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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Electrical Engineering

A STUDY OF MACRO FACTORS ON ELECTRICITY LOAD DEMAND IN JOHOR BAHRU USING STATISTICAL APPROACH

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Master of Science in Electrical Engineering

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A STUDY OF MACRO FACTORS ON ELECTRICITY LOAD DEMAND IN JOHOR BAHRU USING STATISTICAL APPROACH

MOHAMMAD HANIF BIN JIFRI

A thesis submitted
in fulfillment of the requirements for the degree of Master of Science
in Electrical Engineering

Faculty of Electrical Engineering

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2018

DECLARATION

I declare that this thesis entitled "A Study of Macro Factors on Electricity Load Demand in Johor Bahru Using Statistical Approach" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Electrical Engineering.

Signature	:	....
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DEDICATION

I dedicate this thesis to my beloved father and mother, Mr. Jifri bin Ismail, Mdm. Suraya binti Hussin and also to my lovely family

ABSTRACT

As widely known, load demand forecasting plays a vital role in power system planning and management in meeting the load demand requirements particularly during the peak demand period. There are many macro factors currently being identified to have influence over the load demand pattern which includes the population, economy and meteorological factors. However, there are problems pertaining to these factors caused by limited availability of statistical analysis to analyse which factors give the most contributing effect load demand in Johor Bahru. For that reason, three important objectives were defined based on the through literature found by earlier related researches. Besides that, data for electricity consumption were provided by Tenaga Nasional Berhad (TNB). For all others significant macro factors, the data provided are the actual data specifically for Johor Bahru during the year of 2005 until 2011. Initially, an investigation was done to identify which macro factors that will have an effect on the load demand prediction by using Pearson Correlation coefficient. Since only a few mathematical analysis, traditional forecasting technique done previously focused on how to determine the relationship between these macro factors and electricity load, thus this research proposed to explore further the three mathematical models namely regression, time series and hybrid methods. Using these three mathematical models, this present research provides an electricity demand estimation and forecast, whilst comparing the results with official projections. Therefore, the next goal is to find the most influential macro factor which can help improves the accuracy of the medium-term load forecasting. The performance of these different methods were evaluated by using the forecasting accuracy criteria namely, Root Mean Square Error (RMSE) and Mean Absolute Percentage Error (MAPE). As a result, this research found that maximum temperature, population growth and Gross Domestic Product (GDP) have influenced in determining the electricity demand consumption. In addition, the Multiple Stepwise Regression method was identified as the best forecasting method based on the smallest RMSE and MAPE obtained specifically for the city of Johor Bahru load demand prediction. In terms of contribution, it is expected that the mathematical models will help electricity demand planners to accurately plan load demand for future consumption in Johor Bahru area.

ABSTRAK

Seperti yang diketahui, ramalan permintaan beban elektrik memainkan peranan yang penting dalam pengurusan dan perancangan sistem janakuasa elektrik untuk memastikan segala keperluan permintaan beban terutamanya semasa waktu kemuncak dapat dipenuhi. Terdapat banyak faktor makro yang mempengaruhi permintaan tenaga elektrik termasuk faktor penduduk, ekonomi dan meteorologi. Walaubagaimanapun, terdapat masalah-masalah yang berkaitan dengan faktor-faktor ini yang disebabkan oleh kebolehan yang terhad analisis statistik dalam menganalisis faktor-faktor yang manakah yang paling memberi kesan kepada permintaan beban di Johor Bahru. Untuk tujuan itu, tiga objektif penting tealh dikenalpasti berdasarkan kajian yang ditemui oleh penyelidik-penyelidik yang berkaitan terdahulu. Selain itu, data penggunaan elektrik diperolehi melalui Tenaga Nasional Berhad (TNB). Untuk kesemua faktor makro yang signifikan, data disediakan adalah data sebenar khusus untuk Johor Bahru sepanjang tahun 2005 sehingga 2011. Pada permulaannya, satu penyelidikan dibuat untuk mengenalpasti faktor makro yang mana akan memberi kesan ke atas ramalan permintaan beban menggunakan pemalar korelasi Pearson. Oleh kerana hanya beberapa analisis matematik, teknik ramalan tradisional yang dilaksanakan sebelum ini tertumpu pada bagaimana untuk menentukan hubungan diantara faktor- faktor makro dan beban elektrik, dengan itu kajian ini mencadangkan untuk mengkaji dengan lebih mendalam terhadap tiga model matematik yang dinamakan kaedah-kaedah regresi, siri masa dan hibrid. Menggunakan tiga model-model matematik ini, penyelidikan ini menunjukkan angaran dan ramalan permintaan elektrik, disamping membandingkan keputusan-keputusan dengan unjuran-unjuran yang sebenar. Oleh yang demikian, matlamat berikutnya adalah untuk mencari faktor makro yang paling jelas mempengaruhi bagi membantu memperbaiki ketepatan ramalan beban tempoh sederhana. Prestasi daripada kaedah-kaedah yang berlainan ini dinilai menggunakan kriteria ketepatan iaitu ralat punca min ralat kuasa dua (RMSE) dan ralat bermakna min peratusan mutlak (MAPE). Hasil keputusannya, kajian ini mendapati bahawa suhu yang maksimum, peningkatan penduduk dan Keluaran Dalam Negara Kasar (KDNK) telah mempengaruhi dalam menentukan penggunaan permintaan elektrik. Tambahan lagi, kaedah analisis regrasi linear pelbagai langkah demi langkah telah dikenalpasti sebagai kaedah ramalan yang terbaik berdasarkan nilai ralat RMSE dan MAPE yang paling kecil diperolehi khususnya untuk ramalan permintaan beban di bandar Johor Bahru. Dari segi sumbangan, model-model matematik ini dijangkakan akan membantu para perancang pemintaan beban elektrik untuk merancang secara tepat permintaan beban untuk pengunaan masa hadapan di kawasan Johor Bahru.

