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A Goal Programming Approach to Peninsular Of Malaysia Electricity Tariff Structure

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Abstract

Tariff design is the key mechanism used to allocate electricity generation and distribution costs to customers. The designing process can be very complex not only due to the regulatory policies surrounding it but also due to the need of satisfying various parties such as the electricity distributor and the different types of electricity customers. Therefore, it is the aim of this study to formulate an optimum tariff structure for Malaysia that can deal with multiple objective functions. Utilizing secondary data gathered through various energy related sources and a goal programming approach, a new optimum tariff structure has been proposed specifically focused on domestic customers and others in general. The findings show, in the case of domestic users, having only two bands of domestic customers instead of the current practice of five, may have already helped to achieve an optimum tariff structure. The findings also show that for other types of users Malaysian current tariff structure may have yet to achieve its optimum level. While these findings are subjected to few limitations, it is notable that the findings can be used to evaluate the existing tariff structure of Malaysia.

Keywords : Goal Programming, Electricity, Tariff Structure, Optimization

I. Introduction

Malaysia has three major utilities with different electricity tariff structure[1] based on ~~the~~ geographical areas that consist of two main landmass region, that are Peninsular (Tenaga Nasional Berhad-TNB), Sabah (Sabah Electricity Sdn Bhd-SESB) & Sarawak (Sarawak Energy Bhd). For the purpose of this study, the focus is only on peninsular of Malaysia since this area covers the main and majority of the electricity consumers evidenced by dependable capacity of 22,935MW, as compared to 1,302MW (Sabah) and 3,951MW (Sarawak)[2]. The determinants of electricity pricing and tariff structure becomes the main objective of this study. An optimization goal programming approach has been utilized to arrive the optimum possible tariff that satisfying the company's target revenue. Form the past literatures, the problem has been solved using linear programming, which requires only polynomial time as well as metaheuristics programming, such as genetic algorithm and particle swarm optimization and also requires substantial computation time to solve (Tsay, Lin & Lee, 2001; Chen & Liao, 2011; Lee & Chen, 2007). As for this paper, we had formulated the problem as an objective function into goal programming which is one if not the only special linear programming that can deal with the multi-objective of real-world business decision making including optimizing electricity tariff for each of customers in general.

Electricity regulators are facing new challenges to keep the pace of the liberalization process and the revision of regulatory schemes that is taking place all over the world. The pressure is felt by regulated units of many utility companies, particularly the distribution department.

Efficiency achievement as well as compliance with legal and regulatory criteria, such as cost recovery and non-discrimination should be analyzed (Rodrı´guez Ortega & Pe´rez-Arriaga, 2008). In addition to that, there is growing policy and regulatory interest in better aligning electricity tariffs with the cost of providing network services to customers: to provide a better price signal for economically efficient use of the network, and reduce cross subsidies between different customers (Passey, Haghdadi, Bruce & MacGil, 2017).

Basically, there are 6 categories of customers in the electricity tariff structure in Malaysia, namely; Domestic, Commercial, Industrial, Mining, Street lighting and Specific Agriculture (TNB Tariff Book, 2014). The final electricity consumption (ktoe) by each of these customers from 1978 to 2015 in Malaysia can be illustrated in Fig. 1. These tariffs were gazetted under a Gazette Tariff Section 26. However, there are also other categories of electricity tariff known as Customized Tariff under Section 29 which consists of Co-gen (Gazetted tariff rate but customized billing formula), Independent Bulk Lisensee (for instance, Mid Valley, Genting Utility, Sunway Pyramid), Customised High Voltage (based on negotiation), High Voltage Commercial and Thermal Energy Storage (TES) (Commercial Unit, Customer Service Department, Distribution Division, TNB, 6 October 2017).

Fig. 1 below shows an average growth pattern of electricity consumption by sector or utility customers from 1978 to 2015 in Malaysia. Out of 5, there are only 2 types of customers showing growth pattern as represent by exponential line of industrial and commercial with the average of 8.26% and 6.71% respectively throughout the period. However, others indicate linear line with different constant value. With respect to the value of r-square, it is reported for all customers models estimation is in between 56.03% to 95.15% explains a somewhat strong relationship of the variation in electricity consumption' performance.

