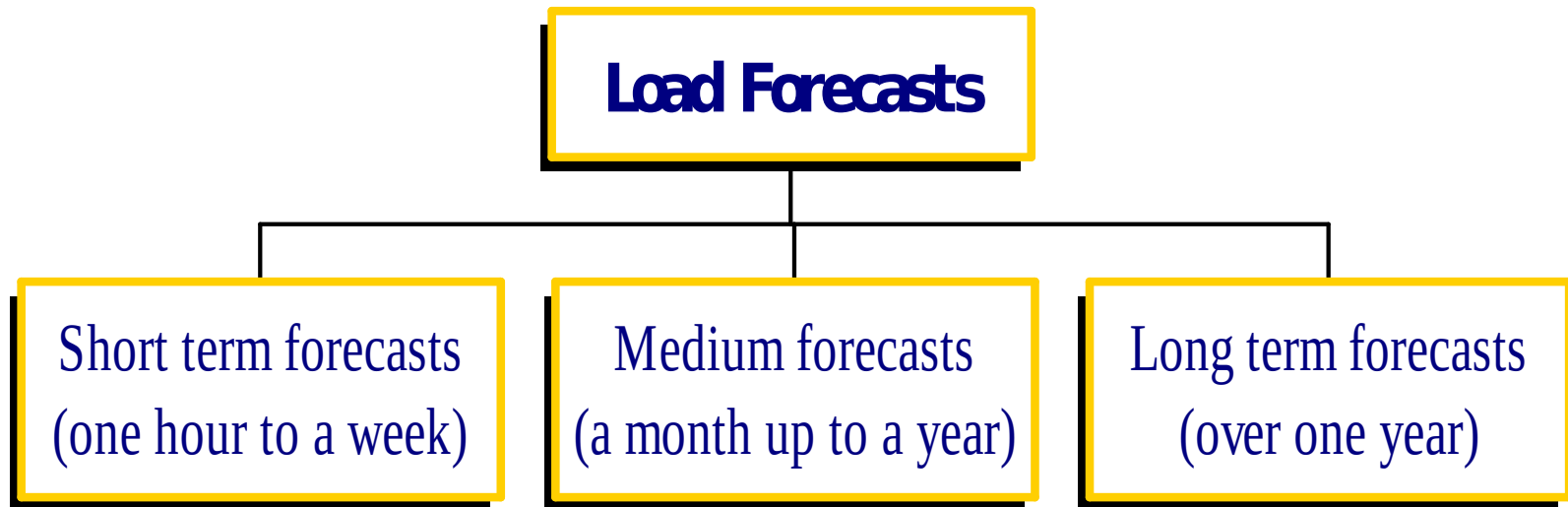# Load Forecasting Techniques

Importance of Load Forecasting in Deregulated Markets

- Purchasing, generation, sales
- Contracts
- Load switching
- Area planning
- Infrastructure development/capital expenditure decision making

Types of Forecasting

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┌─────────────────────────┐
│      Load Forecasts     │
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| Short term forecasts (one hour to a week) | Medium forecasts (a month up to a year) | Long term forecasts (over one year) |

Load Forecasting

- With supply & demand fluctuations and the changes of weather conditions and energy prices increasing by a factor often or more during peak situations, load forecasting is vitally important for utilities.

- Short-term load forecasting can help to estimate load flows and to make decisions that can prevent overloading. Timely implementations of such decisions lead to the improvement of network reliability and to the reduced occurrences of equipment failures and blackouts.

- Load forecasting is also important for contract evaluations and evaluations of various sophisticated financial products on energy pricing offered by the market.

Factors affecting Load Forecasting

Medium & Long-term forecasting

Historical load

Weather data,

Number of customers in different categories

Appliances in the area and their characteristics including age, the Economic and demographic data and their forecasts, the appliance sales data, and other factors.

Short-term forecasting

Time factors,
Weather data,
Possible customers' classes.

Time Factor

- The time factors include the time of the year, the day of the week, and the hour of the day.

- There are important differences in load between weekdays and weekends. The load on different weekdays also can behave differently.

- For example, Mondays and Fridays being adjacent to weekends, may have structurally different loads than Tuesday through Thursday. This is particularly true during the summer time. Holidays are more difficult to forecast than non-holidays because of their relative infrequent occurrence.

Weather Data

Weather conditions influence the load. In fact, forecasted weather parameters are the most important factors for load forecasting.

