International Journal of Computer Applications (0975 – 8887)
Volume 88 – No.15, February 2014

A Comparative Analysis of Techniques for Forecasting Electricity Consumption

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ABSTRACT
The issue of obtaining reliable forecasting methods for electricity consumption has been widely discussed by past research work. This is due to the increased demand for electricity and as a result, the development of efficient pricing models. Several techniques have been used in past research for forecasting electricity consumption. This includes the use of forecasting, time-series technique (FTST) and artificial neural networks (ANN). This paper introduces a modified Newton's model (MNM) to forecast electricity consumption. Forecasting models are developed from historical data and predictive estimates are obtained. This research work utilizes data from Universiti Malaysia Sarawak, a public university in Malaysia, from 2009 to 2012. The variables considered in this research include electricity consumption for different months over the years.

Keywords
Electricity consumption, electricity forecasting, time-series, artificial neural networks, modified newton's method, historical data.

1. INTRODUCTION
Electricity is a key energy source in each country and an important condition for economic development. A reliable forecast of energy consumption represents a starting point in policy development and improvement of production and distribution facilities [1]. Results obtained from past research suggest that total electricity demand will vary according to temperature response across different climatic zones, which allows for differential effects of days with different mean temperatures on households' electricity consumption [2]. It studies the impact of higher temperatures on residential electricity consumption for different climatic zones. [3] examines the development and analysis of a stochastic model predictive control (SMPC) strategy for building climate control that takes into account the uncertainty due to the use of weather predictions. It discusses how these models can increase the energy efficiency in integrated room automation (IRA) while respecting occupant comfort. The study indicates that there is a significant energy savings potential for model predictive control (MPC). [4] seek to determine the long-run equilibrium relationship between carbon emissions, energy consumption, and real output for Brazil over the period between 1980 and 2007. The study postulates that the models developed have a strong forecasting performance with prediction error less than 3%.

A research to undertake a broad examination of monthly residential electricity demand for a region of the mid-Atlantic was carried out using Excel and step-wise regression [5]. It investigates the seasonal effects on electricity demand. Forecasting models for electricity demand and the predictive power of derived models are assessed. The paper proposes that any method could be used to effectively develop forecasts for residential electricity usage, however advises that the method with the smallest percentage error should be selected. [1] predicts the electricity consumption covering an area in Serbia using Holt-Winters method. The research postulates that the introduction and proper choice of a new technique in predicting electricity consumption is expected to provide more reliable forecasts. A study where grey forecasting method is applied to predicting the operating energy performance for an air cooled water chiller (ACWC) units is applied to building heating ventilation and air conditioning (HVAC) installations [6]. In the paper, the use of grey forecasting in energy management systems (EMS) for air conditioning and refrigeration systems is assessed and comparisons with the prediction method based on artificial neural network (ANN) is discussed. [7] compared the performance of three forecasting methods-autoregressive integrated moving average (ARMA), artificial neural network (ANN) and multiple linear regression (MLR) to formulate prediction models of electricity demand. Although the results based on error measurements showed that ANN model was superior to other approaches; paired tests pointed out that there was no significant difference among these errors for the methods. [8] presents the use of a multi-layer feed forward (FF) artificial neural network trained with Back propagation (BP) algorithm to half hourly ahead load and ahead price prediction by using historical weather , load consumption, price and calendar data. The available data of Australia's New South Wales (NSW) states were used for testing the ANN and tested against the performance of multiple regression models. The estimation of Turkey's energy demand with a hybrid model (HAP) is compared with particle swarm optimization (PSO) and ant colony optimization (ACO) via considering gross domestic product (GDP), population, import and export socio-economic indicators [9]. From obtained results, the relative estimation error of the proposed energy demand HAPE model is lowest and provides better-fit solutions. [10] provides a hybrid method, which is a combination of autoregressive integrated moving average (ARIMA) and artificial neural network (ANN) for predicting short-term electricity prices using different seasons.

An integration model of grey model and multiple regression model (IGMMRM) was used to forecast the trend of energy consumption so as to assess the proposed forecasting models [11]. This was compared against the grey model (GM) and multiple regression models and it was discovered the performance of the IGMMRM is higher than other two models based on historical data. The local kernel regression (ELKR) is introduced by [12] and how it can be parallelized for large-scale decentralized smart grid scenarios, it can be applied to a new and expensive training process if the data archive is changed. The assignment to local models saves computations, as only the kernel regression model with the closest codebook vector is taken into account for prediction. ELKR has shown significantly higher accuracies than common kernel regression or back-propagation, and competitive results compared to linear multiple regression (LMR). The performance of forecasting techniques to formulate prediction models for electricity consumption is an essential key factor for the development of any country [13]. This is achieved if demand for electricity is predicted accurately. Energy analysts need exquisite guidelines to choose the most appropriate predictive technique in order to provide accurate forecasts of electricity consumption trends.