Fig. 2 gives a brief overview on the electricity generation in Malaysia by sources of energy (i.e; the highest by thermal usage in average growth of 8.47% with the 97% of variation of estimations is explained by electricity generation and followed by hydro (5.03% at 73.78%). However co-gen show a linear pattern which is significantly does not show any growth rates or constant growth) from 1978 until 2015.

This paper is organized as follows. The next section reviews the past studies on the electricity tariff structure and optimization as well as its impacts to the customers. Next, this paper covers the discussion of research methodology, followed by the result analysis and finally the conclusion and policy implications.

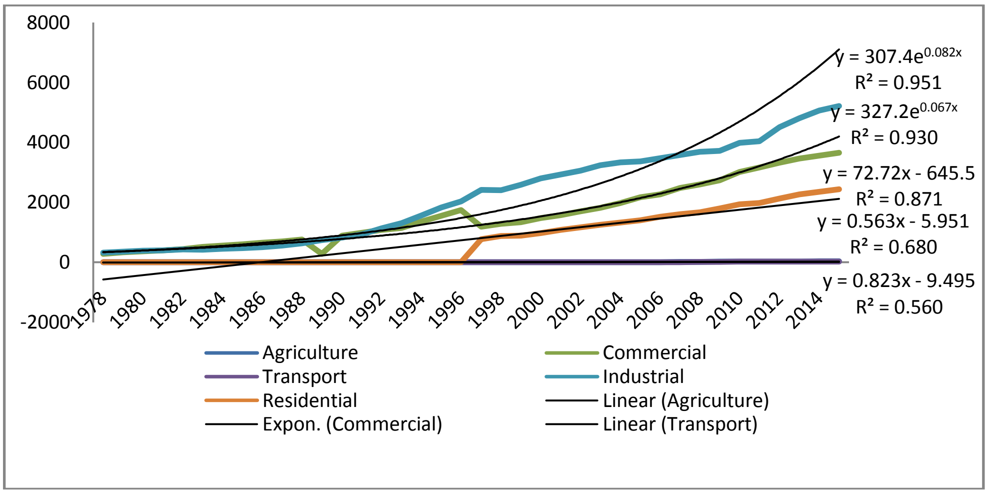

Fig.1. Final Electricity Consumption (ktoe) by Sector from 1978 to 2015 in Malaysia
Data Source: MEIH[3] (2017)

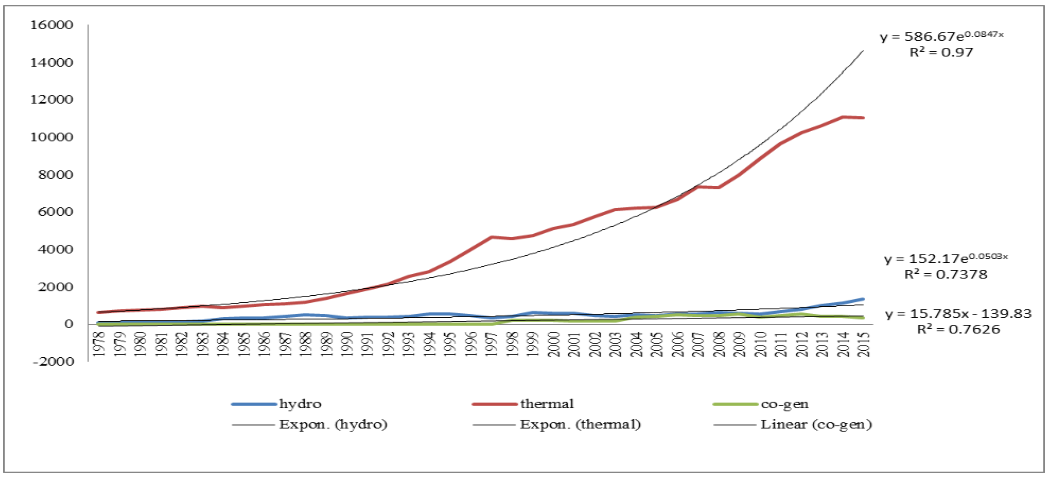

Fig. 2. Total of Electricity Generation (ktoe) from 1978 to 2015 in Malaysia
Data Source: MEIH[4] (2017)

II. Literature Reviews

The existing determinations of tariff rates are currently being derived from the allocation of cost distribution from the upstream activities such as the generation of electricity up to the distribution to retail and commercial customers. Currently, either distributed generation units are exempted from paying distribution tariffs or they are subject to tariffs originally design, according to a traditional pricing model, without distributed generation in the grids, known as load-based pricing. Partial recovery of the allowed distribution company revenue requirements or cross subsidies between customers may ensue from such tariff arrangements (Picciariello, et. al., 2015b).

