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Forecasting electricity demand for Turkey: Modeling periodic variations and demand segregation

Ergun Yukseltan [a], Ahmet Yucekaya [b,*], Ayse Humeyra Bilge [a]

[a] Graduate School of Science & Engineering, Kadir Has University, Istanbul, Turkey
[b] Industrial Engineering Department, Kadir Has University, Istanbul, Turkey

HIGHLIGHTS

- We include the modulation of daily and weekly variations by seasonal harmonics.
- We forecast demand without physical parameters involved.
- We forecasted the demand 1-week and 1-day horizons with %3 MAPE.
- We propose a method to estimate the share of industrial electricity in total demand.
- We use special days, holidays and exceptional events to segregate demand.

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ABSTRACT

In deregulated electricity markets the independent system operator (ISO) oversees the power system and manages the supply and demand balancing process. In a typical day the ISO announces the electricity demand forecast for the next day and gives participants an option to prepare offers to meet the demand. In order to have a reliable power system and successful market operation, it is crucial to estimate the electricity demand accurately. In this paper, we develop an hourly demand forecasting method on annual, weekly and daily horizons, using a linear model that takes into account the harmonics of these variations and the modulation of diurnal periodic variations by seasonal variations. The electricity demand exhibits cyclic behavior with different seasonal characteristics. Our model is based solely on sinusoidal variations and predicts hourly variations, without using any climatic or econometric information. The method is applied to the Turkish power market on data for the period 2012–2014 and predicts the demand over daily and weekly horizons within a 3% error margin in the Mean Absolute Percentage Error (MAPE) norm. We also discuss the week day/weekend/holiday consumption profiles to infer the proportion of industrial and domestic electricity consumption.

1. Introduction

"Poolco" is one of the main market competition structures used in deregulated markets [1]. Trading platforms such as the "day-ahead market", "balancing market" and "intra-day market" are developed to increase the functionality and success of the market mechanism.

The demand forecast has always played an important role in capacity and transmission planning, generation scheduling and pricing. However, the deregulation and privatization of the power markets increased the importance of demand or load forecasting since the success of the markets is highly related to their accuracy.

The demand forecast has different aspects at different forecast horizons. For example, for capacity planning one needs a long term forecast of aggregate demand as a function of economic or demographic parameters. On the other hand, short term (hourly) forecasts are essential for the efficiency of day-ahead markets. Short term variations have a "regular" component depending on daily routines and seasonal effects. Exceptional conditions (extreme weather conditions) and exceptional events (holidays, sports events) cause "irregular" variations that affect and modify this pattern. It is an interesting and challenging problem to forecast the "regular" component of the hourly demand for the planning of the day-ahead market over a long term i.e., year-long horizon. The model that we develop in this paper is based solely on sinusoidal variations and predicts hourly variations over a 1-year horizon, within a 3% Mean Absolute Percentage Error (MAPE),

* Corresponding author.
E-mail address: ahmety@khas.edu.tr (A. Yucekaya).

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without using any climatic or econometric information. The incorporation of the irregular variations to this model will be the subject of ongoing work. These irregular variations fall into "predictable" and "unpredictable" categories. The predictable variations are changes in the demand patterns that are tied to predictable natural or social events and they can be included in the basic model as a new set of regressors. Unpredictable irregular variations are changes in the demand that are of yet unknown origin and they have to be treated with special methods, such as the "feedback" method used in Bilge and Tulunay [2] or time series and stochastic approaches reviewed below.

In the literature, descriptions and comparisons of various forecast methods have been presented by a number of researchers. Linear models, Time Series Methods such as ARMA and ARIMA, statistical models and other numerical methods like Artificial Neural Networks (ANN), Genetic Algorithms (GA), Support Vector Machines (SVM) and Particle Swarm Optimization are common approaches that are used for electric demand forecasting.

Dyner and Larsen present an analysis for the liberalization of electricity markets and discuss the usability of "agent modeling", "simulation", "game theory" and "risk management" for taking into account stochastic characteristics of load and demand [3]. Anand and Suganthi present a review of energy demand forecasting models, discussing traditional methods such as "time series", "regression", ARIMA and new methods such as "Support Vector Machines", "Ant Colony" and "Particle Swarm Optimization" [4]. Hahn et al. present a survey of electricity load forecasting methods and tools for decision making [5]. Conejo et al. compare "time series analysis", "neural networks" and "wavelets" for electricity demand forecasting in the market. They conclude that time series methods provide more accurate results for short term forecasting [6].

