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# Nuclear Power Nuclear Power Nuclear Power and its Fuel Cycle Nuclear Power

TECHNICAL REPORTS SERIES No. **241**

## Expansion Planning for Electrical Generating Systems

A Guidebook



INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 1984

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EXPANSION PLANNING  
FOR ELECTRICAL  
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TABLE 4.I. GENERAL CHARACTERIZATION OF FORECASTING METHODS

Characteristics	Time series	Econometric	End-use
Best forecast horizon	Months to a few years	1 to 10 years	10 to 30 years
Data requirements	Minimal energy/load data only	8 to 12 year time series for several independent variables	Proportional to desired detail of model
Computer requirements	Trivial for trend models; significant for complex models	Moderate – many models can be run on microcomputers	Most models can be run on micro-computers
Specialized skills	Trivial for trend models; significant for complex models	Relatively easy to build models – experience and training needed to detect/solve problems	No specialized training except for optimization models
Suitability for analysis of system shocks/scenarios	Poor	Good for variables explicitly in model	Generally the best method of all

#### 4.4. LOAD FORECASTING

The maximum instantaneous load within a given utility service territory is called its peak demand. In electric systems with predominantly thermal capacity, it is more important to know the peak demand than to know the amount of electrical energy demanded, since the peak demand often sets the capacity expansion goal. For systems with large amounts of hydroelectric capacity, it may be more important to know energy demand because these systems may have energy limitations. Knowledge of the peak demand is also important for planning the type of generating capacity that should be built, when it should be scheduled for maintenance, and how much reserve will be needed (both spinning and standby). Since customer characteristics vary throughout the area served by the utility, each distribution substation may experience its peak demand at a different time of day. The system peak is usually defined as the coincident peak of all substations in the entire utility service territory.

Most of the time, it will be easier to model energy use than peak use. Given an energy forecast, the simplest way to obtain a peak load forecast is to compute it, using the simple identity:

$$\text{Peak load} = \frac{\text{Energy}}{\text{Load factor} \times \text{period of time}} \quad (4.4)$$

where load factor is defined as the ratio of average demand to peak demand for the period of time considered. Utilities employing some variant of this technique usually forecast the load factor judgementsly or by extrapolating its trend.

While this method is quite easy to implement, it is subject to severe 'turning point' errors if fundamental changes occur in the load factor. These can be caused by such things as a rapid increase in the use of air conditioning or a rapid growth in a certain type of economic activity, such as hotels supporting a tourist industry, with a high demand at a particular time of the day.

Taking the simple load factor identity one step further, one can estimate the statistical relationship between peak demand and energy over some recent historical time period and use the resulting equation to forecast peak loads. When a significant portion of the load is weather-sensitive, usually because of a high level of space conditioning in residential and commercial buildings, the above model can be improved by regressing peak demand against base energy, plus a weather variable:

$$\text{Peak load} = a + b \times \text{base energy} + \text{weather} \quad (4.5)$$

where base energy is the non-weather-sensitive portion of the load<sup>5</sup> and weather is some index of meteorological conditions known to be correlated with space conditioning loads.

Such models can be prepared for various seasons of the year to measure the peak-to-energy relationship more accurately. Typically this is done by separating the sample into rainy and dry seasons, winter and summer seasons, or monthly periods. The smaller the time intervals, the more useful is the forecast for scheduling maintenance.

Another approach to peak load forecasting is to use a time series analysis. This analyses variations in peak demand in isolation from energy use. Two approaches to time series analysis are suggested here: one is a simple arithmetical decomposition of a time series and the second is a statistical model.

A time series can be thought of as containing three components: trend, seasonal and random. First, the seasonal component is broken out by taking the ratio of a monthly or quarterly data point to a moving average of all periods for

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<sup>5</sup> Usually obtained by subtracting from total energy the estimated use of energy for space conditioning or by using total electrical energy demand during the months of the year when weather is not a factor influencing demand.

TABLE 4.II. SAMPLE MONTHLY LOAD DATA

	(a) Monthly observation  (MW)	(b) Moving ave. of last 24 months (MW)	(c) Ratio of of (a)/(b)	Monthly data with seasonal effects removed ((a)/(c)) (MW)
Jan.	2300	2000	1.15	2000
Feb.	1900	1996	0.95	2000
Mar.	1850	1990	0.93	1989
Apr.	1840	1984	0.93	1978
May	1890	1980	0.95	1989
June	1920	1978	0.97	1979
July	1905	1974	0.96	1984
Aug.	2010	1976	1.02	1971
Sep.	1910	1973	0.97	1969
Oct.	1855	1968	0.94	1973
Nov.	1890	1965	0.96	1969
Dec.	2100	1971	1.06	1981

the last two to three years. Suppose, for example, one observed the monthly load data displayed in Table 4.II. The seasonal adjustment factors in column (c) may themselves show a trend from year to year and might be extrapolated according to their own trend in developing the forecast. For example, if the seasonal adjustments for the month typically containing the system peak were 1.10, 1.13, 1.18 and 1.21 for the last four years, an upward trend in that month's contribution to peak would be indicated.

