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Long-term electricity forecasting: A system dynamics approach

Salman Ahmad Akhwanzada[1+], and Razman bin Mat Tahar[2]

[1,]Universiti Malaysia Pahang

[2]Universiti Malaysia Pahang

Abstract. Electricity has become an important source of energy for human development. Forecasting electricity demand plays a pivotal role in electricity planning. It provides a mechanism to have a balance between supply and demand. A system dynamics model is developed using population and per capita consumption of electricity to forecast electricity demand for coming 10 years. Malaysia is used as a case study. It is found that that by using two variables, a fairly accurate forecast can be obtained. The simulation model estimates that at the current rate of consumption and population growth there will be a need of 192.5trillionwatt-hour of electric energy in year 2021.

Keywords: **S**ystem dynamics, electricity, long-term forecasting,

1. Introduction

Electricity forecast are broadly divided in two categories: short term and long term. Short term forecast are useful in daily operations of a utility companies whereas long term forecast are needed for strategic planning. Planning in electricity sector is very challenging due to following reasons: electricity generation capacity is capital intensive, it takes long period of time in construction, and the commodity cannot be stored in large amounts. Along with this, there is high level of uncertainty involved in planning; change in demand (due to any externality) and liberalisation of electricity are among the top causes. Due to this peculiarity of the sector, it is not an exaggeration to say that demand forecasting plays a critical role in of integrated electricity planning process. Reliable forecasts alleviate any shortcoming of electricity supply and demand balance that can jeopardise socioeconomic well being of the people of a country.

The goal of this paper is develop a dynamic simulation model that can be used for forecasting electricity demand. To show to future researchers that simulations have the capability forecast fairly accurate and can be modified for policy analysis.

In section 2, system dynamics model development and structure is described. In section 3, the output of simulation model and its comparison with actual data is shown. Finally, section 4 concludes the paper.

2. The system dynamics model

System dynamics methodology was developed by Prof J W Forrester and colleagues around 1950s at MIT Sloan School of Management [1]. It is a computer-oriented approach that makes use of interrelation of variables in a complex setting. This methodology was initially developed for managerial decision making but later has been successfully applied to other areas including electricity sector, for example in [2].

+ Corresponding author. Tel.: +60169517929;
E-mail address: salman_psh@yahoo.com

According to Colye [3], “System dynamics is a method of analysing problems in which time is an important factor, and which involve the study of how system can be defended against, or made benefit from, the shocks which fall upon it from the outside world.”

Building a system dynamics model is an iterative process making use of causal and feedback relationships. These relationships are built in differential equations, parameters and variables [4]. In simple words system dynamics model consists of stocks and flows connected through auxiliaries depicting a system.

2.1. Model development

Malaysian electricity sector is used in this research. Malaysia has seen an enormous rise in electricity demand per capita. In this case the system dynamics boundary is the Malaysia electricity sector. No differentiation is made in demand for different sectors of the economy on the premise that breakdown is not required at strategic level; it is fairly simple to get sector demand based on individual sector growth.

The system dynamics model proposed in this study comprises of one stock and two flow and fours auxiliary variables. The structure of the model is shown in figure 1. The interaction of Population and per capita consumption of electricity are modelled in this study to provide total electricity demand. Figure 1 shows the logical setup of the model whereas the following equations are mathematical formulation of the model.

$$Population\ (t) = population(t - dt) + (increase\ factor - decrease\ factor) * dt \qquad (1)$$

$$perCapita\ demand = 159.73*TIME + 884 \qquad (2)$$

$$total\ electricity\ demand = per\ Capita\ demand * population \qquad (3)$$

Factors	**Definition**	**Units**
population	*Total population of Malaysia. Initial value 19,503,000.0 people in 1989 value*	*people*
birth fraction	*23.1birth per 1000 people*	*ratio*
Death fraction	*5 death per 1000 people*	*ratio*
increase factor	*= population * birth rate*	*people/year*
Decrease factor	*= population * death rate*	*people/year*
per capita demand	*= 159.73*TIME + 884* R^2 *= 0.9982 , in kilowatt-hour*	*kilowatt-hour(kWh)*

