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Grid electricity for Fiji islands: Future supply options and assessment of demand trends

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ABSTRACT

Electricity is a secondary energy source and one of the main drivers for economic development of a nation. Long-term planning for electricity demand is essential for strategic expansion of supply options which would require significant investment in terms of human resources and capital. This paper is focused on the past trends in annual grid-electricity demand for Fiji, from which forecast is done using statistically significant linear regression models. The regression models reveal that domestic grid-electricity demand variance is explained by population, GDP and electricity price. However, for non-domestic demand, the variance is explained by changes in population and GDP with electricity tariffs playing a small role. The absolute deviation of forecasts for total demand from 5 different regression models ranges from 1.2 to 32%. For domestic demand it ranges from 3.0 to 5.0% while non-domestic deviation ranges from 1.7 to 19%. Analytic hierarchy process was employed to choose the best model for demand forecast which then led the discussion on future supply options for grid-electricity expansion in Fiji. Biomass power plants, hydro and GCPV are seen to be the most promising supply.

1. Introduction

The most obvious way to carry out a preliminary forecast for electricity needs of a nation is by studying the current demand trends. However, it should be noted that relationships which drive the current electricity demand today may change in the future. Electricity demand is determined by economic conditions, prevailing weather conditions and consumer usage patterns and it varies by second, minute, hour, week, public holiday, month and season over every year into the future planning horizon [1,2]. Forecast of electricity demand is needed for government departments and the power utility (Fiji Electricity Authority-FEA) to plan for their grid expansion and finance planning. Better policy decisions can be made once the past energy usage trends and current energy usage patterns are analyzed [3] and studied to provide rigorous analysis of the determinants of electricity demand [4].

Forecasting per se, does not guarantee a successful strategy but it provides a credible and justifiable reason to base strategies for electricity generation expansion [5]. Without a reasonable forecast, the strategies would be baseless and would most likely be ineffective. The forecasting and strategic implementations are iterative processes and knowledge is gained in the process from past experience [5]. The main steps for successful electricity demand forecast can be:

1. Defining the electricity demand.
2. Division of the total electricity demand into its main components.
3. Analysis of drivers of the electricity demand which includes GDP and population. A forecasting model for these drivers is necessary to forecast energy demand.
4. Finally, some tools can be used to gauge the models which include sensitivity analysis and retrospective projections.

In general, forecasting techniques can be classified as judgmental (made by experts), univariate (considers one explanatory variable) and multivariate (considers two or more explanatory variables) [6]. The forecasting models can be explanatory model (where the predictor variable is explained by external factors (explanatory variables) or time series model such as ARIMA,

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exponential smoothing and structural models (here prediction of future is based on past values of a variable) or a model based on combination of explanatory variables and time variables [7]. A number of researchers have used times series or explanatory models to forecast electricity demand which are discussed below.

Foley et al. [1] reviewed the different electricity system modeling techniques and discussed a number of propriety electricity system models used in the USA and Europe. Bianco et al. [8] noted two main issues for reliable forecasts; (i) there has to be sufficient and necessary information available and (ii) even though complex models provide accurate forecasts, it is difficult to manage. Authors [8–11] have used cointegration, integrated fuzzy regression algorithm and trigonometric grey prediction model to forecast electricity consumption. Other authors [12–15] have used advanced models such as Auto Regressive Integrated Moving Average (ARIMA), Seasonal ARIMA and Multiplicative Seasonal ARIMA to forecast demand of electricity.

Underlying Energy Demand Trend (UEDT) and Structural Time Series Model (STSM) are used by authors [16,17] to forecast residential electricity demand. Hyndman and Fan [2] devised a methodology to forecast the probability distribution of annual and weekly peak electricity demand for South Australia since 2007. A multiple regression model was developed to forecast monthly electricity demand from 1996 to 2003 based on weather variables, gross domestic product and population growth [18].

The aim of this paper is to study the trend and forecast of total, domestic and non-domestic grid-electricity demand in Fiji and discuss the possible options to satisfy the increasing requirements. The first section of this paper presents a brief literature review followed by discussion on the electricity utility in Fiji and methodology used. Section 4 discusses past trends of total, domestic and non-domestic demand followed by construction of linear regression models for total, domestic and non-domestic demands. These models are then used to forecast demand till 2040 in section 6. Section 7 presents validation of models which then led to choosing the best model to forecast demand using multi-criteria decision analysis. Following this is a discussion on supply options for grid electricity in future. Finally, conclusions of this study are presented.