Most commonly used load predictors are: Temperature and humidity

Among the weather variables listed above, two composite weather variable functions,
THI (temperature-humidity index) and
 WCI (wind chill index),
are broadly used by utility companies.

Customer Class
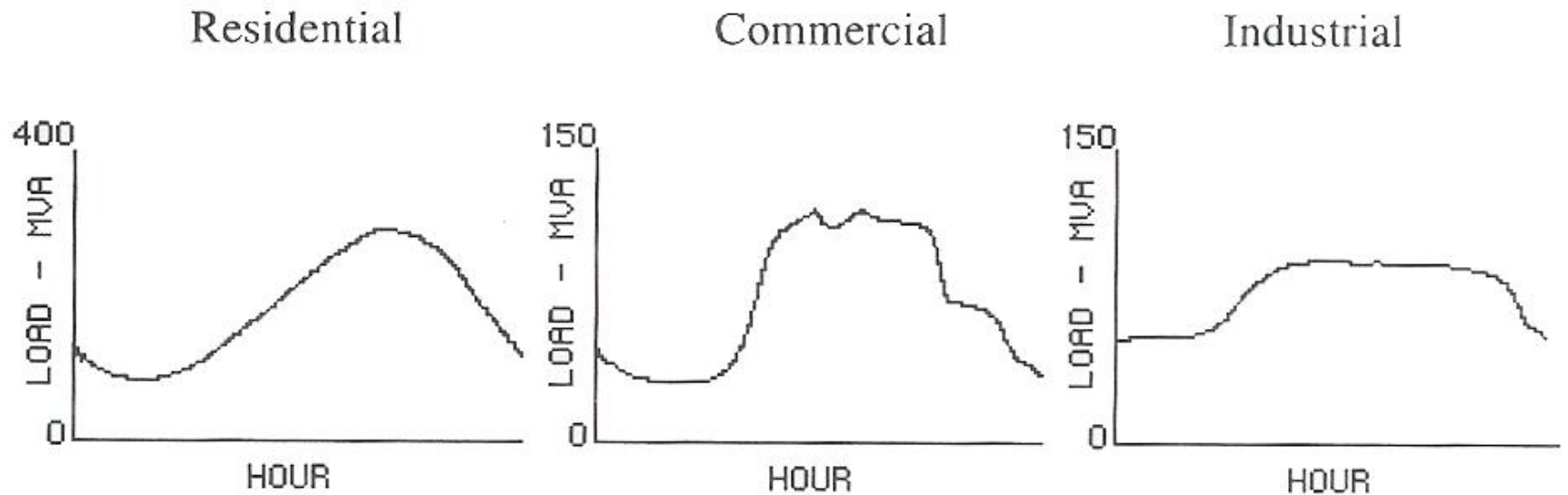
Electric utilities usually serve different

types of customers such as residential,

commercial, and industrial. The following

graphs show the load behavior in the

above classes by showing the amount of

peak load per customer, and the

Load Curves

Residential   Commercial   Industrial

Methods of Load Forecasting

Statistical approaches usually require a mathematical model that represents load as function of different factors such as time, weather, and customer class.

The two important categories of such mathematical models are:

Additive models- the sum (additive) of a number of components.

Multiplicative models- the product (multiplicative) of a number of factors.

Methods of Load Forecasting

An additive model that takes the form of predicting load as the function of four components:

$$= Ln + Lw + Ls + Lr,$$

where L is the total load,

Ln represents the "normal" part of the load, which is a set of standardized load shapes for each "type" of day that has been identified as occurring throughout the year,

Lw represents the weather sensitive part of the load,

Ls is a special event component that create a substantial deviation from the usual load pattern,

Lr is a completely random term, the noise.

It is also suggested electricity pricing as an additional term

that can be included in the model. Naturally, price increases /decreases affect electricity consumption. Large cost sensitive industrial and institutional loads can have a significant effect on loads.

Methods of Load Forecasting

A multiplicative model may be of the form
$$L = Ln \cdot Fw \cdot Fs \cdot Fr,$$

Ln is the normal (base) load and the correction factors

Fw, *Fs*, and *Fr* are real numbers that can increase or decrease the overall load.

These corrections are based on current weather (*Fw*), special events (*Fs*),and random fluctuation (*Fr*). Factors such as electricity pricing (*Fp*) and load growth (*Fg*) can also be included.

Methods of Load Forecasting

The end-use modeling, econometric modeling, and their combinations are the most often used methods for medium- and long-term load forecasting.

