OPTIMAL COMBINED LOAD FORECAST BASED ON MULTI-CRITERIA DECISION MAKING METHODS

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To my beloved family and friend

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ABSTRACT

Owing to the importance of load forecasting, accurate models for electric power load forecasting are essential to the operation and planning of a utility company. Their main idea is to establish the mathematical optima model for forecasting, intend to match the data, and make predict error least, and attain superior forecast result. This paper present the analyzing of soft method such as decision making analyses to solve load forecast in power system demand that are unstructured problems of multi-factors. The combined forecasting problem is treated as multi-hierarchies and multi-factors evaluation by composing qualitative analyses and quantitative calculation. In addition, the experiences and judgments of experts will be collected to implement judgment matrices in group decision making. This paper proposed the soft method based on Analytic Hierarchy Process (AHP), Fuzzy Analytic Hierarchy Process (Fuzzy AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to carry out long middle term load demand combined forecast. A hierarchy structure has been established by analyzing various factors that affect the load forecast. It is the key to determine the combined weight coefficients in the optimal combined forecasting method. Fuzzy complementary judgment matrixes of pair-wise comparison will be formed by expert in each hierarchy and be converted to a fuzzy consistent matrix. The eigenvector can be calculated using its general formula and be regarded as weight coefficient in combined forecasting. The combined forecast methods based on the Analytic Hierarchy Process (AHP), Fuzzy Analytic Hierarchy Process (Fuzzy AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) are of clear hierarchy structure, sufficient judgment information and simple calculation formula. The forecasting examples show that this method is practical, convenient and accurate.

ABSTRAK

Berhubung dengan pentingnya peramalan beban, model-model yang tepat untuk peramalan beban kuasa elektrik adalah perlu bagi operasi dan perancangan sebuah syarikat. Tujuan utamanya adalah untuk membina optima matematik model untuk peramalan, berniat untuk menandingi data, minimumkan ralat dan menghasilkan satu keputusan peramalan yang sangat tepat. Kertas ini membentangkan kajian menggunakan kaedah lembut seperti pembuatan keputusan analisis untuk menyelesaikan ramalan beban dalam sistem permintaan sistem kuasa yang mempunyai masalah-masalah tidak tersususun yang terdiri dari perbagai faktor. gabungan ramalan beban di perlakukan sebagai pelbagai hierarki dan pelbagai factor yang akan dianalisis dengan mengubah analisis kualitatif dan pengiraan kuantitatif. sebagai tambahan, pengalaman dan pertimbangan pakar-pakar akan dikumpulkan kepada melaksanakan matrik-matrik penghakiman dalam pembuatan keputusan kelompok. Kertas ini mencadangkan kaedah lembut berdasarkan Analytical Hierarchy Process (AHP), Fuzzy Analytical Hierarchy Process (FAHP) dan Technique For Order Preference By Similarity To ideal Solutuion (TOPSIS) untuk menjalankan permintaan beban panjang separuh penggal bergabung ramalan. Struktur hierarki telah ditubuhkan dengan menganalisa pelbagai faktor yang menjejaskan ramalan beban. Ia adalah kunci kepada menentukan pekali-pekali berat yang digabungkan dalam kaedah peramalan bergabung yang optimum. Penghakiman saling melengkapi fuzzy matrik sepasang perbandingan bijak akan dibentuk oleh pakar dalam setiap hierarki dan akan ditukarkan kepada satu acuan konsisten fuzzy. Vektor eigen boleh dikira menggunakan formula amnya dan dianggap sebagai pekali berat dalam peramalan bergabung. kaedah-kaedah ramalan bergabung berdasarkan Analytic Hierarchy Process (AHP), Fuzzy Analytic Hierarchy Process (Fuzzy AHP) dan Technique For Order Preference By Similarity To Ideal Solution (TOPSIS) ialah struktur

hierarki yang jelas, maklumat penghakiman yang mencukupi dan formula kiraan yang mudah. Contoh-contoh peramalan menunjukkan bahawa kaedah ini praktikal, mudah dan tepat.

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CHAPTER 1

INTRODUCTION

1.1. project Background

A power system serves one function and that is to supply customers, both large and small, with electrical energy as economically and as reliability as possible. Another responsibility of power utilities is to recognize the needs of their customers (Demand) and supply the necessary energies. Accurate forecasting of energy requirement for future development of the country is one of the most important factors of energy management. Adequacy of energy is the main factor for the development of a country.