An increasing amount of distributed generation can cause an increase or a decrease on distribution network costs. Li & Tolley (2009) mentioned that assessing the validity of network tariffs is complex, since different evaluation criteria might be chosen and different weights assigned to each of them based on regulatory priorities such as Incentive Based Regulation (IBR)[5] policy. Moreover, the element of subsidy based on the regulatory requirements are also need to be considered including, the changes of government policy, government services tax[6] (GST) exemption, MYR20 subsidy for eligible customers, lifeline band, cross-subsidy among consumer groups and discounts to selected customers (EC, 2017; Tariff Optimization Workshop 2.0, TNB- Uniten, 6-8th October, 2017; Tariff Optimization Workshop 3.0, TNB- Uniten, 1-3rd December, 2017; Mohd Saad, et. al, 2018). Besides the subsidy, the tariff setting is probably meant to promote the renewal energy program such as feed-in- tariff (FiT) (EPU, 2013). Moreover, the criteria to set up the electricity tariff often conflicting (Rodríguez Ortega et al., 2008). This analysis adopts cost reflectivity as main criterion for assessing the validity of distribution-network tariffs. In order to carry out an analysis of cross-subsidies, it is necessary to first define cross-subsidies and then to analyze when and why they are likely to appear. It is difficult to define cross-subsidies because it is difficult to measure them, and vice versa (Heald, 1996; Picciariello, et. al., 2015b).

In an environment of declining sales growth and rising costs, electric utilities and their stakeholders are exploring new rate designs that will better reflect costs while preventing inequitable bill increases for many customers. Residential demand charges have emerged as an attractive option. A demand charge would better align the price that customers pay with the nature of the costs that they are imposing on the system (Hledik, 2014). Later, Hledik & Greenstein (2016) further studied on the residential electricity rate structures and claimed that the rates have remained essentially unchanged for the past century. If the principle of efficient prices is prioritized, the recovery of residual costs through fixed charges would result because this would allow the variable charge (or demand charge) to be set at LRMC. In practice this approach is not followed because it is perceived to be unfair relative to current tariffs, customers with low consumption would pay more and customers with high consumption would pay less. Gradualism recognizes the fact that customers may have made investment decisions expecting current tariff structures to continue into the future. Unlike efficiency or gradualism, however, ‘‘fairness’’ is not clearly defined. In practice, regulators have to strike a careful balance, making trade-offs to reflect relevant policy considerations (Brown, Faruqui & Grausz (2015).

Rubin (2015) analyzed six types of residential rate designs shows that designing residential rates with seasonal consumption charges might make significant progress toward a more efficient rate design. Seasonal usage rates are understandable to customers, avoid many of the problems with demand-based rates, do not require significant implementation expenditures, and may avoid the extreme bill impacts of some demand-based rate options. He claimed that from a utility’s perspective, having most distribution costs collected in the peak season could create concerns with revenue stability. Any potential rate design must represent a compromise involving a series of trade-offs.

In addition to that, Nojavan, Zare & Mohammadi-Ivatloo (2017) said that an electricity retailer seeks to determine selling price for end-user consumers under fixed pricing (FP), time-of-use pricing (TOU) and real-time pricing (RTP). Furthermore, in order to provide power exchange between the retailer and the power market, bidding and offering curves should be prepared to bid and offer to the day-ahead market. Therefore, they propose a robust optimization approach (ROA) to obtain optimal bidding and offering strategies for the retailer. To achieve this, ROA is used for uncertainty modeling of power market prices in which the minimum and maximum limits of prices are considered for uncertainty modeling. Lower and upper bounds of price is consecutively subdivided into sequentially nested subintervals which allows formulating robust mixed-integer linear programming (RMIP) problem. The proposed RMIP model helps retailer to select a robust decision in the presence of market price uncertainty.