Descriptions of appliances used by customers, the sizes of the houses, the age of equipment, technology changes, customer behavior, population dynamics are usually included in the statistical and simulation models based on the so-called end-use approach.

In addition, economic factors such as per capita incomes, employment levels, and electricity prices are included in econometric models.

These models are often used in combination with the end-use approach. Long-term forecasts include the forecasts on the population changes, economic development, industrial construction, and technology development.

Methods of Load Forecasting

End-use models

The end-use approach directly estimates energy consumption by using extensive information on end use and end users, such as appliances, the customer use, their age, sizes of houses, and so on.

Statistical information about customers along with dynamics of change is the basis for the forecast.

End-use models focus on the various uses of electricity in the residential, commercial, and industrial sector.

These models are based on the principle that electricity demand is derived from customer's demand for light, cooling, heating, refrigeration, etc. Thus end-use models explain energy demand as a function of the number of appliances in the market

sensitive to the amount and quality of end-use data. For example, in this method the distribution of equipment age is important for particular types of appliances. End-use forecast requires less historical data but more information about customers and their equipment.

Methods of Load Forecasting

Econometric models.

The econometric approach combines economic

theory and statistical techniques for forecasting electricity demand.

The approach estimates the relationships between energy consumption (dependent variables) and factors influencing consumption.

The relationships are estimated by the least-squares method or time series methods.

One of the options in this framework is to aggregate the econometric approach, when consumption in different sectors (residential, commercial, industrial, etc.) is calculated as a function of weather, economic and other variables, and then estimates are assembled using recent historical

data.

Integration of the econometric approach into the end-use

approach introduces behavioral components into the end-use equations.

Methods of Load Forecasting

Statistical model-based learning

The end-use and econometric methods require a large amount of information relevant to appliances, customers, economics, etc. Their application is complicated and requires human participation. In addition such information is often not available regarding particular customers and a utility keeps and supports a profile of an "average" customer or average customers for different type of customers. The problem arises if the utility wants to conduct next-year forecasts for sub-areas, which are often called load pockets. In order to simplify the medium-term forecasts, make them more accurate and avoid the use of the unavailable information.

Methods of Load Forecasting

The focus of the study was the summer data. We compared several load models and came to the conclusion that the following multiplicative model is the most accurate

$$L(t) = F(d(t), h(t)) \cdot f(w(t)) + R(t),$$

where $L(t)$ is the actual load at time t,

$d(t)$ is the day of the week,

$h(t)$ is the hour of the day,

$F(d, h)$ is the daily and hourly component,

$w(t)$ is the weather data that include the temperature and humidity,

$f(w)$ is the weather factor, and $R(t)$ is a random error.