2. Methodology

The grid-electricity demand data was collected from Fiji Bureau of Statistics (FBoS) and FEA. Total, domestic and non-domestic demand data (1976–2014) was collected from FBoS Key Statistics Books [19] while historical electricity price data was obtained from FEA. Demographic and economic data (population and GDP) were also obtained from FBoS. The trends for these data were first studied and linear regression models (univariate and multivariate) were created using SPSS at 95% confidence. The dependent variable was taken to be grid-electricity demand. The explanatory variables used were population, GDP and electricity price. The data used for analysis was from 1976 to 2010 and the data from 2011 to 2014 was used to test the validity of the models created. These regression models were then used to forecast demand till 2040. For deciding the best model for demand forecast, AHP was used.

3. Electricity utility in Fiji

Being an island nation, with two major islands and approximately 300 other outer smaller islands, connection of grid electricity to all population in Fiji is not possible. FEA, the sole electricity utility, is responsible for generation, transmission and distribution of all grid-connected electricity in Fiji. Considering grid – electricity production and sales for FEA data (2006–2012) from FBoS, there is an average of 8.6% difference between them. Fiji Department of Energy is responsible for electrification of other smaller islands and rural areas. According to last census data (2007) 75% of the population is connected to grid electricity while 14% have access to electricity based on distributed generation (solar home systems and micro hydro) [20].

FEA supplies grid electricity in Viti Levu, Vanua Levu and Ovalau as shown in Fig. 1. The main source for electricity generation is hydro power stations and diesel generators. FEA's aim is to supply electricity with as much renewable based electricity as possible [21]. In 2014, the mix of electricity generation was 45% from hydro, 51% from diesel generators and 4% from independent power producers (using biomass energy). These percentages are variable over the years. Considering generation data from 1998 to 2014 [21], hydro power electricity generation ranges from 46 to 85%. This percentage mainly depends on the rainfall and peak demand. Table 1 shows the peak demand for grid electricity, installed capacity and available capacity of generation for the 3 islands. There is no interconnection of grids between the islands. The number of customer account increased by 2.95% from December 2014 to December 2015, bringing the total number of customer account to 171939 [22]. From the total number of customers, 90% are domestic customers, with 9.6% commercial customers and only 0.06% industrial customers.

4. Trends for grid-electricity demand

4.1. Total grid-electricity demand trend

Electricity demand data from 1976 to 2014 was obtained from Fiji Bureau of Statistics and this was analyzed. The demand has been increasing with an overall 368% increase in the last 38 years (from 1976 to 2014), Fig. 2. The average annual increase in grid electricity demand is 4.3%.

An interesting key point to note is that: there are “3 steps” in the grid-electricity demand (i) prior to 1983, (ii) between 1984 and 2000 and (iii) from 2001 to date, Table 2. From 1983 to 1984, there was 24% increase in demand while from 2000 to 2001 as earlier discussed there was 25% increase. The jump in 1983–1984 was due to new 80 MW Monasavu hydro power scheme coming online while 2000 to 2001 jump was because more people were being connected to the grid and increase in economic activity despite the political unrest in 2000. A few dips in electricity demand trend were observed, 1987, 2000, 2006 and 2010. This first three dips (1987, 2000 and 2006) could be contributed to political unrest in Fiji. The 2010 dip was because the tariff charged to customers (electricity price) increased and this led to customers consuming less.

4.2. Sectorial grid-electricity demand trend

The objective of this section is to consider three main sectors (residential, commercial and industrial) for their grid electricity demands. It should be noted at this point that commercial and industrial customer definition used by FEA is [24]:

(i) Domestic – these are residential customers who pay FJD0.3310/kWh consumed. If their consumption is less than or equal to 85 kWh/month then domestic customers only pay FJD0.1720/kWh. The rest (FJD0.1590/kWh) is subsidized by government.
(ii) Commercial - these are both commercial and industrial customers whose maximum demand is less than 75 kW. The tariff charged to them is FJD0.3990/kWh for consumption up to 14999 kWh per month. If their consumption exceeds 14999 kWh/month then they pay FJD0.4180/kWh.

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