Energy requirement depends on number of variables, some of them which are cardinal to the energy consumption and addressed here are population, number of electricity consumers, per capita electricity consumption, peak electricity demand, gross domestic product and annual electricity consumption of the country. Unfortunately, it is difficult to forecast load demand accurately over a planning period of several years. This fact is due to the uncertain nature of the forecasting process. There are a large number of influential that characterize and directly or indirectly affect the underlying forecasting process, all of them uncertain and uncontrollable. Many load forecasting problems in practical usually are solved by experts with the judgment and experience. Therefore it can't represent the innate character of the forecasting problem completely too only make use of the mathematics programming. In hard methods it is be devoid of the analysis, judgment and control to forecasts and results.

In this paper, soft method is presented to carry out combined forecast for the electrical power load demand, through integrating different forecast methods, combining the mathematics method and expert's experience and using the intellection of the decision maker sufficiently. The combine load forecast problem is settled to the decision-making problem through combining the quantitative calculation and qualitative analysis. The structure of hierarchy process for the combined load forecast is established. Multi-criteria factors are counted. Expert's judgments are combined.

The Analytic Hierarchy Process (AHP), Fuzzy Analytic Hierarchy Process (Fuzzy AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is adopted in the long-middle term electric power load combined forecast. The soft method of electric power load combined forecast is account for not only the highest fitting accuracy (HFA), but also suitability of methods to actual state (SMS) and believability of forecasting results (BFR) as the criteria of decision adjudicate. HFA is same as the object of hard methods. Different hard forecast methods and their different results are analyzed synthetically. The forecasting load value of electricity power MWH and MW in further years can be recommended according to the synthetic analysis

1.2. Problem Statement

According to the statistics provided by TNB as shown in Figure 1.1 [10], the demand of the electric power was increasing year by year from 2005 to 2008. Figure 1.1 shows the total electricity sales of Tenaga Nasional Sdn.Bhd (TNB) in the year 2005 to 2008. The total electricity sales increased 5.34% from 2005 to 2006, 5.65% from 2006 to 2007 and 3.85% from 2007 to 2008. The sales increased 15.58% within three years of total electricity sales.

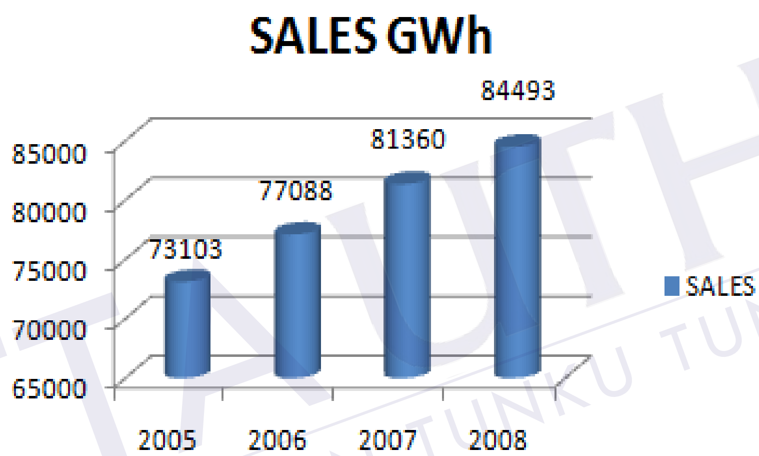

Figure 1.1: The total electricity sales (GWh) of TNB [7]

The electric power demand in Peninsular Malaysia has steadily increased in the past four years. This trend is certain to continue in future. The electrical load is the power that an electrical utility needs to supply in order to meet the demands of its customers. Electricity load forecasting is thus an important topic, since accurate forecasts can avoid wasting energy and prevent system failure. The forecast results obtained from the different forecast methods may very different. Which method or which forecast result can be agreed upon? For the more accurate and satisfactory forecast result can be obtained, many forecasting are integrated and forms the combined forecasting method. This paper present the analyzing of soft method such as decision making analyses to solve load forecast in power system demand that are unstructured problems of multi-factors. The combined forecasting problem is treated as multi-hierarchies and multi-factors evaluation by composing qualitative analyses and quantitative calculation. In addition, the experiences and judgments of experts will be collected to implement judgment matrices in group decision making.