Load Forecasting

- In fact, $w(t)$ is a vector that consists of the current and lagged weather variables. This reflects the fact that electric load depends not only on the current weather conditions but also on the weather during the previous hours and days. In particular, the well-known effect of the so-called heat waves is that the use of air conditioners increases when the hot weather continues for several days
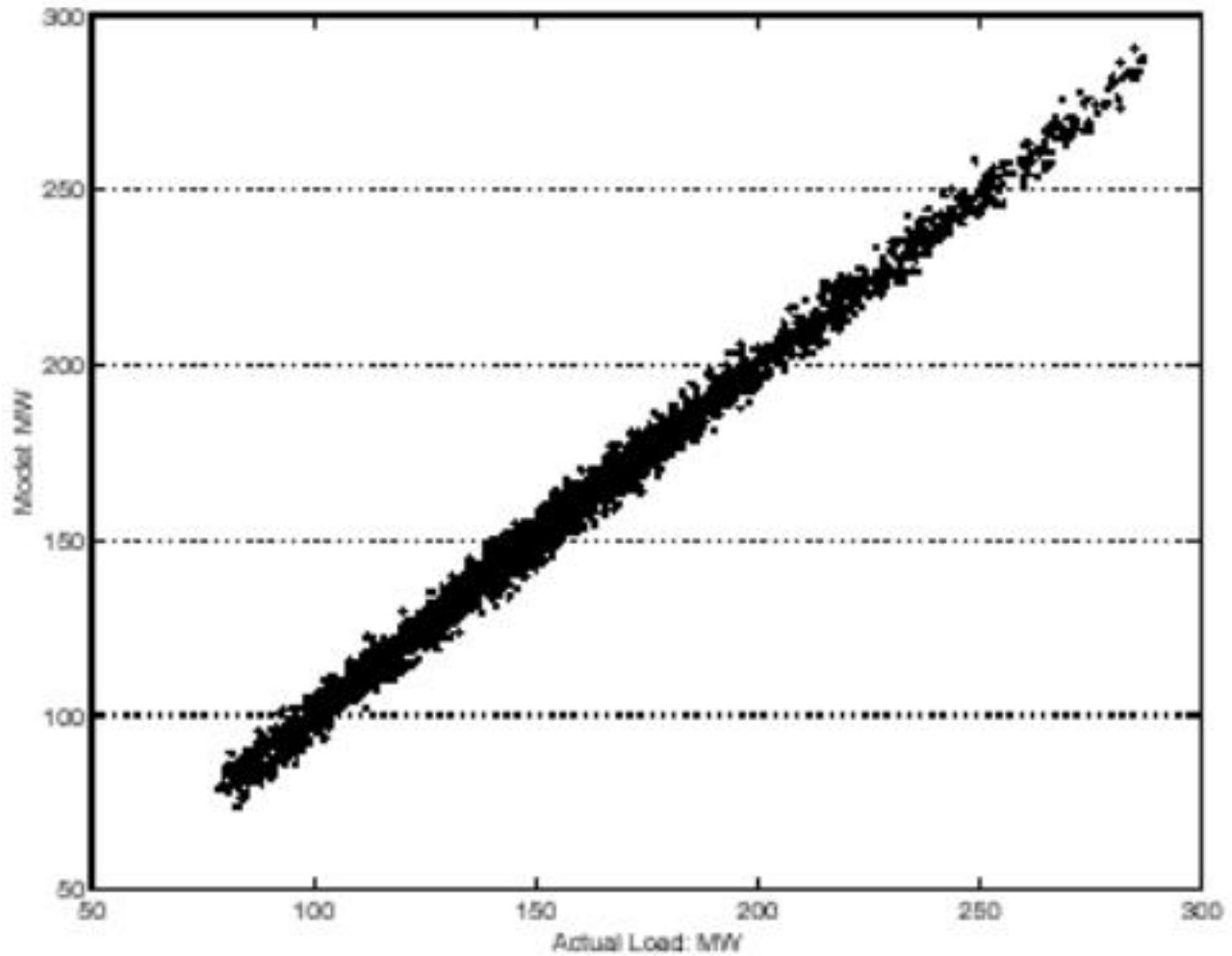
Figure 12.1. Scatter plot of the actual load vs the model.

Methods of Load Forecasting

Methods of Short Term Load forecasting

Similar-day approach

Regression methods

Time series

Neural networks

Expert systems

Fuzzy logic.

Methods of Load Forecasting

Similar-day approach

This approach is based on searching historical data for days within one, two, or three years with similar characteristics

to the forecast day.

Similar characteristics include weather, day of the week, and the date. The load of a similar day is considered as a forecast.

Instead of a single similar day load, the forecast can be a linear combination or regression procedure that can include several similar days.

The trend coefficients can be used for similar days in the previous years.

Methods of Load Forecasting

Regression methods

- Used to model the relationship of load consumption and other factors such as weather, day type, and customer class.

- several regression models for the next day peak forecasting. Their models incorporate deterministic influences such as holidays, stochastic influences such as average loads, and exogenous influences such as weather.

Methods of Load Forecasting

Time series

- Time series methods are based on the assumption that

  the data have an internal structure, such as autocorrelation, trend, or seasonal variation.

- Time series forecasting methods detect and explore such a structure. Time series have been used for decades in such fields as economics, digital signal processing, as well as electric load forecasting.

Methods of Load Forecasting

Neural networks

The use of artificial neural networks (ANN) has been a widely studied electric load forecasting technique since
1990.

Neural networks are essentially non-linear circuits that
have the demonstrated capability to do non-linear curve fitting.

