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Medium term system load forecasting with a dynamic artificial neural network model

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Abstract

This paper presents the development of a dynamic artificial neural network model (DAN2) for medium term electrical load forecasting (MTLF). Accurate MTLF provides utilities information to better plan power generation expansion (or purchase), schedule maintenance activities, perform system improvements, negotiate forward contracts and develop cost efficient fuel purchasing strategies. We present a yearly model that uses past monthly system loads to forecast future electrical demands. We also show that the inclusion of weather information improves load forecasting accuracy. Such models, however, require accurate weather forecasts, which are often difficult to obtain. Therefore, we have developed an alternative: seasonal models that provide excellent fit and forecasts without reliance upon weather variables. All models are validated using actual system load data from the Taiwan Power Company. Both the yearly and seasonal models produce mean absolute percent error (MAPE) values below 1%, demonstrating the effectiveness of DAN2 in forecasting medium term loads. Finally, we compare our results with those of multiple linear regressions (MLR), ARIMA and a traditional neural network model.

Keywords: Medium term load forecasting; Artificial neural networks; Dynamic neural networks; Neural network applications

1. Introduction

Many researchers have studied power system load forecasting. The majority of this research has primarily focused on short term load forecasting (STLF). The goal in STLF is to predict the future hourly and daily loads for an electrical power generation and distribution system. Some studies extend the forecast horizon to as long as a week. Approaches to STLF have ranged from linear regression models [1], to various ARIMA configurations [2] and artificial neural networks (ANN) [3–8]. The ANN modeling approach, in particular, has seen wide application and acceptance in the past decade. The popularity of this approach can be attributed to the non-linear nature of electrical load over time, and the availability of adequate data in this field of study. Authors have used a number of different ANN architectures to solve STLF problems with feed forward back propagation (FFBP) algorithms. Regardless of the choice of modeling approach, the overall objective in such studies is accurate load forecasting, to determine the optimal utilization of generators and power stations [5]. See ref. [6] for a recent survey of these applications.

Medium term load forecasting (MTLF: 1 month to 1 or 2 years) provides useful information for power system planning and operations, and offers significant benefits for firms operating in a regulated or deregulated energy industry. An example of a regulated firm that could benefit from MTLF is the Taiwan Power Company (Taipower), a state-owned, integrated power generation, transmission and distribution company [9]. For Taipower and similar firms, MTLF information can provide an index for regional and national energy consumption and growth [10], and assist in medium and long term energy planning [11]. Medium term load forecasts can also be used to schedule and coordinate maintenance across an integrated system, effectively negotiate fuel purchases for power generation, maximize the utilization of intermittent resources such as wind energy and coordinate

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production across a network of generators. Typically, major decisions regarding long term power system development require longer term forecasts, such as the construction of a power plant which requires 2 or more years to complete [12]. However, MTLF can provide pertinent information to guide the development of other infrastructure elements that require a shorter timeframe for completion, such as the improvement of the transmission grid. Transmission grid congestion is a significant issue for distribution systems, and can greatly impact the overall system efficiency and cost of energy for the consumer [13]. Generally, in a regulated industry MTLF can be used to optimize energy production and transmission, and improve overall system reliability.

Many of the benefits gained in a regulated energy industry through accurate MTLF can also be made in a deregulated energy industry. For example, the issue of transmission congestion impacts all energy distribution systems regardless of regulation, and in a deregulated energy industry transmission and distribution firms are similarly affected. MTLF information can be effectively used by these deregulated firms to guide the improvement of their transmission grid to better serve their customers.

The State of California provides an example of a deregulated energy industry with firms that could benefit significantly from MTLF. In competitive markets like California, where energy is traded, the accurate forecast of monthly, quarterly and yearly energy demands can provide an advantage in negotiations, and assist in the development of medium term generation, transmission and distribution contracts. The authors of ref. [14] found that power generators exercising wholesale market power contributed significantly to the problems following California's energy market deregulation. The risk of such a scenario occurring could be significantly mitigated through the use of medium term contracts between firms, such as the contract between Duke Energy (a generator) and Pacific Gas & Electric (a distributor) [14]. These forward contracts are negotiated more effectively with accurate MTLF by generators, transmitters and distributors. Forward contracting also provides additional benefits to deregulated energy industry firms. The guaranteed revenue stream provided by a medium term contract eliminates the fiscal uncertainty that accompanies daily or weekly power negotiations, allowing generators and distributors the funding for their respective system improvements and operations. A predetermined production agreement also provides generators with the ability to advantageously negotiate and schedule fuel purchases, production cycles and maintenance activities. Distributors also benefit from medium term contracts through improved coordination and management of their energy supply base and transmission network.

The economic impact of accurate load forecasting is significant, and more pronounced in a deregulated energy market or an environment of high demand growth, like those of developing nations or rapidly expanding economies [15,16]. Inaccurate forecasts may result in either inadequate supply that could negatively impact the economic growth of a developing region, or oversupply that would result in utility cost overruns that might ultimately be transferred to consumers. Accurate medium and long term load forecasting techniques are required in order to avoid such costly errors [15].

The accuracy of existing STLF and MTLF methods is often measured by the mean absolute percent error (MAPE) metric, with results typically ranging from 3 to 12% [1,8,16–18]. Clearly, the economic significance of improved accuracy is scenario dependent. For example, ref. [18] reports that a 1% reduction of error in load forecasting can save the British power system up to 10 million pounds per year (in 1984). The deregulation of energy markets and subsequent increase in the trade of electricity as a commodity has further emphasized the importance of accuracy in prediction.

Medium and long term load forecasting has not been studied as extensively as STLF. Literature on MTLF categorizes the methodologies for modeling MTLF into two general groups. The first group focuses on economic analysis, management and long term planning and forecasting of energy load and energy policies (referred to as the conditional modeling approach). Researchers in this group have noticed that the socioeconomic condition of some regions may rapidly change, and thus impact energy demands. The fast growing economies, migration or religious events such as pilgrimage periods are examples of such scenarios. Medium term load forecasting of such regions require inclusion of additional variables to represent these changes. Researchers often use economic indicators (GNP, CPI, exchange rates, average wages, etc.) and/or electrical infrastructure measures (number of connections, appliance saturation measure, etc.) in addition to information on historical load data and weather related variables to forecast future energy demands. The second approach (referred to as the autonomous modeling approach), primarily uses past monthly loads and weather information to forecast future electricity demand. This modeling approach is more suited for stable economies. However, the choice of weather variables (temperature measures, humidity factors, cooling degree days, duration of bright sunshine, wind speed, etc.) still depends on the regional weather characteristics [15–17,19–23].

Some of the researchers from group one [17,21] have developed models to define a set of optimal economic conditions for energy production. The authors in ref. [21], for example, have developed linear and mixed integer programming models to minimize total production costs of power generation for a region while satisfying a set of economic, physical and environmental constraints. Their solution defines monthly generation requirements and a schedule for self-production, exchange contracts and spot market business for participating power plants. The authors noted that a complete problem formulation resulted in a non-linear model that impeded solvability. Certain assumptions were required to transform the problem and facilitate its solution through linear and mixed integer programming. Other researchers in this group have developed models to forecast energy demand of fast growing regions [15,16,20,23]. They have incorporated the "number of electrical connections at the end of each month" or "summer air-conditioning demand" variables as a measure of economic development for capturing the load demand of such regions. Finally, the authors in ref. [20] have included macroeconomic indicators, such as the consumer price