This paper presents the use of MNM technique to predict electricity consumption considering historical data from Universiti Malaysia Sarawak; by considering data from 2009 to 2012. The real data consists of electricity consumption measurements taken during different months for the respective years. The remainder of this paper is organized as follows: Section 2 outlines the models used; Section 3 discusses the empirical analysis and results and the last section summarizes and concludes the paper.

2. MODELS

In past research work, traditional methods have been used to estimate and forecast for future values. Some of them include forecasting, time-series technique and artificial neural networks.

2.1 Forecasting, Time-series Technique

FTST is a commonly used method for predicting data because of the high degree of uncertainty involved in the process. This research will investigate electricity consumption for different months by using FTST method. In applying this procedure, new estimates of electricity consumption is considered to be the dependent variable, while actual electricity consumption for different months will be considered as independent variables.

FTST can be represented as the following [5]:

$$Y_t = b_0 + b_1X_{1t} + b_2X_{2t} + \cdots b_nX_{nt} + e_t \quad (1)$$

where X_{1t} to X_{nt} are electricity consumed for different months. The X's denote independent variables while the Y denotes the dependent variable. The e_t term denotes the random variation in the time-series not accounted for by the model. Since the values of Y_t are assumed to vary randomly, the expected value of e_t is 0. (1) represents the line passing through the time-series that minimizes the sum of squared differences between actual values (Y_t) and the estimated values ($\hat{Y}_t$).

2.2 Artificial Neural Networks

The ANN method is a technique based on pattern recognition. It is able to forecast for non-linear models. It uses the back-propagation algorithm concept, which is widely used in the field of machine learning. The back-propagation concept has been used to forecast residential construction demand in Singapore [14]. It consists of three or more layers i.e., input layer, output layer and the hidden layer.

The function of the network is described as follows:

$$Y_j = f(\textstyle\sum_i w_{ij}X_{ij}) \quad (2)$$

where Y_j is the output of node j, f(.) is the transfer function, w_{ij} the connection weight between node j and node i in the lower layer and X_{ij} is the input signal from the node i in the lower layer to node j.

For data analysis, the input variables consists of electricity consumed for the different months over the years 2009-2012, while the output variable is measured in KWh.

2.3 Modified Newton's method

An MNM technique is introduced in this study for forecasting electricity consumption data. It is obtained by combining standard error (SE) estimates with Newton's method (NM) algorithm. NM is used to estimate the roots of a function f(x) using an iterative process. It utilizes the unconstrained non-linear optimization technique for generating reliable estimates which are used for developing error corrector models used in forecasting. For a multivariate function, it attempts to find a minimum of a scalar function of several variables, starting at an initial estimate.

It can be expressed as follows[15] :

For f(x) a polynomial, the Taylor series of f(x) about the point $x = x_0 + \epsilon$ is given by

$$f(x_0+\epsilon) = f(x_0) + f'(x_0)\,\epsilon + \tfrac{1}{2}f''(x_0)\,\epsilon^2 + \cdots \quad (3)$$

Keeping terms only to first order,

$$f(x_0+\epsilon) = f(x_0) + f'(x_0)\,\epsilon \quad (4)$$

Equation (4) can be used to estimate the amount of ϵ needed to be closer to the initial guess x_0.
Setting $f(x_0+\epsilon) = 0$ and solving for (4) for $\epsilon = \epsilon_0$ gives

$$\epsilon_0 = \frac{f(x_0)}{f'(x_0)}, \quad (5)$$

By letting $x_1 = x_0 + \epsilon_0$, calculating a new ϵ_1, and so on, the process can be repeated until it converges to a fixed point(which is a precise root) using

$$\epsilon_n = \frac{f(x_n)}{f'(x_n)}, \quad (6)$$

with a good starting point x_0 the algorithm can be applied iteratively to obtain

$$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)} \quad (7)$$

for n=1,2,3,……..an initial point x_0 that provides safe convergence of NM is called an approximate zero.

For the forecasting process, MNM is used to obtain electricity consumed and can be expressed as:

$$MNM = x_{n+1}x_n - \frac{f(x_n)}{f'(x_n)} + SE \quad (8)$$

with SE given to be;

$$SE = \sum_{t=1}^{n}\sqrt{\frac{(Y_t - X_t)^2}{n}} \quad (9)$$

Hence,

$$MNM = x_{n+1}x_n - \frac{f(x_n)}{f'(x_n)} + \sum_{t=1}^{n}\sqrt{\frac{(Y_t - X_t)^2}{n}} \quad (10)$$