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Experimental study on electricity price forecasting using neural network

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Abstract: It is very important to forecast electricity price in a deregulated electricity market for choosing the bidding strategy, and it is the most important signal for other players. It engulfs information for both customers and producers in order to maximize their profit. Thus, choosing the best method of price forecasting is a crucial task to have the most accurate forecast. In this paper the price forecasting is done based on Neural Network (NN). The method is examined by using data of an electricity market. The results are compared and described well in the results section.

Keywords: price forecasting, Neural Network (NN), transmission.

Introduction

Electricity has become an essential commodity in a modern society. Our daily lives depend on the use of electricity in various forms. Rapid rise of industrialization in the last century has contributed to a phenomenal growth of electricity consumption and hence the tremendous increase in generation of electrical energy.

The advent of bulk generation of electrical energy required that the electrical energy be transmitted to load centers via elaborate networks of transmission lines. At the load centres, electrical energy is then distributed by a complex web of distribution networks. This basic configuration of generation, transmission and distribution is still in use all over the world. A part of the electrical energy is lost during its transmission. This puts a physical limit as to the distances of generation centers from the load centers. That is why electrical systems have evolved mainly within their own geographical jurisdiction. Although by employing a different technique, called DC transmission, it became feasible to transport electrical energy over longer distance, electrical systems predominantly remained bound to their geographical jurisdiction.

Natural Monopoly and Regulation

Generation, transmission and distribution of electrical energy require huge capital investment for operation, maintenance and expansion. This type of investment was achieved by awarding monopoly over the entire geographical jurisdiction. In some places, crown corporations were established and given monopoly of generation, transmission and distribution of electrical energy within prespecified geographical boundaries. A single entity used to run and control all aspects of generation, transmission and distribution within a geographical jurisdiction. The single entity could set its own rate sometimes with the approval from a regulatory body. A natural monopoly guaranteed a decent return on the huge investment that a single entity or a crown corporation would typically make. However, regulation became part of the electricity industry all over the world. Its chief objective was to protect the consumer, from the inevitable consequences of a monopoly industry.

The regulated electric market is still a natural monopoly industry but carefully watched by the government. Its vertically integrated structure is shown in Figure 1. Back in the 1970’s in India, there was usually a limited number of huge corporations owning and operating few vertically integrated electric systems. Each corporation was an independent system. Combined, they controlled more than 90 percent of the total electric market in the country. In a vertically integrated system, local consumers have no other choice for electricity service but the local provider. In a natural monopoly (regulated) electric market, electricity price is high and services are usually limited.

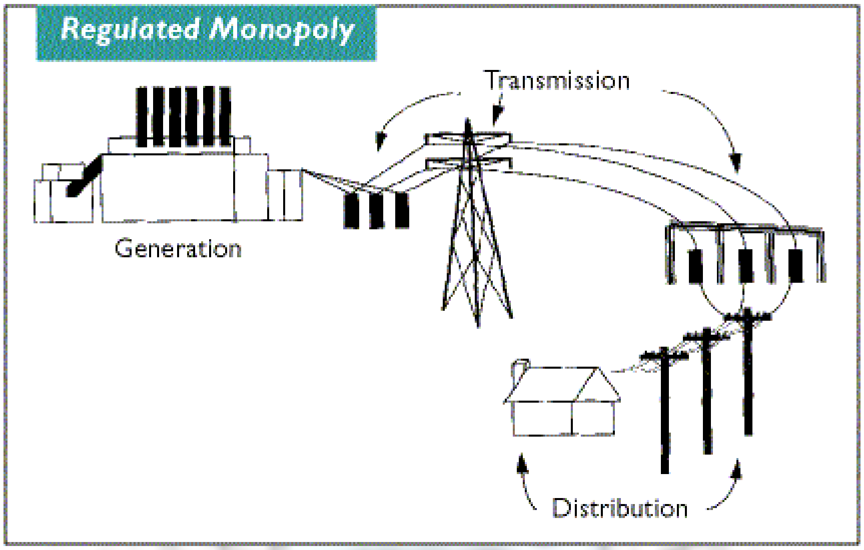

Figure 1: Regulated Electric Market

Deregulated Electric Market: The meaning of deregulation is the reduction or elimination of government control in a particular industry. The purpose of deregulation is to promote more competition within the same industry and same geographical jurisdiction. It is generally believed that fewer and simpler regulation will lead to a raised level of competitiveness and would overall result higher productivity, more efficiency and lower prices. Deregulation of electrical markets calls for the restructuring of the electricity industry. The traditional vertically integrated system is to break down as three separate businesses; 1) generation company, 2) transmission company and 3) distribution company.

