COMBINED EMPIRICAL MODE DECOMPOSITION AND DYNAMIC REGRESSION MODEL FOR FORECASTING ELECTRICITY LOAD DEMAND

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To my beloved parents, siblings, and friends for their love, support, and encouragements.

I really appreciate it!

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ABSTRACT

Electricity load demand forecasting is an important element in the electric power industry for energy system planning and operation. The forecast accuracy is the main characteristic in the forecasting process. Hence, in an attempt to achieve a good forecast, combined methods of empirical mode decomposition (EMD) and dynamic regression (DR), known as EMD-DR is proposed. Besides, the forecast performance of the combined model EMD and DR is compared with a single DR model. EMD is a powerful analysis technique for detecting non-stationary and nonlinear signal, while DR is a method that involves lagged external variables. The data used in this study are retrieved from half-hourly electricity demand (kW) and reactive power (var), whereby the reactive power data acts as exogenous variable for the DR method. The investigation is conducted using Statistical Analysis Software (SAS) for DR method and Matlab software for EMD. The findings reveal that the combined method, EMD-DR, give mean absolute percentage error (MAPE) 0.7237%, whereas for the DR method, 0.8074% is obtained, which suggests percentage improvement of 10.37%.

ABSTRAK

Ramalan bebanan permintaan elektrik merupakan elemen yang penting dalam industri penjanaan kuasa elektrik; kerana kegunaannya dalam perancangan dan operasi jana kuasa elektrik. Ukuran kejituan merupakan karakter utama dalam proses ramalan. Untuk mendapatkan model yang terbaik, kajian ini telah mencadangkan kaedah penggabungan model penguraian mode empirikal (EMD) dan regressi dinamik (DR) yang dikenali sebagai model EMD-DR. Ukuran kejituan kaedah penggabungan EMD dan DR dibandingkan dengan model tunggal DR. EMD merupakan satu kaedah analisis yang mantap bagi mengesan amaran yang tidak tetap dan tidak linear, manakala kaedah DR merupakan kaedah yang melibatkan pembolehubah luaran tersusul. Data setiap setengah jam bebanan permintaan elektrik (kW) dan data kuasa bertindak balas (var) merupakan data yang digunakan dalam kajian ini, di mana data kuasa bertindak balas bertindak sebagai pembolehubah luaran untuk kaedah DR. Kajian dijalankan mengunakan perisian analisis statistikal (SAS) bagi kaedah DR dan perisian Matlab bagi EMD. Dapatan kajian menunjukkan ukuran peratus purata ralat mutlak (MAPE) bagi kaedah penggabungan, EMD-DR, adalah sebanyak 0.7237%, manakala kaedah DR sebanyak 0.8074% juga menunjukkan peningkatan kejituan sebanyak 10.37%.

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LIST OF ABBREVIATIONS

TNB	-	Tenaga Nasional Berhad
PJM	-	Pennsylvania-New Jersey-Maryland Interconnection
SAS	-	Statistical Analysis Software
STLF	-	Short Term Load Forecast
EMD	-	Empirical Mode Decomposition
DR	-	Dynamic Regression
EMD-DR	-	Empirical Mode Decomposition and Dynamic Regression
IMFs	-	Intrinsic Mode Functions
W	-	Watt
kW	-	Kilowatt
kWh	-	Kilowatt-hour
VA	-	Volt Ampere
var	-	Volt-amperes Reactive
AC	-	Alternating Current
RMS	-	Root Mean Square
OLS	-	Ordinary Least Square
AR	-	Autoregressive
SAR	-	Seasonal Autoregressive
MA	-	Moving Average
SMA	-	Seasonal Moving Average
ARIMA	-	Autoregressive Integrated Moving Average
ARIMAX	-	Autoregressive Integrated Moving Average with Exogenous Variable
SARMAX	-	Seasonal Autoregressive Moving Average with Exogenous Variable
SARIMAX	-	Seasonal Autoregressive Integrated Moving Average with Exogenous Variable
ANN	-	Artificial Neural Network
FFNN	-	Feed Forward Neural Network
MFNN	-	Multi-output Feed Forward Neural Network
BPNN	-	Back Propagation Neural Network
ARIMA-ANN	-	Autoregressive Integrated Moving Average and Artificial Neural Network
GA	-	Genetic Algorithm
PSO	-	Particle Swarm Optimization
PSO-BP	-	Particle Swarm Optimization and Back Propagation Neural Network
PSO-SVR	-	Particle Swarm Optimization and Support Vector Regression
GA-ARIMA	-	Genetic Algorithm and Artificial Neural Network