1.3. Project objectives

There are three objectives for this project:

a) To determine which the existing forecast method more accurate and satisfactory by using multi criteria decision making system.

b) To implement multi-criteria decision-making methods such as AHP, fuzzy AHP and TOPSIS in the power demand system

c) To determine the effectiveness of multi-criteria decision making methods in the power demand system

1.4. Scope project

This project is primarily concerned with the optimal combine load forecasting base on multi-criteria decision method. The scope of this project work includes the following;

a) Electrical power demand in Sabah

b) Develop the three stages of hierarchy structure:

  i. Goal which is the Satisfactory an accurate of electrical power Load forecast

  ii. Criteria Hierarchy may be a factor that affects the total goal. Using soft method which is combining the mathematics method and expert experience

  iii. Candidate Scheme Hierarchy which is a set of composed hard forecast methods and their forecast results

c) Comparison of simulation and experimental results. The analysis will focus on to calculate the weight vector for each load forecast because it reflects the important degree for each forecast methods and results, which is relative to the accuracy load forecast.

CHAPTER 2

LITERATURE REVIEW

2.1 Load Forecast

Accurate models for electric power load forecasting are essential to the operation and planning of a utility company. Load forecasting helps an electric utility to make important decisions including decisions on purchasing and generating electric power, load switching, and infrastructure development. Load forecasts are extremely important for energy suppliers, ISOs, financial institutions, and other participants in electric energy generation, transmission, distribution, and markets [6]. From the Table 2.1 below load forecasts can be divided into four categories:

Load forecasting	**Period**	**Importance**
Long-term	One year to ten Years	• To calculate and to allocate the required future capacity. • To plan for new power stations to face customer requirements. • Plays an essential role to determine future budget.

Medium-term	One week to few months	• Fuel allocation and maintenance schedules.
Short-term	One hour to a week	• Accurate for power system operation. • To evaluate economic dispatch, hydrothermal co-ordination, unit commitment, transaction. • To analysis system security among other mandatory function.
Very short-term	One minute to an hour	• Energy management systems (EMS).

Table 2.1: Load Forecast categories

To improve forecasting accuracy, combine forecasts derived from methods that differ substantially and draw from different sources of information. Combining is useful to the extent that each forecast contains different yet valid information. The key principles for combining forecasts are to use [3]

- Different methods or data or both,
- Forecasts from at least five methods when possible,
- Formal procedures for combining,
- Equal weights when facing high uncertainty,
- Trimmed means,
- Weights based on evidence of prior accuracy,
- Weights based on track records, if the evidence is strong, and
- Weights based on good domain knowledge.

Combining is most useful when there are [3]

- Uncertainty as to the selection of the most accurate forecasting method,
- Uncertainty associated with the forecasting situation, and
- A high cost for large forecast errors.

Compared to the typical component forecast, the combined forecast is never less accurate. Usually it is much more accurate. Also under ideal conditions, the combined forecasts were often more accurate than the best of the components. Combined forecast can be better than the best but no worse than the average. That is useful for forecasters.

2.2 Comparison Methodologies of Load Forecast.

Methodology	Advantages	Disadvantages
Time series	• Easy to implement – requires only the historical data of the variable to be projected	• Accuracy depends solely on the stability of historical trends
Regression	• Better portrays the changes in demand through its various drivers (GDP, price, etc)	• Requires more resources & knowledge of the underlying relationship of the independent & dependent variables
Elasticity	• Easy to implement, incorporates the development process of the country	• Requires judgmental input • Lack of statistical test to determine accuracy
Intensity	• Sectoral demand linked to economic performance & explained by its drivers (GDP, floor space, etc)	• Absence of price variable • Lack of statistical test to determine accuracy
Load curve	• Helps to understand changes in demand	• Requires more resources & knowledge of the underlying relationship of the independent & dependent variables
End-use	• Better portrays the usage of electricity by the consumers	• Model is data intensive • Requires a detailed knowledge on how & where electricity is utilised

Table 2.2: Comparison Methodologies Load Forecast [10]

