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Electricity Tariff Structure Optimization

N. Mohd Saad[1*] and Z. Abdullah[2]
[1,2]College of Business Management & Accounting, Universiti Tenaga Nasional, Kampus Sultan Hj Ahmad Shah, 26700 Muadzam Shah, Pahang
[*]E-mail: noriza@uniten.edu.my

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Abstract

The design of electricity tariff can be very complex not only due to the regulatory policies factors but also the concern of satisfying various parties such as the utility firms and their respective customers. This paper addresses the optimized electricity tariff structure based on the 2014 electricity tariff structure in Peninsular of Malaysia by considering the customer and demand growth factors in next year forecast. Two optimization procedures are proposed namely, hybrid of goal programming and stochastic optimization and ILOG optimization system. In both estimation models, scenario-based influenced the current and forecast sale which mainly reflected by the tariff setting for each of the electricity customers including domestic, industrial, commercial, specific agriculture, mining as well as street lighting. In overall, firstly, both optimization methodology approaches reveal the similar result with respect to the lifeline bands of tariff especially by ILOG produce on average value for each of the customer category that useful for further analysis. Secondly, the small changes in demand growth and customer growth across the scenarios insignificantly change in the tariff structure among electricity customer except for domestic.

Keywords: *Electricity Tariff; Optimization; Stochastic; ILOG; Malaysia.*

1. Introduction

In Malaysia, the electricity tariff schedule for Peninsular has been effective since 1st January 2014, where the tariff has been reviewed for every three years and the last revised tariff is in January 2014 until December 2017. On 1st January 2018, the Ministry of Energy, Green Technology and Water (KeTTHA), Putrajaya on 26 December 2017 released news on electricity tariff review in Peninsular, Sabah and Federal territory of Labuan effective. According to the media release, the cabinet meeting on 13 December 2017 had decided to maintain current electricity tariff rates in the Peninsular effective 1st January 2018 to 31st December 2020. Therefore, the news about to maintain the tariff schedule is clearly demonstrating the concern of the Malaysian government's unwavering efforts to reduce at least a partial of cost of living among its citizen. Thus, with this decision the consumers in Peninsular will not experience any changes in electricity charges from the gazette period, if they consume the same amount of electricity as previously (KeTTHA, 2017). However, Malaysia has a general election on 9 May 2018 that changes the political scenario whereby new government was given a mandated. Then, up to this paper was studied there are no other new policies and regulatory on the electricity tariff structure was announced to regulate by Energy Commission or utility company.

Based on these scenario and circumstances, we can say that the Malaysian electricity market is highly regulated. The electricity tariffs for the different consumer groups are distributed by the Tenaga Nasional Berhad (TNB), which are based on a base tariff rate as stipulated by the regulatory agency, the Malaysian EC (Mohd Saad et al., 2018a). Accordingly, 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 (Mohd Saad et al., 2018b).

Thus, a formal mechanism to distribute the provided base tariff too efficiently and equitably as well as justifiable to the consumer groups is needed. With that, the objective of the study is to design a fair electricity

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tariff framework and schedule for the different consumer groups by considering the inputs from single buyer, system operator, transmission, distribution and customer service from two different optimization techniques between goal and stochastic programming and ILOG optimization to show is there any discrepancy in the electricity tariff structure. Does optimized electricity tariff structure using ILOG Optimization System is more efficient than Goal Programming & Stochastic Optimization Approach? More efficient here means provide an ideal tariff for both perspectives, utility industry and electricity customers that can capture the cost of service (COS) as well as meet the targeted revenue requirement (RR).

The reminder of paper is structured as follows. Section 2 analyses the past studies related to the tariff design and its impact on optimization towards utility customers. Next, in section 3 presents the proposed model; goal and stochastic optimization, ILOG optimization system, resource constraints and sensitivity analysis based on different scenarios. In the following section, section 4 deliberates the results. Lastly, section 5 accomplishes the paper and highlights the policy implications.