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A	-	Additive
AAA	-	Local Additive Seasonal Model
AAN	-	Local Trend Model
ACF	-	Autocorrelation Function
A_d	-	Additive damped
ADF	-	Augmented Dickey Fuller
AIC	-	Akaike's Information Criterion
ANA	-	Additive Error, No Trend, Additive Season
ANN	-	Artificial Neural Network
LLM	-	Local Level Model
AR	-	Autoregressive Model
ARAR	-	Autoregressive Autoregressive Algorithm
ARARMA	-	Autoregressive Autoregressive Moving Average
ARIMA	-	Autoregressive Integrated Moving Average
ARIMAX	-	Autoregressive Moving Average with Exogenous
ARMA	-	Autoregressive Moving Average Model
ARMAX	-	Autogressive Moving Average Model with Exogenous Variables
ARX	-	Autogressive Model with Exogenous Variables
ASEAN	-	Association of Southeast Asian Nations

CM	-	Crude Material
d	-	Differencing
DR	-	Technology-Organizational-Environmental Framework
ES	-	Exponential Smoothing
GARCH	-	Generalized Autoregressive Conditional Heteroskedasticity
GDP	-	Gross Domestic Product
GPS	-	Global Positioning System
IPP	-	Independent Power Producers
LEAP	-	Long-range Energy Alternative Energy Planning System
LES	-	Linear Exponential Smoothing
LTLF	-	Long-Term Load Forecasting
M	-	Multiplicative
MA	-	Moving Average
MAE	-	Mean Absolute Error
MAPE	-	Mean Absolute Percentage Error
MAX	-	Moving Average Model with Exogenous Variables
M_d	-	Multiplicative damped
MLR	-	Multiple Linear Regressions
MLTF	-	Medium-Term Load Forecasting
MMD	-	Malaysian Meteorological Department
MSW	-	Municipal Solid Waste
MW	-	Megawatts
N	-	None
PACF	-	Partial Autocorrelation Function

R	-	Correlation Coefficient
R^2	-	Multiple Coefficient Of Determination
RMSE	-	Root Mean Square Error
SARIMA	-	Seasonal Autoregressive Integrated Moving Average
SES	-	Simple Exponential Smoothing
SLTF	-	Short-Term Load Forecasting
SPSS	-	Statistical Package for the Social Science
TBATS	-	Exponential Smoothing State Space Model with Box-Cox Transformation, ARMA Errors, Trend, and Seasonal Components
TNB	-	Tenaga Nasional Berhad
VIF	-	Variation Inflation Factor

LIST OF PUBLICATIONS

Journal Papers

Jifri, M.H., Hassan, E.E., Miswan, N.H., 2018. Investigate The Forecasting Technique For Electricity Load Demand In Urban Area Via Statistical Approach. Journal of Fundamental and Applied Sciences, 10 (7), pp. 298-310.

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Jifri, M.H., Hassan, E.E., and Miswan, N.H., 2017. Forecasting performance of time series and regression in modeling electricity load demand. In: 2017 7th IEEE International Conference on System Engineering and Technology (ICSET), pp.12–16.