2.3 Simplified Work Flow For Middle-Long Term Demand Forecasting

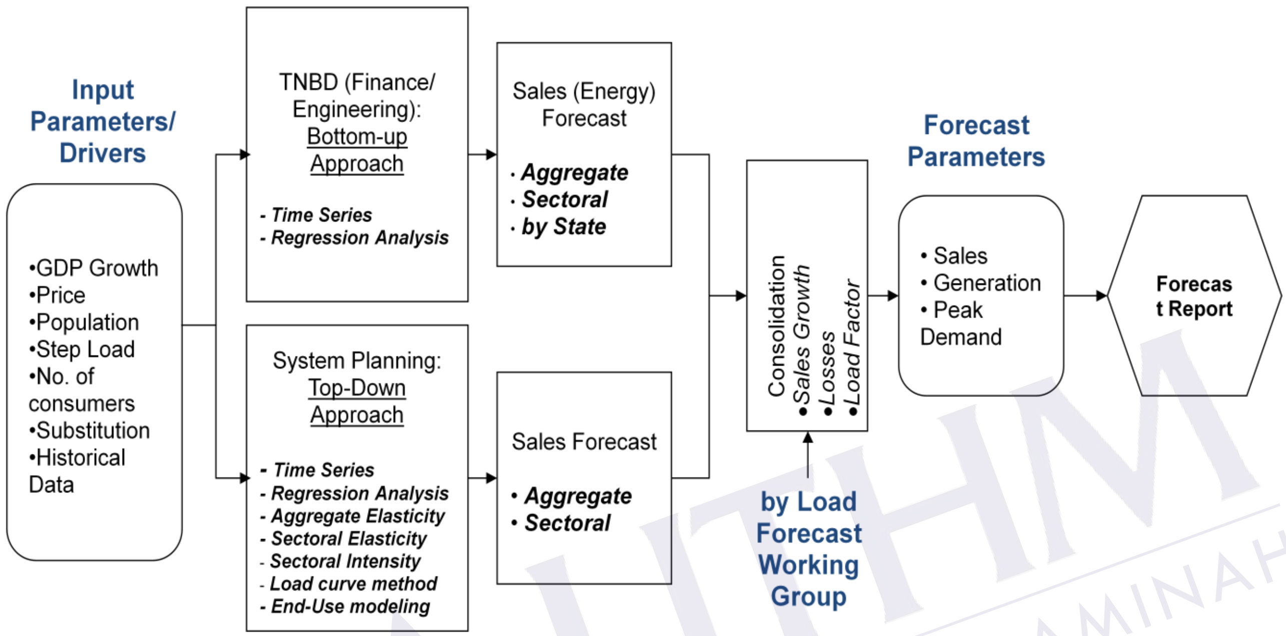

Figure 2.1: Simplified Work Flow for Middle-Long Term Demand Forecasting [10]

Bottom-Up Approach: assesses the demand at micro level e.g. Growth centers/areas (step loads, number of customers).

Top-Down Approach: analyses the demand at macro level e.g. GDP, prices, population, etc.

2.4 AHP

Analytic Hierarchy Process (AHP) is a method developed for creating structured models of multi-criteria decision problems. The method helps to find an alternative which suits best the given needs of the deciding person. Analyzing the set of possible alternatives, the AHP method finds the one with the best rating, based on the structure of the problem and given preferences. Saaty formulated the principles of AHP in late 1970s (Saaty, 1980), and the method has been broadly studied and applied in many cases since the time [4].

The method combines mathematical and psychological aspects, starting with defining the structure of the problem, then quantifying the relative preferences, computing the priorities and finally computing the evaluation of all considered alternatives [4].

- First of all, the multi-criteria decision problem is converted into a hierarchy of sub-problems and every of the sub-problems are then independently analyzed.
- The criteria of the sub-problems in the hierarchy may have very heterogeneous nature; they may be precisely or vaguely defined, with crisp or fuzzy parameters, formal or intuitive, etc.
- The relative preferences of heterogeneous criteria are then quantified by human decision-maker using his/her ability of comparing various aspects of the problem.
- The decision maker systematically compares the criteria in pairs and quantifies the relative importance either by available data or by intuitive judgment.
- The relative preferences found in pairs are then used to compute weights (priorities) for every part of the hierarchy model.
- The evaluation computed for all decision alternatives then shows their relative strength from the point of view of the entire problem.

- It is the advantage of AHP that even considerably diverse criteria can be used in the model, and that not only exact data but also human judgments can be applied to describe various aspects of the problem

Since 1977, Saaty proposed AHP as a decision aid to solve unstructured problems in economics, social and management sciences. AHP has been applied in a variety of contexts: from the simple everyday problem of selecting a school to the complex problems of designing alternative future outcomes of a developing country, evaluating political candidacy, allocating energy resources, and so on. The AHP enables the decision-makers to structure a complex problem in the form of a simple hierarchy and to evaluate a large number of quantitative and qualitative factors in a systematic manner under multiple criteria environment in the conflation [4].

