Spatial Load Forecasting

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The reliability, efficiency, and economy of a power delivery system depend mainly on how well its substations, transmission lines, and distribution feeders are located within the utility service area, and how well their capacities match power needs in their respective localities. Often, utility planners are forced to commit to sites, rights of way, and equipment capacities years in advance. A necessary element of effective expansion planning is a forecast of where and how much demand must be served by the future T&D system, a forecast with sufficient accuracy and detail to allow meaningful determination of sites and sizes for future substation, transmission, and distribution facilities.

Small-Area Load Forecasting

Methods that forecast future demand by location divide the utility service area into a set of small areas, as shown in Figure 1, forecasting the load growth in each. Most modern small-area forecast methods work with a uniform grid of small areas that covers the utility service area, but the more traditional approach was to forecast growth on a substation-by-substation or feeder-by-feeder basis, letting equipment service areas implicitly define the small areas.

Regardless of how small areas are defined, most forecasting methods themselves invariably fall into one of two categories, trending or land use. Trending methods extrapolate past historical peak loads using curve fitting or some other method. By contrast, land-use simulation involves mapping existing and likely additions to land coverage by customer class definitions like residential, commercial, and industrial, in order to forecast growth. Either way, the ultimate goal is to project changes in the density of peak demand on a locational basis, as shown in Figures 2 and 3.

Computer Applications to Small-Area Forecasting

Geographic assessment of electric load has been a part of T&D planning since the mid-1930s, when AIEE journals first began to include papers on procedures (mostly graphical or nomographical) for projecting future electric demand by location. Computerized approaches began in the 1960s, and by the mid 1970s several dozen attempts had been chronicled in industry publications.

Looking back, three early projects stand out as important contributors to modern technology. The first was work done from 1958 to 1968 at Arizona Public Service by Americo Lazzari, who experimented with a variety of approaches to improve T&D planning in Phoenix, Arizona. Ultimately, Lazzari settled upon land-use analysis applied on a 1-mile grid basis, using a computer program that modeled load density as a three-dimensional bell curve centered in the downtown area, with height at any location indicating local customer density. Forecasts were made by extrapolating the bell’s volume, expanding it upward in load density and outward to cover new territory.

The second important project was EPRI RP-570, from 1975 to 1979. Victor Wilreker, Douglas Wall, and Ewell Menge at Westinghouse Advanced Systems Technology developed two different computer programs. The first, popularly called Trend, applied polynomial curve fitting to extrapolate the annual peak load history of each small

Figure 1. Small-area load forecasts divide the utility service territory into small areas, using either a uniform grid of small areas or equipment service areas as their geographic basis.

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area. Flexible, easy to use (by contemporary standards), but not very accurate, it was nonetheless used by several dozen utilities into the early 1980s.

The other EPRI RP-570 program, called Multivariate, applied a multivariate regression analysis to land-use and kWhr sales data on a grid basis. The program proved difficult to use and only slightly more accurate than Trend, and thus never saw widespread application.

However, it was an excellent tool for study of small-area load growth behavior. As a result, project RP-570 contributed a great deal to the industry's understanding of how electric load grows at the small-area level, and why.

The third project was a decade-long R&D effort carried out at Houston Lighting and Power beginning in 1972 by Lee Willis, Joseph Gregg, and Jim Aanstoos. After testing a number of existing methods, the HL&P team selected the land-use/grid method and developed a program that applied a modified version of Lazzari's bell curve approach, to which was added a multi-dimensional pattern recognition to identify those small areas most likely to develop.

**Characteristics of Small-Area Load Forecasting**

Several important lessons came from those three research projects. One of the most important was that small-area load growth is not a smooth, continuous process from year to year. Instead, growth in a small area is intense for several years, then drops to very low levels while high growth suddenly begins in other areas (nearby or across town).

This led to characterization of small-area load growth with the S curve (Figure 4), whose meaning is often misinterpreted. Its use does not imply that small-area growth always follows an S-shaped load history, but only that there is seldom a middle ground between high and low growth rates. Thus, small-area forecasting is less a process of extrapolating trends than it is a determination of when small areas transition among zero, high, and low growth states.

An allied finding of all three early projects was that land-use based methods, while more expensive and difficult to apply, provided more accurate forecasts than trending. The reason was (and still is) that land-use methods are much better at predicting such growth-state transitions.

In addition to superior accuracy, land-use based simulation methods have another advantage, which is the ability to forecast meaningfully in response to "what-if?" input. Figure 5 shows a typical application; if approved by local voters, a controversial new loop highway would...
redistribute growth by changing commuting and development patterns. Planners need to consider how this possible event could alter their T&D plans, hence, a multiscenario analysis. Despite considerable work, trending methods have never been able to perform such multiscenario forecasts as well as land-use methods.

But, perhaps the most important lesson from that early work was that small-area load growth is a spatial process, that the majority of load growth effects in any small area are due to influences from other small areas, some quite far away, and a function (often nonlinear) of the distances to those areas. Thus, the forecast of any one area must be based upon an assessment of data not only for that area, but for many other areas, neighboring and far away.

Spatial Load Forecasting Methods

Building on that early work, more than three dozen new algorithms were developed at utilities, universities, and consulting firms in the early 1980s, all employing some form of spatial analysis in which computation was based on location and relative locations among the small areas, as well as their load histories. Many used nonalgebraic techniques such as pattern recognition, or Boolean logic. The overall performance of small-area forecasting software improved significantly.

At present, the best available trending method in terms of tested accuracy is load-trend-coupled (LTC) extrapolation, using a modified form of Markov regression, in which the peak load histories of up to several hundred small areas are extrapolated in a single computation, with the historical trend in each area influencing the extrapolation of others. The influence of one area’s trend on another’s is determined by using pattern recognition as a function of past trends and locations, making LTC trending a true spatial method. LTC trending’s chief advantage is economy of use. Only the peak load histories of substations and feeders and X-Y locations of substations are required as input. It requires no special expertise or training to apply.

Figure 5. Projected growth of Figure 2 under an alternate scenario in which a new loop highway is completed across the city’s north-western periphery, changing the locations, but not total amount, of growth. Compare to Figure 3.
Modern Requirements and Performance

Figure 6. The spatial forecast method employs land-use and end-use data analysis and projection both by location and in time.

Figure 7. Test error for an LTC trending algorithm and a land-use/end-use simulation method in forecasting load growth of Houston, Texas, in the period 1971-1992.

industrial sites to a small fraction of the total territory. Our pattern recognizer evaluates up to 20 such factors for each customer/land-use class.

The final stage converts projection of future customer density on a small-area basis into estimates of electric load, by applying the end-use load curve model on a class by class basis.

For Further Reading


Biographies

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