The outputs of an artificial neural network are some linear or nonlinear mathematical function of its inputs. The inputs may be the outputs of other network elements as well as actual network inputs.
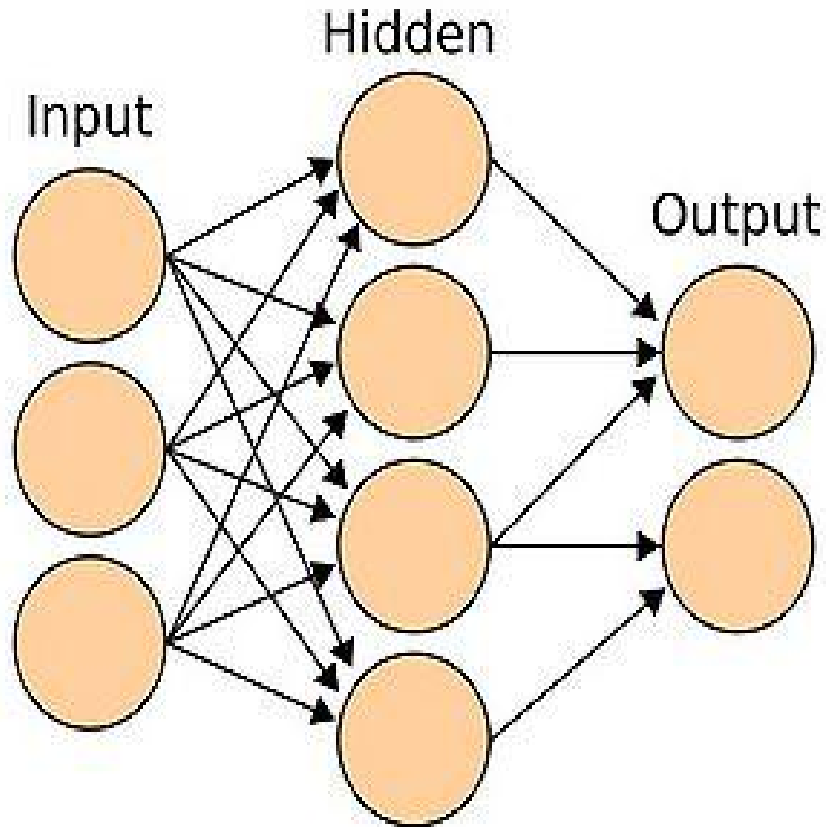
In practice network elements are arranged in a relatively small number of connected layers of elements between network inputs and outputs.
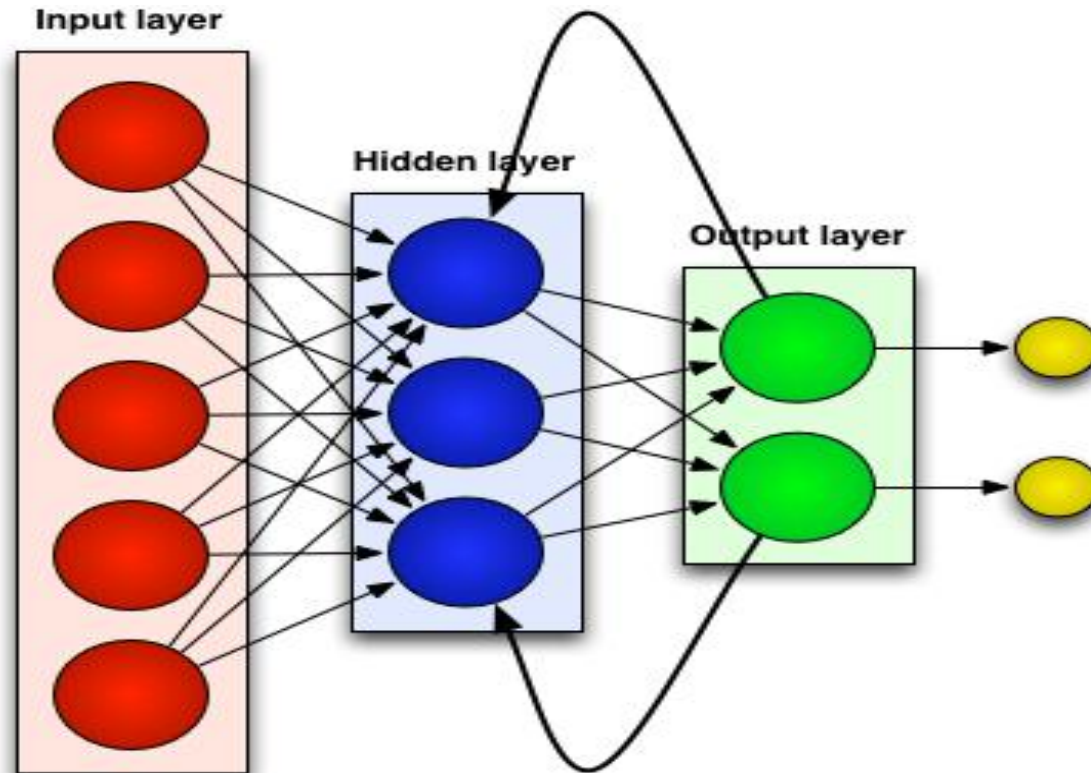Feedback paths are sometimes used.