Table1. Model parameters and definitions

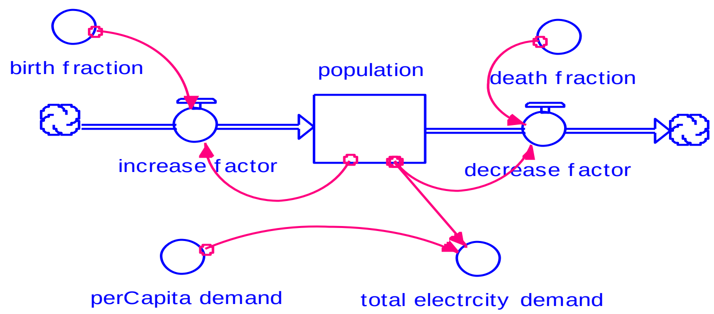

Fig. 1. The system dynamics model of electricity demand in iThink[R].

The time period considered for parameter estimation is from 1993 to 2003 for per capita demand and population. For validation purpose actual data from year 2004 to 2011 is used. It is stated that all data used in this study is from Asian Development Bank [4] and from [5].

The actual total demand and model output is shown for the time period from 1993 to 2010 is show in the figure 2

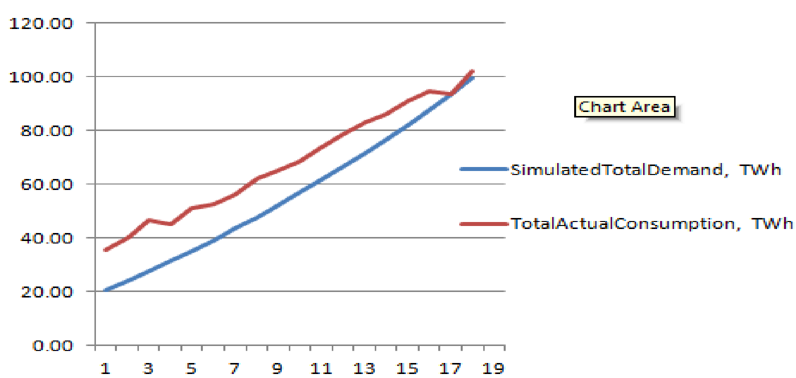

Fig.2. Actual total demand and model output demand.1on x-axis denotes year 1993

3. Model Analysis

The forecasting was done from year 2011 till 2021. To generate insights for the planners it is assumed to have 5% and 10% increase in per capita demand also. The result is show in the figure 3.

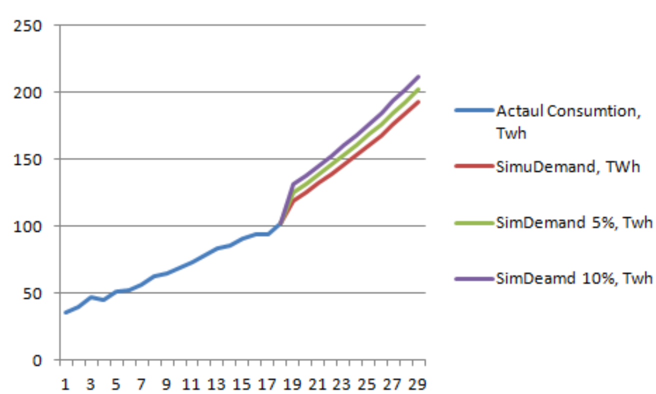

Fig.3. Forecasting from year 2011 to 2021

With base case it is estimated that by year 2021 the total electricity demand would reach to 192.5TWh whereas for 5 and 10% increase in per capita consumption the demand can be as high as 202.13TWh and 275TWh respectively.

4. Conclusion

This paper shows that system dynamics is an effective technique in forecasting long-term electricity demand. The case study using the system dynamics modeling to estimate the total electricity demand from 2011 to 2021 for Malaysia was successful. The population and per capita electricity consumption data was used in the study. The significance of study is in showing that small and simple simulation models are not inferior to their counterpart econometric models.

5. Acknowledgements

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