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CHAPTER 1

INTRODUCTION

1.1 Background

Johor Bahru (JB) is the southernmost city in Malaysia. It consists of ten districts and considered as the second largest city in the country with more than 2.7 million population including those in the suburbs. The current mega project of Iskandar Malaysia according to experts will transform Johor Bahru into the biggest industrial and commercial centre in Malaysia. Tenaga Nasional Bhd (TNB) expects load demand for electricity in Johor Bahru to surge within the next 10 years especially in the southern and southeastern part of Johor. The government of Johor is planning to transform the state into a new regional oil and gas (O&G) hub in line with the Economic Transformation Programme.This pose as another factor that would contribute to the surge in power load demand in the state. Besides that. the load demand for electricity in the 9,712.45ha Nusajaya was projected to be high due to huge development in the area. Among the key developments that would contribute to high usage of electricity in Nusajaya includes Medini Iskandar Malaysia with Legoland Theme Park and EduCity (multi-varsity campuses) where Iskandar Malaysia was launched on Nov 4, 2006. It covers over 2,217 sq km with five flagship development zones – the Johor Baru City Centre, Nusajaya, Eastern Gate Development, Western Gate Development and Senai-Kulai. The demand for electricity has facilitated Johor Bahru overall development growth while economic development of Johor Bahru's regions depended upon the availability of electricity supply to stimulate economic growth. Therefore, it is of utmost importance for this study to ensure greater supply reliability which is crucial to support huge developments taking place in Iskandar Malaysia and the O&G hubs in the coming years.

Load forecasting helps electric utility providers to make important decisions, which includes decisions on purchasing and generating electric power, load switching, and infrastructure development. The subject of load forecasting has been in existence for more than a decade for the reason of having better forecast of electricity load demand in the future. This involves an accurate prediction of both the location and geographical features of the research area as the electrical load demand changes over different periods throughout the year. Electricity demand forecasting is considered as one of the critical factors in achieving optimum economic operation level of power systems. This is agreed by (Singh and Khatoon, 2013) as the accurate load forecasting provides a great saving potential for electric utility corporations.

A wide range of methodologies exists for load forecasting. Some examples are Pattern Recognition (PR), Artificial Neural Network (ANN), Mining Default Rules Based on Rough set (MDRBR) algorithm, Structural Neural Network (SNN) (Dai and Wang, 2007), Fuzzy Method (FM) (Osman et al., 2009), Support Vector Machines (SVM) (Li et al., 2006; Lu, 2008), Cloud Model (CM) (Sachdeva and Verma, 2008), Semi Parametric Regression (SPR), Time Series Modeling (TSM), Exponential Smoothing (ES), Bayesian Statistics (BS), Time-Varying Splines Decomposition technique (TSD), Transfer Functions (TF), Gray Dynamic models (GD) and Judgment Forecasting (JF) (Chaoyun and Ran, 2007). Besides that, Holt-Winters Exponential Smoothing and Artificial Neural Networks (ANN) are known to have been developed and implemented for load forecasting method particularly for short-term load forecasting (STLF) solution (Fei and Thang, 2004).

This study is carried out to investigate the performance of electricity load demand in Malaysia specifically in Johor Bahru district. A statistical approach is proposed to analyze the macro factors that affect the electricity load demand here. This district was chosen because it has rapidly expanding and good mix of urbanization, commercial, manufacturing and residential sectors. It provides suitable environment to forecast for electricity load demand and consumption. The best possible solution is identified to be based on the least Root Mean Square Error (RMSE) that gives an absolute measure of fit, resulting in an accurate forecasting of load demand.

1.2 Problem Statement

According to the annual energy report (Commission, 2017) on electricity generation system performance, the demand for electricity generation increased by 10.67%, from 20,710MW in 2015 to 22,919MW in 2016. In term of electricity growth, macro factors such as high temperature, population growth, emerging markets and developing economies, caused a surge in electricity demand. Studies advocating the increase of electricity load demand in Johor Bahru have often pointed out it is due to the increase in urbanization, commercial, manufacturing, residential sector and extreme weather conditions in the country (Jifri et al., 2017). Based on news article (The Star, 2016) with the title "Peak Power Usage on Wednesday", the electricity consumption in Peninsular Malaysia inclined to spike from 12,906 MW on Jan 1 in 2016 to 17,788MW on April 20 in 2016 which indicated a 37.82% increase due to the hot and dry weather as a result of El Nino phenomenon. From the report, El Nino is often associated with the increased usage of electric cooling appliances such as fans and air conditioners. As a result, consumers logically have a tendency to lower the temperature settings, increase air-