SVR	-	Support Vector Regression
LSSVM	-	Least Square Support Vector Machine
LSSVM-ARIMAX	-	Least Square Support Vector Machine and Autoregressive Integrated Moving Average with Exogenous Variable
EMDSVRAR	-	Support Vector Regression hybridized with EMD method and Auto Regression
SES	-	Seasonal Exponential Smoothing
AFCM	-	Adaptive Fuzzy Combination Model
MCP	-	Market Clearing Price
MFES	-	Multi-output Feed Forward Neural Network with EMD based Signal Filtering and Seasonal Adjustment method
MFE	-	Multi-output Feed Forward Neural Network with EMD-based Signal Filtering
MFS	-	Multi-output Feed Forward Neural Network with Seasonal Adjustment
AIC	-	Akaike Information Criteria
BIC	-	Bayesian Information Criteria
SSE	-	Sum Square Error
MAE	-	Mean Absolute Error
MSE	-	Mean Square Error
MAPE	-	Mean Average Percentage Error

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Forecasting is a vital activity in commerce, economics, energy industries, and marketing (Chatfield, 2004). The quality of forecast and its significance is an essential process because its implementation in managerial decision that is extended in numerous fields is needed. Throughout the years, diverse methods have been developed for forecast.

Chatfield (2004) categorized forecasting methods into three types, which are judgmental forecasts, univariate methods, and multivariate methods. Basically, judgmental forecasts are related to instinctive perception, common sense, 'inside' and commercial comprehension. Meanwhile, univariate methods can be categorized as forecasts based only on past and present values of single series forecasting, very likely added by a function of time, for example, linear trend. On the other hand, multivariate method is a method of forecast of a specified variable that depends, leastwise partially, on values of one or extra time series variables, known as explanatory or predictor variables. Multivariate forecasts, mostly taking into account on a multivariate model, require more than one equation if the variables are jointly dependent.

Besides, combined methods can also be categorized as a forecasting method. This method could be merged with one of the above methods proposed by Chatfield (2004). For example, when univariate or multivariate forecasts are modified intuitively, which is also considered as exterior information that fails to show conventional aspect in a mathematical model, these combined methods are the most appropriate solution.

In this study, combined methods of univariate and multivariate had been introduced. The implementation of the combined methods is to improve the accuracy of forecast. Thus, in order to examine the effectiveness of the combined methods, a comparison study is conducted between single method and combined methods. Therefore, the following subsection describes the background of the study.

This chapter presents the background of the study. Next, it describes the problem statement, the objectives, the scope, and the significance of the study. Finally, a brief explanation for each chapter is provided at the end of this chapter.

1.2 Background of the Study

This study attempted to forecast electricity load demand. The univariate method, such as Box-Jenkins (BJ) method, is one of the most famous methods for forecasting electricity load demand, while for multivariate method; most studies used regression analysis. Meanwhile, for load forecasting, combined methods is also one of the effective methods, such as ARIMA-ANN method, GA-ARIMA method, LSSVM-ARIMA method, and Gray method with ANN.

The purpose of this study is to forecast electricity load demand using combined methods of Empirical Mode Decomposition (EMD) and Dynamic Regression (DR). A single method of DR acted as a benchmark for the combined methods. The multivariate method, such as Dynamic Regression, has been frequently used for various similar studies because this method can include explanatory variables. On the other hand, EMD is a new method for load forecasting, and previous studies have proven the efficiency of forecasting performances using the EMD method.

In addition, this study highlighted the procedures on modeling and forecasting electricity load demand using the DR method and the combined methods of EMD and DR, thus a comparative study between these two methods is carried out.