Regression methods that are quite convenient and easy to implement have been applied widely for electricity demand forecasting. Vilar et al. use a "nonparametric regression" technique to forecast the next-day electricity demand and price with a semi-functional partial linear model. Their model is applied to Spanish data and the results are compared with that of "naïve" and "ARIMA" methods [7]. Taylor uses statistical forecasting methods for short term electricity demand forecasting. He extends the three double seasonal methods in order to accommodate the intra-year seasonal cycle and applies the method to six years of British and French data [8]. Clements et al., show that a multiple equation time-series model can forecast the load as accurately as complex nonlinear and nonparametric forecasting models. They apply the method to Australian data and they reach a very low MAPE using an 11-year data set [9]. Fan and Hyndman propose "semi-parametric additive models" to estimate the relationships between demand and inputs such as calendar variables, lagged actual demand observations, and historical and forecast temperature. Their method is applied to the Australian National Electricity Market to forecast half-hour electricity demand for up to one week [10]. Wang et al. use the "PSO optimal Fourier method", the "seasonal ARIMA" model and apply their combinations to the Northwest electricity grid of China for correcting the forecasting results of seasonal ARIMA. Their results show that the prediction accuracy of the combined models is higher than that of the single seasonal ARIMA [11,12]. A "semi-parametric additive regression" model is proposed to estimate the relationships between demand and temperatures, calendar effects and some demographic and economic variables in Hyndman and Fan [10], Fan and Hyndman [13]. Hyndman and Fan then calculate the density forecasts and full probability distributions of the possible future values of the demand while also considering the holidays and weekends. A similar regression approach is proposed in McSharry et al. [14] to analyze the relationship between demand and other variables. The author uses five different exponential smoothing methods to apply the methodology to British and French half-hourly load data in Taylor [15].

The application of time series methods to the forecast of the electricity demand is also popular in the literature. "ARIMA" is preferred mostly for short and long term electricity demand. Future demand is predicted using an ARIMA model and profit function is developed as an objective in Niu et al. [16]. Andersen et al. propose an econometric modeling approach for the long term forecasting of hourly electric consumption in local areas. Data from the Danish market is used for the analysis and the estimated load profiles are used by the transmission operator [17]. Lo and Wu examine local forecast uncertainty: Artificial Neural Networks and ARIMA models are used to calculate the load, highlight high risk in different periods and evaluate daily value at risk [18]. In Chakhchoukh et al. [19] the authors use statistical analysis methods to forecast the short term demand. They compare these methods with classical models like ARIMA and show that the proposed method can outperform the classical ones. The authors develop a multiple linear regression model based on calendar and weather related variables to analyze the relationship between meteorological variables and monthly electricity demand. The method is applied to forecast the electricity demand in Italy and returns promising results [20].

In addition to the basic approaches cited above, based on the problem scope and objective, a number of alternative methods are also proposed in the literature. Zhang and Dong use an "artificial neural network" model and wavelet transformed data together to forecast electricity demand for short periods [21]. Heuristic approaches such as "particle swarm optimization", "evolution algorithms" or hybrid approaches are also used to forecast the electricity demand [22,11,12,23]. Azadeh et al. use "neural networks" and "genetic algorithms" to predict the electrical energy consumption using economic indicators such as price, value added, number of customers and consumption in previous periods. The integrated GA and ANN method returns less (MAPE) when applied to the Iranian electricity market [24]. Pai and Hong propose a method to forecast the electricity load using recurrent Support Vector Machines (SVM) with Genetic Algorithms. They use electricity data from Taiwan and they show that the proposed method outperforms the SVM, neural network and regression models [25]. Wang and Ramsay develop a "neural network" based estimation for electricity spot prices, focusing particularly on weekends and public holidays [26]. A similar approach for electricity demand forecasting with a focus on weekends and public holidays is given in Srinivasan et al. [27].

It is true that the temperature and climate can affect electricity demand, and hence, can be included in the forecasting model. The effect of weather on electricity consumption is studied by Taylor and Buizz, who use weather conditions to forecast short term electricity demand for 1–10 days ahead. Various weather scenarios are included in their models and it is shown that the model that includes weather scenarios returns more accurate results for the short term than the traditional weather forecasts [28]. Felice et al. use statistical modeling to analyze the influence of temperature on load forecasting in Italy both at the national and regional level using unprecedented historical load data [29].

In Crowley and Joutz [30] the authors show that electricity consumption due to increased cooling needs continues even after the high temperatures return to normal due to the heat capacity of the buildings. This shows that the effects of weather conditions on electricity consumption is far from being simple. This is also to show that approaches that can capture the demand pattern without using physical parameters might return better forecasts, as we present in this research. Table 1 provides an overview of methods and resources.