These three businesses are to be owned and operated by three different entities. Deregulators advocate that deregulated electric market will bring cheaper electricity and meantime, more choices for the **customers.**

In a deregulated market, instead of only one generation provider in a local area, there are now several generation providers in the same area. The local regulatory body can no longer set the electricity price. Consumers have more choices about their local electricity providers. They can choose different electricity providers depending on their requirements and demand. Although competition is allowed in the generation and distribution sector, the transmission sector remained regulated. The principle reason behind the continued regulation of the transmission sector is that in order for a fair competitive environment in the generation sector all competitors in that sector must have equal access to the transmission network. Same goes for the bulk energy distribution. The transmission network is operated by an independent non-profit entity called, independent system operator (ISO) or independent market operator (IMO).

In my thesis work Ontario electricity bill data for California city has been taken as a lot or previous work is done by taking this data as reference. We have also taken so that we can accurately compare our work to previous work done. Later on our proposed work can be extended to any Indian electricity distributer company.

1.3.1 Ontario Electric Market

The Independent Electricity System Operator (IESO) is a crown corporation responsible for operating the electricity market and directing the operation of the bulk electrical system in the province of Ontario, Canada. The IESO is an independent and non-profit entity established in April 1999. A board whose directors are appointed by the Government of Ontario governs it. Ontario Energy Board sets its fees and licenses. Most importantly, it operates independently of all participants in the electricity market.

In Ontario, homeowner and certain designated consumers are part of the regulated price plan (RPP) set by the Ontario Energy Board (OEB). The threshold under the RPP varies by season to reflect changing consumption patterns. Some regulated prices are shown below. Summer Regulated Price Plan Rates (May 1 to October 31).

Residential users

- 5.3 ¢/kWh for the first 600 kWh in a month
- 6.2 ¢/kWh for each additional kWh

Low-volume business users

- 5.3 ¢/kWh for the first 750 kWh in a month
- 6.2 ¢/kWh for each additional kWh

Regulated price plan applies to homeowners and designated consumers that include hospitals, universities, schools, farms and specified charitable organizations. Other consumers such as large volume users who consume more than 250,000 kWh a year pay the wholesale price of electricity. These include industrial facilities, large retail operations such as supermarkets or department stores and other medium- and large-sized businesses. These customers consume almost half of all electricity used in Ontario.

Consumers in Ontario can purchase electricity either from their local utilities or through an electricity retailer licensed by the OEB. Consumers' electricity bill includes energy use that indicates how much electricity they used in the certain time period. This is the deregulated part where price may vary depending on the providers' rates. The next part is the delivery charge where price is regulated by the OEB. This includes charge to transmit electricity though transmission and distribution systems. Other chares such as regulatory and debt retirement charges are also applied on every bill.

Electricity Market Clearing Price

Market clearing price by definition is the price that exists when a market is clear of shortage and surplus, or is in equilibrium. It is a common and non-technical term for equilibrium price. In a market graph, the market clearing price is found at the intersection of the demand curve and the supply curve. Figure 2 shows the electricity market clearing price (MCP) in California electric market. The MCP in Figure 1.3 is $200 per MWh, and the demand at that price is 30,000 Mega Watts.

The equilibrium price or the MCP price is the final product of market bidding price. When electric market clearing price is determined, every supplier whose offering price is below or equal to the electric MCP price will then be picked up to supply electricity at that hour. They will be paid at the same price, the electricity market clearing price, but not the price they offered. The reason for that is to keep fairness of the market and to avoid market manipulation.