The application of the AHP to the complex problem usually involves four major steps

1) Break down the complex problem into a number of small constituent elements and then structure the elements in a hierarchical form.
2) Make a series of pairwise comparisons between the elements according to a ratio scale.
3) Use the eigenvalue method to estimate the relative weights of the elements.
4) Aggregate the relative weights and synthesise them for the final measurement of given decision alternatives [4].

The AHP is a powerful and flexible multi-criteria decision-making tool for dealing with complex problems where both qualitative and quantitative aspects need to be considered. The AHP helps analysts to organise the critical aspects of a problem into a hierarchy rather like a family tree.

The essence of the process is decomposition of a complex problem into a hierarchy with a goal at the top of the hierarchy, criteria and sub-criteria at levels and sub-levels of the hierarchy, and decision alternatives at the bottom of the hierarchy. Figure 2.2 illustrates the scheme of the Analytic Hierarchy Process (AHP).

REFERENCES

[1] Zhou Ren-jun; Duan Xian-zhong "*Optimal Combined Load Forecast Based on the Improved Analytic Hierarchy Process*" Engineering in Electrical and Electronic Huazhong University of Science and Technology

[2] S. Mahmoodzadeh J; Shahrabi, M. Pariazar; and M. S. Zaeri; *"Project Selection by Using Fuzzy AHP and TOPSIS Technique"* World Academy of Science, Engineering and Technology 30 2007

[3] J. Scott Armstrong (ed.): Norwell, MA: Kluwer Academic Publishers, 2001. *Principles of Forecasting: A Handbook for Researchers and Practitioners University of Pennsylvania*, armstrong@wharton.upenn.edu

[4] Aşkın ÖZDAĞOĞLU; Güzin ÖZDAĞOĞLU "*COMPARISON OF AHP AND FUZZY AHP FOR THE MULTICRITERIA DECISION MAKING PROCESSES WITH LINGUISTIC EVALUATIONS"* İstanbul Ticaret Üniversitesi Fen Bilimleri Dergisi Yıl: 6 Sayı: 11Bahar 2007/1 s. 65-85

[5] Jarret M. Lafleur; "*Probabilistic AHP and TOPSIS for Multi-Attribute Decision-Making under Uncertainty"* Daniel Guggenheim School of Aerospace Engineering Georgia Institute of Technology

[6] Eugene A. Feinberg; Dora Genethliou "Load Forecasting" *State University of New York, Stony Brook*

[7] Zülal Güngör; "*Methodology of Fuzzy AHP*" Gazi University, Faculty of Engineering and Architecture, Industrial Engineering Department, 06570 Maltepe-Ankara, Turkey

[8] Gülçin Büyüközkan; "*AHP methodology*" Department of Industrial Engineering, Galatasaray University, Çırağan Caddesi No: 36, Ortaköy, İstanbul 34357, Turkey

[9] R. Soltani;V. Roshanaei " *Methodology of Topsis Method*" Department of Industrial Management, Management and Accounting Faculty, Allameh Tabatabaei University, Tehran, Iran

[10] TNB SDN.BHD Demand Forecast Section System Planning Transmission Division

[11] Dashti, Z., Pedram, M. M. & Shanbehzadeh, J.. A Multi-criteria Decision Making Based Method for Ranking Sequential Patterns. *International Multi Conference of Engineers and Computer Scientist 2010, 1.* 2010.

[12] Xue, D., Zhao, Q. L. & Guo, X. Y.. TOPSIS MMethod for Evaluation Customer Service Satisfaction to Fast Food Industry. *IEEE International Conference on Service Operations and Logistics and Informatics 2008 , 1*. 2008. pp. 920 – 925.

[13] Dodangeh, J., Rosnah, M. Y. & Jassbi, J.. TOPSIS Method with Goal Programming for Best Selection of Strategic Plan in BSC Model. *Journal of American Science, Department of Mechanical and Manufacturing, UPM*. 2010. pp. 136 – 142.

[14] Wang, T. C. & Lee, H. D.. Developing a Fuzzy TOPSIS Approach Based on Subjective Weight and Objective Weights. *Expert Systems with Applications, 36(5)*. 2009. pp. 8980 – 8995