With respect to economic efficiency of such tariffs, Passey, Haghdadi, Bruce & MacGil (2017) suggested that tariff assessment method on demand charge tariff structure can be adjusted to make it significantly more cost-reflective. This method can be applied onto any tariff that includes a capacity-based component. Of course, economic efficiency is not the only criterion for designing tariffs. Fairness and gradualism are two other criteria that play heavily in the design of electricity tariffs (Brown, Faruqui & Grausz (2015).

As compared to Rubin (2015) studied on six types of residential rate, Schlereth, Stepanchuk & Skiera (2010) argued that tariff structures with fewer two-part tariffs are generally sufficient, because additional two-part tariffs only negligibly increase service providers’ profit. They also proposed a tariff optimization problem that maximizes the service providers’ profit by determining the optimal prices (fixed fees and usage prices) of the tariffs in a tariff structure, according to individual rationality and incentive compatibility constraints.

Nijhuisa, Gibescua & Cobben (2017) revealed that a peak load based network tariffs score best on the reflectivity while having an acceptable level of predictability. The switch from an energy consumption based network tariff, which is now most often applied, towards a peak load based network tariff should therefore, be considered.

III. Data and Research Methodology

This study has utilized secondary data. The data were gathered from various sources, Malaysia Energy Information Hub (MEIH) website, EC of Malaysia report 2017, TNB-Uniten workshop for 3 series in 2017 and TNB Handbook (21st November 2016 slides presentation by J.P.Morgan).

According to Mohd Saad, et. al. (2018), Tariff/Price optimization model is proposed to determine how different types of customers (i.e; Residential, Commercial, Industrial, etc) will respond to different tariff/prices for electricity. It used to determine the tariff/prices that will help the utility company to determine a fair tariff while meeting its desired objectives. The data used in tariff/price optimization includes operating costs, inventories and historical tariff/prices and sales.

According to Picciariello, et. al. (2015a), the distribution tariff design consists of two stages. First, determination of the total allowed revenue for the different distribution companies and, second is to allocate the costs to the customers of the distribution network, for instance in deciding the tariff structure.

Thus, the objective of the paper is to focus on the second stage of the process, which is to allocate the average tariff to each of customers. Since the last tariff review for Peninsular of Malaysia was in 2014[7], the data available for optimization is only one year from the period of 2015 until 2017. Fernández, et al. (2013) mentioned that as long as the methodology is useful to optimize the tariff, length of data period with even a single year data is acceptable.

Decision Variables

This study assumes that the average tariff for peninsular of Malaysia is at MYR 0.3853[8] perkWh and the estimated revenue requirement for the purpose of goal programming optimization study is MYR40 billion[9] . Next, the model for convex or minimize objective function was developed by capturing the resources constraint and was mainly focused on every life band for the domestic customers. The other types of customers' tariff were averaged out since there is a constraint to identify the tariff for each sub-category. Thus, the resources constraints for other types of customers will be ignored since the cross subsidies element might be need to be considered in order to get the optimize and fair tariff and therefore, it will be discussed in next paper. The model equation is as follows:

Let,

$tariff_i$ = tariff where is the customer category with $i \in \{1, \dots, n\}$

$surplus_i$ = tariff_surplus

Minimize

Subject to:

RRi=X1+……….+Xn

X1 = 0.218
X2 = 0.334
X3 >= X2
X4 >= X3
X5 >= X4
CR>= RR
TS = COS
AT <=TU

Where;

X1 = Tarif Domestic_200
X2 = Tarif Domestic_300
X3 = Tarif Domestic_600
X4 = Tarif Domestic_900
X5 = Tarif Domestic_High
CR = Calculated_Revenue
RR = Revenue_Requirement
TS = Tariff Surplus
COS = Cost of Services
AT= Average Tariff
TU = Tariff UpperLimit/Unbound

IV. Results and Discussions

The result of goal programming on the customer electricity tariff reported in Table 1. Generally, there are different number of bands practiced by different countries especially for domestic customers, for instances; Malaysia has 5 bands (TNB), 6 bands (SESB), 9 bands (Sarawak Energy Bhd), Thailand has 3 to 7 bands in Normal Rates, Singapore has 1 (SP Group) and the Philippines has 8 (Meralco). There are many factors to be considered for the number of bands to each of utility customers. In this study, it proposes to have only 2 bands for the domestic customers as a result from the goal programming optimization subject to the boundary constraints or resources constraints as shown in Table 1.