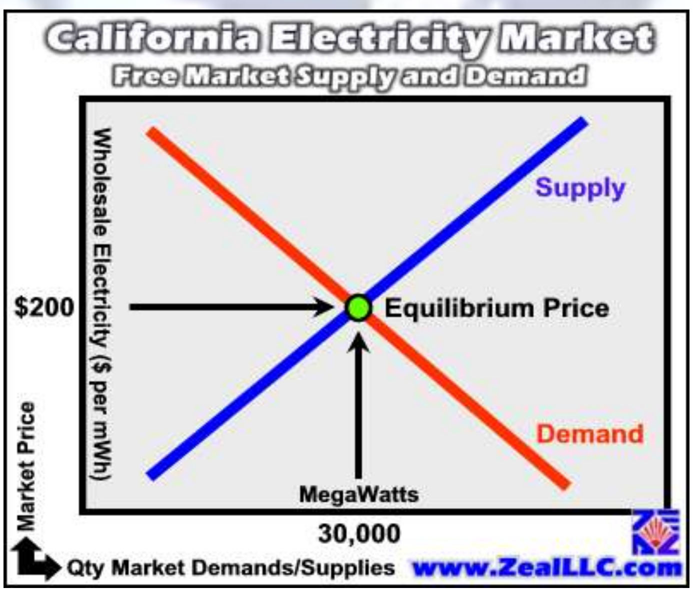

Figure 2: Electric Market Clearing Price

In Ontario deregulated electric market, for those consumers paying wholesale price from a 24- hour operation wholesale electricity market, the wholesale price is set every 5 minutes. The process of electricity market clearing price determination starts by finding out electricity demand at the first place. Each day, the IESO issues forecasted electricity demand throughout the following day and up to the month ahead. This forecasted electricity demand also includes an energy reserve of approximately 1400 MW above what will actually be consumed. This extra 1400MW is on standby and reserved for emergency usage. The forecasted electricity demand is continually updated as new information comes in such as changes in weather. Typically, the day ahead forecasted electricity demands from IESO are highly accurate, with less than two percents variance from the actual demand figures. After the determination of electricity hourly demand, the next step is to start the electricity auction (electricity market bidding price).

Generators and electricity providers review the forecasted information and decide how much electricity they will supply and what price they will charge at various hours. They will then send that information to IESO. Meanwhile, large volume consumers will send their demand information and the price they are willing to pay for the electricity. Large volume consumers have the ability to change their consumption plans. The market is structured so that the consumers can agree to cut consumption at pre-determined price levels. If these large volume consumers feel the wholesale price that offered by the electricity providers is too high to accept, they can cut their electricity usage to save money. After the actual electricity demand been finally determined, the IESO then matches the offer to supply electricity against the forecasted demand. It accepts the lowest priced offers first and then "stacks" up the higher priced offers until enough have been accepted to meet customer demands. All suppliers are paid the same price, the market clearing price. This is based on the last offer been accepted. The Market Clearing Price approach ensures the lowest possible price while maintaining reliability of the system.

When the market clearing price is determined, the IESO collects bids and offers until two hours before the electricity is needed. This way, new bids can still come so that the actual market clearing price can be adjusted instantly. The IESO will issue its instructions to the winning bids suppliers. Those winning bid providers or picked providers will then supply electricity into the electric system, through the transmission lines and to the end user.

Electricity Market Clearing Price Forecasting

Electricity market clearing price (MCP) forecasting is a prediction of future electricity price based on given forecast of electricity demand, temperature, sunshine, fuel coast and precipitation. Good electricity MCP forecasting can help suppliers and consumers to prepare their electricity usage and bidding strategy in order to maximize their profits. Electricity MCP forecasting is very complex task as there are too many variables with various uncertainties that affect the electricity MCP in various way. Some of these variables are straightforward and could be managed to forecast quite accurately such as temperature, sunshine, natural gas price and precipitation.

Other variables, however, are very complicated and highly unpredictable such as market clearing price bidding strategy, spot market price, spinning reserve market price, business competing strategy and even unethical business behaviours. The short-term electricity MCP forecasting is commonly known as the 24-hour day-ahead MCP forecasting. It forecasts the electricity MCP for the next 24 hours. A producer with low capability of altering MCPs (price-taker producer) needs day-ahead price forecasts to optimally self-schedule and to derive his bidding strategy in the pool. Retailers and large volume consumers also need the forecasted day-ahead electricity MCP for the same reason. In most electric market, 24-hour day-ahead electricity MCPs for the next day is required around 10 a.m. in the previous day. The mid-term electricity MCP forecasting focuses electricity price on a time frame between one month and six months. It can be utilized in decision making and mid-term planning purposes. Some examples include adjustment of mid-term schedule and allocation of resources. The forecast of electricity MCP as mentioned before depends on variables such as fuel cost, electricity demand and supply, temperature, sunshine, congestion, transmission loss, transmission constrains and precipitation. The forecasting of electricity MCP is a highly nonlinear problem. Variables such as bidding strategy, business competition strategy and unethical business behaviours impose an unrealistic burden on the forecasting process due to the fact that these variables are difficult to quantize.

Results & Discussion

To implement the proposed work, MATLAB's neural network toolbox is used. Neural Network Toolbox provides functions and apps for modeling complex nonlinear systems that are not easily modeled with a closed-form equation. Neural Network Toolbox supports supervised learning with feed forward, radial basis, and dynamic networks. It also supports unsupervised learning with self-organizing maps and competitive layers. With the toolbox you can design, train, visualize, and simulate neural networks. You can use Neural Network Toolbox for applications such as data fitting, pattern recognition, clustering, time-series prediction, and dynamic system modeling and control.