After removing the effects of seasons from the data, the analyst can look for a trend, which is a systematic change in the level of the time series. The trend might be determined simply by plotting the observations with seasonal effects removed and looking for a pattern, or by running a series of regression fits of the data using alternative specifications of the model. After the trend has been determined, it can be extrapolated for any number of periods into the future. The trend value should then be readjusted for seasonal effects to produce the actual predicted value for that future period.

This technique is more appropriately described as fitting rather than modelling a time series. *Fitting* only seeks a formula for reproducing a given series of values;

*modelling* seeks to understand why certain changes occurred in the trends at particular points (interventions) or why the pattern of monthly variation changed. This is a general class of time series models that use various combinations of autoregressive terms and moving averages, thereby enabling the analyst to bring more reasoned judgement to bear in selecting the functional form of the model. The best example of such a technique is the Box-Jenkins analysis, which isolates all the time series components discussed above as well as structural changes in the time series called interventions, as discussed in Section 4.3.1 above. These time series components are then used to project the time series into future periods. Historical data obviously cannot incorporate changes in the future which are unexpected or which differ significantly from the past. However, if some fundamental structural change occurred in the historical series, its effect must be modelled in order to isolate the previous trend from the fundamental change. The use of the intervention or structural change components requires judgement by the modeller as to whether the shift is of a long-term (permanent) or short-term (temporary) nature.

#### 4.5. LOAD DURATION

Now let us suppose that the analyst has carefully prepared a forecast of total energy demand and peak demand for a given future period. To use a typical expansion planning model, one must specify further information about the nature of electricity use. It is necessary to have a description of how many hours of a given period loads will have at a given value. One common way is to use load duration curves.

A load duration curve shows the cumulative frequency distribution of system loads. It represents graphically how much energy is supplied to various levels of system load (Fig. 4.3). System load is shown in MW on the vertical axis and in hours during which that load was exceeded on the horizontal axis. The shape of the load duration curve will directly affect the mix and operation of generating capacity. As the peak is reduced, the need in predominantly thermal systems for less efficient turbine peaking units decreases and, as a result, oil and/or gas consumption decreases. As the load duration curve flattens out, better use can be made of efficient baseload thermal plants.

It should be stressed that load factor alone is only a crude measurement of load characteristics. The distribution of loads, as shown by the load duration curve, gives the planner vital information for determining the proper mix of base, intermediate and peaking capacity. It also helps to determine the cost of failing to meet loads on demand.

To project load demand characteristics for future years, a simple technique is to use the latest known normalized seasonal load duration curves and to weight the curves by the projected peak load for each corresponding period. This assumes

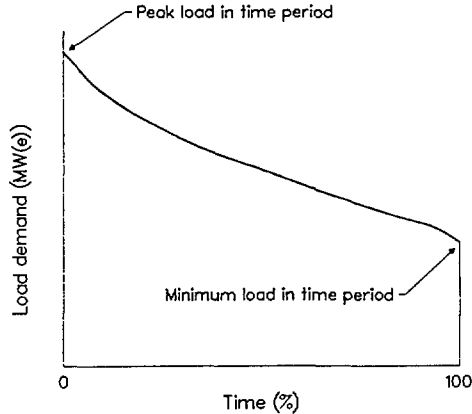


FIG.4.3. Load duration curve.

that electricity use characteristics will not change within a season and that load growth is distributed consistently over all types of demand.

If the load demand characteristics change, the above method will not reflect these changes. In typical practice the analyst often adds or subtracts from the shape of the load curve in some arbitrary fashion to make total energy (the area under the load duration curve) correspond to the energy forecast. The shape of the load duration curve has a strong bearing on the selection of capacity and the cost of the system. Arbitrary adjustments (those chosen without a specific reason) will therefore lead to equally arbitrary expansion plans.

A less arbitrary way of modifying the curve is to use reasoning similar to that used to project loads. First, fit an appropriate mathematical function to load curves for a number of historical periods (say the last 5–10 years). Next, note the trends, if any, in the parameters of the model. Finally, extrapolate the trend in the parameters and recompute the curve. New load duration curves can then be computed from these projected load curves.

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