Table 1. Tariff Structure (2014-2017)

Customer Category	Electricity Tariff in *Peninsular	Result of Electricity Tariff Min Optimization	Percentage of increase/ decrease
Domestic Tariff *in) (average*	0.437	0.2934	-33%
Band 1 First 200 kWh :	0.218	0.218	0%
Band 2 Next 100 kWh :	0.334	0.334	0%
Band 3 Next 300 kWh :	0.516	0.334	-35%
Band 4 Next 300 kWh :	0.546	0.334	-39%
Band 5 Beyond 900 kWh :	0.571	0.334	-42%
Commercial Tariff *in) (average*	0.3789	0.44	16%
Industry Tariff*(in average)*	0.3121	0.3918	26%
Street Lighting Tariff*(in average)*	0.235	0.25	6%
Mining Tariff*(in average)*	0.2813	0.3567	27%
Specific Agriculture Tariff *(in average)*	0.359	0.3918	9%

Notes: All the tariff values are denote in unit per MYR cent/kWh.

*The Average tariff values are based on the total tariff per cent perkWh divided by total number of bands for each of the customer categories from Tariff Book as an effective on 1st January 2014.

Based on the Table 1, on average, the optimized tariff for domestic customers is suggested to be 0.2934 cent per Kwh for all 5 bands as compared to 0.4370 of that is currently are imposed on customers. Even though the average value shown above has an enormous different, (a variance of 0.1436 cent/Kwh @ decrease for 33%), however, the suggested tariffs for band 1 and 2 report a similar value of the current tariff, that are 0.2180 cent per kWh for the first 200 kWh (1-200 kWh) per month and at 0.3340 for the next 100 kWh (201-300 kWh) per month as stated in the Tariff Book for electricity tariff in Peninsular.

On the other hand, the average of other type of electricity customers currently stand lower as compare of what is being suggested from the results of convex optimization. It can be seen for instance, for commercial tariff, it is currently charged at 0.3789 cent per kWh on average which supposedly to be charged at minimum cost of 0.4400 cent per kWh. Similarly, the tariff set for industrial, street lighting, mining and specific agriculture tariff were also lower than the suggested and optimized tariff. It shows that, on average, the utility company in Peninsular of Malaysia has been considering a slightly lower tariff for their customers (6% to 28%). All in all, this study suggests the utility operator to be allowed to increase the tariff to other types of customers, and at the same time to reduce the domestic tariff. This formulation is seen to be optimum under the convex optimization exercise, after considering all the cost of services while maintaining the desired revenue requirement.

V. Conclusion and Policy Implications

The main objective of this study is to formulate an optimum tariff structure using a goal programming approach that can deal with the multiple objectives of real world business decision making process including optimizing electricity tariff for different types of electricity users. The findings show, particularly in the case of domestic users, having only two bands of domestic users may have been sufficient to achieve an optimum tariff structure. While current tariff structure utilizes five different rates for five different types of domestic users, the optimization model only generate two different rates for domestic users leading to the possibility of relooking the numbers of domestic bands that Malaysia have. Additionally, the findings also show the existing tariff rate for other types of electricity users namely commercial, industry, street lighting, mining and specific agriculture may have yet to achieve its optimum level as the optimization model produce slightly higher rates.

The findings, however, are to be interpreted with caution due to several limitations. It is notable that the analysis is conducted with a much greater focus on domestic users as compared to other types of users. These indicate that several assumptions related to other types of users may have not been considered in the generation of the optimization model. Furthermore, due to confidentiality of the information, this study utilizes calculated average data that may have imposed some variance to the actual data. It is proposed that future study should provide a more comprehensive optimization model utilizing a much more updated and accurate data. Nonetheless, it is important to highlight that the generation of this optimum model has provided an avenue for related parties to relook and evaluate the current structure of Malaysian Peninsular electricity tariff.

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