The data set used for the proposed work is a table of historical hourly loads, prices and temperature observations from the New England ISO for the years 2004 to 2008. The weather information includes the dry bulb temperature and the dew point. Since for neural network training test data and trained data is required, so the database has to be divided into test data and trained data, but before that preprocessing or calibration on the dataset has to be done. The matlab file generated named 'genPredictors.m' which categorise datato different categories as shown in table 1.

Table 1: Labels for calibrated data

```
labels = {'DryBulb', 'DewPoint', 'Hour', 'Weekday', 'IsWorkingDay',
'CurrentLoad', 'PrevWeekSameHourLoad', 'prevDaySameHourLoad',
'prev24HrAveLoad'...
        'PrevWeekSameHourPrice', 'prevDaySameHourPrice', 'prev24HrAvePrice',
'prevDayNGPrice', 'prevWeekAveNGPrice'};
```

The data before 2008-01-01 is taken as training data and data collected after this date is taken for testing purpose. Then feed forward neural network is used to create the network and train test data as per the training set. Parameters used for neural network is shown in table 2 and neural network interface while training is shown in figure 3 below.

Table 2: Parameters for feed forward neural network

```
net = newff(trainX', trainY', 20);
    net.performFcn = 'mae';
    net.trainParam.epochs=100;
    net.trainParam.lr = 0.3;
    net = train(net, trainX', trainY');
```

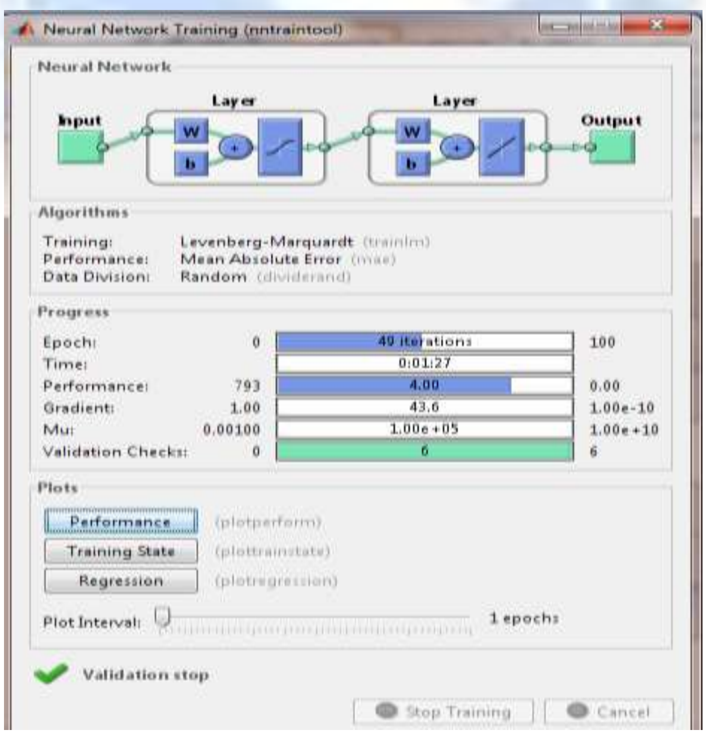

Figure 3: Neural Network training interface

The training loop runs for 49 epochs and a performance curve is shown in figure 2 for neural network. The performance of a trained network can be measured to some extent by the errors on the training, validation, and test sets, but it is often useful to investigate the network response in more detail. One option is to perform a regression analysis between the network response and the corresponding targets. Linear regression analysis shows how much exactly test data is trained to target. Maximum value is 1 in this case. Figure 3 shows the regression chart in our case. Figure shows the exact tracking of test data to target data. After training neural network the forecasted price should match to the actual electricity price. In our case also our forecasted price almost matches to the actual price.

Conclusion

In this work electricity price forecasting in the newly deregulated market is studied in detail. Previously reported price forecasting methods are discussed and some of the main input variables that play a crucial role in setting up the next day's market price are also investigated. The issue of strategic bidding is also briefly discussed in this study. Once the next day electricity price forecast is available, the next task to generating companies is preparing their bid and the subject of how generating companies arrange their generation scheduling to maximize their profit and formulate their bidding strategies is also addressed. The aim of this thesis work was to develop mathematical models for prediction of future electricity market prices. Accordingly, different electricity market price forecasting models are developed using multiple linear regression approach to forecast next day's hourly market prices. The method of list square is applied to calculate the regression coefficients and simple Matlab programs are written to calculate the coefficients, make the forecast based on these values and subsequently plot the graphs. A single forecast model for each hour of the day is applied and models are developed based on previous day and previous week prices of the same hour. The models developed are applied to forecast electricity market prices in the Nord Pool market where satisfactory results are obtained. These models are quite simple to develop and to make the task; yet they provide results with good efficiency.

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