respects to a certain objective. This procedure uses the eigenvector analysis to calculate the individual and overall influence of factors on the goal. The priority vector witch gives the ranking of the factors is obtained by normalizing the principal eigenvector $\boldsymbol{p}$ of judgment matrix witch is obtained by solving the eigenvalue problem:

$$[\mathbf{A}] \cdot \mathbf{p} = \lambda_{\max} \cdot \mathbf{p} \qquad (1)$$

where $\lambda_{\max}$ is the principal or the largest real eigenvalue of judgment matrix. The priorities in the n – level hierarchy with respect to the goal can be calculated using the following matrix equation:

$$\begin{bmatrix} p_{1,n}^{1,1} \\ p_{2,n}^{1,1} \\ \cdots \\ \cdots \\ p_{n,n}^{1,1} \end{bmatrix} = \begin{bmatrix} p_{1,n}^{1,n-1} & p_{1,n}^{2,n-1} & \cdots & p_{1,n}^{m_{n-1},n-1} \\ p_{2,n}^{1,n-1} & p_{2,n}^{2,n-1} & \cdots & p_{2,n}^{m_{n-1},n-1} \\ \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ p_{m_n,n}^{1,n-1} & p_{m_n,n}^{2,n-1} & \cdots & p_{m_n,n}^{m_{n-1},n-1} \end{bmatrix} \cdots\cdots \begin{bmatrix} p_{1,3}^{1,2} & p_{1,3}^{2,2} & \cdots & p_{1,n}^{m_2,2} \\ p_{2,3}^{1,2} & p_{2,3}^{2,2} & \cdots & p_{2,n}^{m_2,2} \\ \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ p_{m_3,3}^{1,2} & p_{m_3,3}^{2,2} & \cdots & p_{m_3,3}^{m_2,2} \end{bmatrix} \cdot \begin{bmatrix} p_{1,2}^{1,1} \\ p_{2,2}^{1,1} \\ \cdots \\ \cdots \\ p_{m_2,2}^{1,1} \end{bmatrix}$$

where m_i is the number of elements at level i and $p_{i,j}^{k,l}$ is the priority of element i at level j with respect to element k at level l.

III. CASE STUDY

The sample study illustrate using the analytic hierarchy process to calculate the probability distributions of load growth [2]. The supposed factors affecting load growth are changes in economic conditions, customer behavior including end-use practices and response to technology changes, and DSM (demand side management) impacts, mainly on load demand and energy.

Figure 1 shows the hierarchical structure consists of three layers, from main goal down to the three objectives (high load growth, base load growth, low load growth).

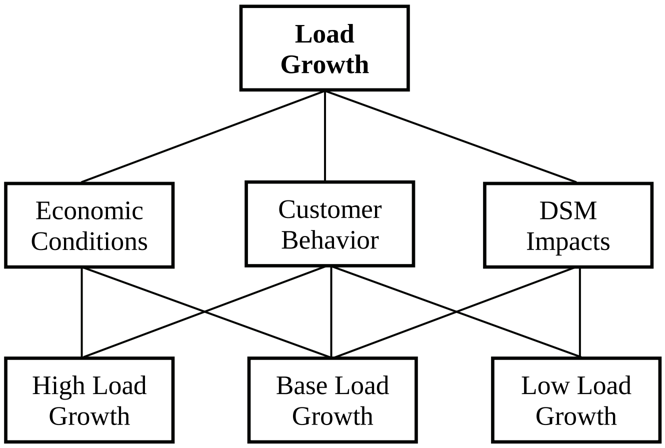

Fig. 1. Hierarchy for load growth assessment

Starting from second layer of the hierarchy, pair-wise comparison of relative importance between each pair of factors at that level with respect to every connected factor on the upper layer is made. The result of these pair-wise comparisons is judgment matrices to each level, as given in Table 1.

For example, the supposed intensity of importance on ratio questions “ how much important is the factor ‘economic conditions’ in comparison with ‘customer behavior’ and ‘DSM impacts’ is 3 (weak importance) and 5 (strong importance) respectively (according to scale proposed by Saaty [1]). Table 1 also gives the local priority vector associated with each judgment matrix for each evaluation level calculated using the eigenvector prioritization method.

TABLE 1. JUDGMENT MATRICES AND PRIORITY VECTORS FOR THE HIERARCHY OF FIGURE 1

Level 2.1 Load Growth				
Economic conditions	1	3	5	0,6571
Customer Behavior	1/3	1	1/2	0,1466
DSM Impacts	1/5	2	1	0,1963

Level 3.1 Economic conditions				
High Load Growth	1	1/5	1/3	0,1047
Base Load Growth	5	1	3	0,6370
Low Load Growth	3	1/3	1	0,2583

Level 3.2 Customer Behavior				
High Load Growth	1	1/7	1/3	0,0810
Base Load Growth	7	1	5	0,7306
Low Load Growth	3	1/5	1	0,1884

Level 3.3 DSM Impacts				
High Load Growth	1	1/5	1/7	0,0719
Base Load Growth	5	1	1/3	0,2790
Low Load Growth	7	3	1	0,6491

The global priority vector, i.e., the composite priority vector from the bottom layer with respect to the top layer, is computed according to (1). The resulting global priority vector is given below and indicates that the relative weight i.e., in this case, probability of high, base, and low load growth is 0,095; 0,58; 0,325 respectively (2).

$$\begin{matrix} high \\ base \\ low \end{matrix} = \begin{bmatrix} 0,0948 \\ 0,5804 \\ 0,3248 \end{bmatrix} \tag{2}$$

IV. CONCLUSION

Accurate load forecasting is very important for power system planning process, especially in a competitive environment created by the electric industry deregulation [4]. The results of the classical long-term forecasting methods are insufficient to establish demand forecast for long-term power system planning. There are always a number of uncertainties regarding future socio-economic conditions, national economy restructuring and energy developments. For Macedonia, as a transition country, this is magnified by dependence on regional trade and political stability. Usually approach, in those conditions, is to prepare three main scenarios (Reference, Low, High) for expected electric energy growth rate [5]. It is useful to made additional effort to made probability assessment of load growth in order to support the decision making process. In this paper, method of analytic hierarchy process is used for this purpose. The obtained resulting global priority vector represent the relative weight i.e. probability of load growth rate.

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