1.3 Problem Statement

The main issue in forecasting is the accuracy of forecast. Lately, a combination of two methods is believed to improve the forecasting performance compared to a single method. To produce accurate forecasts using DR model, the lagged external variables, which match the electricity demand series, must be identified first. Moreover, forecasting electricity load demand is usually affected by other causal factors of data or disturbances, such as high frequency, non-stationary, non-constant variance and mean, and multiple seasonality, which are very likely related to half-hourly, hourly, daily, and weekly periodicity, and the calendar effects, for example, holidays and weekends. Therefore, modeling such data type poses multitude of challenges and the method must satisfy the causal factor that affects forecasting process. One of the methods that eliminate the causal factor of electricity demand data is the EMD method. Then, it had been necessary to combine the EMD with the DR method, in order to improve forecast accuracy, rather than using a single method and also to investigate the elimination of causal factor in electricity demand data.

1.4 Objectives of the Study

The purpose of this study is to develop the best model to forecast the Malaysian electricity load demand. In an attempt to discover the best model, some specific objectives had been needed. The objectives of the study are to:

i) Model the electricity load demand data using DR and EMD methods.

ii) Forecast electricity load demand using DR model, and a combined model of Empirical Mode Decomposition with Dynamic Regression (EMD-DR) model.

iii) Conduct a comparative evaluation on the performance between DR and EMD-DR model.

1.5 Scope of the Study

The scope of the study is divided into two, which are sample data series and method of forecasting. The data used in this studycare half-hourly of electricity demand and reactive power from January 1st 2013 to May 31st 2013. The total data points are 14496 for both electricity demand and reactive power, and the units of measurements are Kilowatts (kW) and Volt-amperes Reactive (var) respectively.

Nevertheless, this study is limited to modeling and to forecasting electricity load demand by using DR method and a combined method of EMD-DR. The reactive power data acted as explanatory variables in the DR method. Lastly, a comparative study that looked into forecasting performance is conducted between a single model (DR) and a combined model (EMD-DR).

1.6 Significance of the Study

The results from this study are useful to forecast electricity demand. The load forecasting results can be used in electricity generation, such as energy reservation and maintenance scheduling. Limitation of energy resources requires the employment of electric energy appropriately, more efficient power plants, and transmission lines. Thus, it is very important to forecast electricity demand correctly and accurately.

Besides, in the attempt to reveal the best model for forecasting electricity load demand, contributions have been made. The contribution is by investigating electricity load demand forecasting to assist in the expansion of new models that can lead to a decrease in the forecast error of the already existing models, which will result to a rise in profit margin for energy industries.

Lastly, the results of this study help in contributing new literature pertaining to electricity load demand forecasting and the methodologies used. Furthermore, it may serve a guideline for those who would want to conduct a similar study.

1.7 Thesis Organization

This thesis consists of six chapters. The first chapter is the introduction. This chapter provides the introduction, the background of the study, the problem statement, the objectives of the study, the scope, and the significance of the study.

Meanwhile, the Literature Review is in Chapter Two. This chapter represents the literature review on basic definition of load forecasting, short-term load forecast, and reactive power. Moreover, some strengths and weaknesses of DR and EMD methods are reviewed, and besides, some related researches on DR and EMD are presented. The conclusion and the summary are given to close the discussion of the chapter.

Next, Chapter Three is the Research Methodology. This chapter starts with a detailed discussion on DR and EMD methodologies, and then, it discusses the technique of combining EMD and DR procedures for load forecasting. The chapter ends with forecasting evaluation method and concluding remarks.

On the other hand, Chapter Four depicts the application of DR method to half hourly load demand in Malaysia. It begins with the introduction and a brief discussion on data series. Next, it discusses on analyzing the data using regression and correlation analyses. Then, it presents the procedures in determining Transfer Function model in detail. Finally, the discussions of the chapter are closed with the results of one-step ahead in-sample and out-sample forecast, and a conclusion of DR model.

After that, Chapter Five discusses the application of EMD-DR method in electricity load demand forecasting. First, it presents the introduction to the chapter, followed by the basic concepts of EMD, and the extraction of IMFs for electricity load demand and reactive power. Next, it presents EMD-DR implementation and the results of load forecasting using EMD-DR method. Lastly, a comparative study between the single and the combined models is discussed in this chapter and it ends with a summary.

Finally, Chapter Six ends the thesis by drawing up conclusions based on the results and findings, and also recommendations for future research.

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