Prof.Sweta Shah_LF Techniques

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Single layer feed forward network

Input Layer

Output Layer
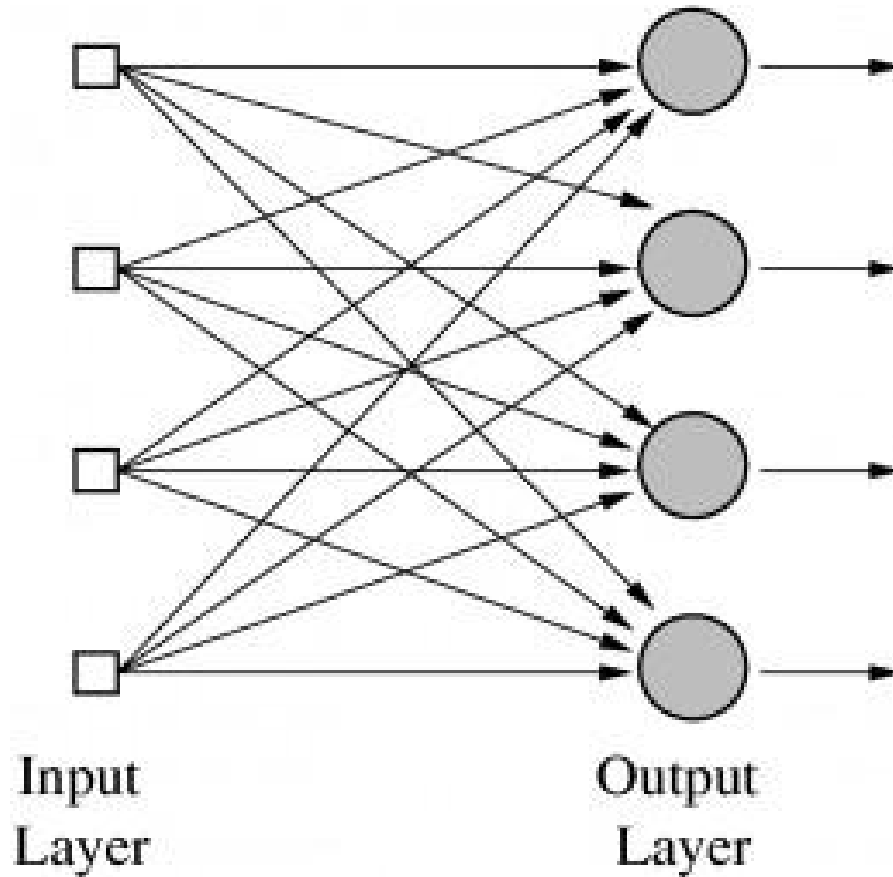
Multi layer feed forward network

Recurrent neural network

Methods of Load Forecasting

Neural networks

In applying a neural network to electric load forecasting, one must select one of a number of architectures (e.g. Hopfield, back propagation, Boltzmann machine), the number and connectivity of layers and elements, use of bi-directional or uni-directional links, and the number format (e.g. binary or continuous) to be used by inputs and outputs,and internally.

The most popular artificial neural network architecture for electric load forecasting is back propagation.
Back propagation neural networks use continuously valued functions and supervised learning.

Expert systems

Rule based forecasting makes use of rules, which are often heuristic in nature, to do accurate forecasting.

Expert systems incorporates rules and procedures used by human experts in the field of interest into software that is then able to automatically make forecasts without human assistance.

This rule base is complemented by a parameter database that varies from site to site.

Methods of Load Forecasting

Fuzzy logic

Fuzzy logic is a generalization of the usual Boolean logic used for digital circuit design. An input under Boolean logic takes on a truth value of "0" or "1".
Under fuzzy logic an input has associated with it a certain qualitative ranges.

For instance a transformer load may be "low", "medium" and "high".

Fuzzy logic allows one to (logically) deduce outputs from fuzzy inputs. In this sense fuzzy logic is one of a number of techniques for mapping inputs to outputs (i.e. curve fitting).

Among the advantages of fuzzy logic are the absence of a need for a mathematical model mapping inputs to outputs and the absence of a need for precise (or even noise free) inputs.

Methods of Load Forecasting

The development and improvements of appropriate mathematical tools will lead to the development of more accurate load forecasting techniques. The accuracy of load forecasting depends not only on the load forecasting techniques, but also on the accuracy of forecasted weather scenarios.