2. Literature Review

Redesigning the tariff structure may improve electricity distribution efficiency and providing better service at better prices. The exercise can increase the public utilities' revenue from different categories of consumers where it is currently under recovered. Nevertheless, in the short-run, the tariff reform is expected to reduce the overall revenue inflow as the current structure allows the cross- subsidy practice. Then, the design of electricity tariff structure should be exposing to the customer in order to show the transparency of tariff reform and its cost efficiency (Piarapakaran, 2016; Ifrim, O'Sullivan & Simonis, 2014; Somma, Yan, Bianco, Luh, Graditi, Mongibello & Naso, 2016; Somma, et al, 2016). With respect to the methodology used in setting the optimized tariff structure, most of the study considered the cost of service approach (Somma, et al, 2016; Ahluwalia & Bhatiani, 2000), Performance Based Ratemaking (PBR) (Somma, et al, 2016; Ahluwalia & Bhatiani, 2000) and revenue requirement basis or Revenue Cap/Price Cap approach (Eskom, 2017); Ahluwalia & Bhatiani, 2000). These data then was plugging in into the several methodology techniques such as goal programming and stochastic optimization and/or ILOG optimization system.

Supported by Eskom (2017), tariff structural changes are performed on a revenue-neutral basis; that is, the total all the changes to the tariff charges multiplied by their component volumes must equal the revenue requirement. The tariff structural changes, however, could impact the average price for individual tariffs or individual customers within a tariff structure. It is not possible to make changes to tariffs without impacting some customers negatively or others positively. Tariffs are the formulae used for the recovery of a utility's revenue combining volume (kWh, number of customers, kVA etc.) and rates (c/kWh, R/customer. R/kVA) for each tariff and customer category, and consequently need to be structured to recover the revenue sufficiently, in terms of the level of the rates and in the combination of different charging bounds that will recover the revenue.

Revenue requirement or targeted revenue is important element in tariff structure setting. According to Wang & Lee (2014) and Tower (1977) who found that the association between electricity tariff and revenue among distribution firms can be identify in three ways; (1) the optimum-welfare tariff is higher than the maximum-revenue tariff when the upstream firm adopts uniform input pricing and if the number of foreign competitors is sufficiently large. 2) the maximum-revenue tariff is greater than the optimum-welfare tariff when domestic upstream monopolist discriminate the input pricing, and (3) the optimum-welfare tariff will exceed the maximum-revenue tariff if the sizes of domestic and foreign firms become more unevenly distributed when foreign upstream monopolist discriminate the input pricing.

Therefore, the designing of electricity tariff is different based on regulatory policy, cost of service and might probably the customer category. However, in general, Ramachandra (2015) highlights several issues need to be addressed in designing tariff principles. It should considered the establishing the financial capability of the utilities that is essential to attract investments (both private & public), to protect the interest of the consumers, encouraging efficiency in the sector, compliant with legislation, recognition by stakeholders, regulatory commitment, adapting the government's need to pursue social economy objectives such as subsidies and harmonising between the need to increase prices to cost reflective levels as well as efficiency improvements that regulators may bring about to reduce the prices and risk perception of the prospective investors.

By utilizing the electricity tariff structure optimization without considering the scenarios analysis, Mohd Saad, et al. (2018c) revealed that, there are 14 lifeline bands achieved an optimum tariff structure mainly from industrial, mining and streetlight customers. However, utility firms still have options to optimize the tariff for domestic, commercial and agriculture customers since the findings also showed that the current tariff structure may have yet to achieve its optimum level. While these findings are subjected to minimize the cost of service (COS) as an objective function by maximizing the given revenue targeted. In the study, they proposed that domestic, commercial and industrial to have only 3, 4 and 3 lifeline bands instead of 5, 5 and 7 lifeline bands respectively. With respect to the other type of customers, it was proposed to have only 1 lifeline band respectively.

3. Methodology

This study considered to use similar data and resources constraint for approaches, goal programming and stochastic optimization and ILOG optimization system to make the fair comparable of the results in setting the electricity tariff structure. The similar weight-age and growth rate are also applied.

Data Collection

This study has utilized secondary data. The data were gathered from various sources, Malaysia Energy Information Hub (MEIH) website, and Energy Commission of Malaysia report 2017, TNB-Uniten workshop for 3 series in 2017 and TNB Handbook (21st November 2016 slides presentation by J.P. Morgan) as well as TNB Tariff Book. The objective of this study is to allocate the average tariff to each of utility customers at optimized level based on two scenarios analysis, demand growth and customer growth. This study assumed that the growth rate for the demand scenario 1, 2, and 3 is at 0.8 percent, 1.5 percent and 2 percent respectively with similar revenue growth rate for the subsequent year, which is at 5 percent. With respect to the customer growth, it was considered at 1 percent level for all the scenarios. Since the last tariff review for Peninsular of Malaysia was in 2014, 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. This is also supported by Reneses et al. (2011), they presented a case study in which tariffs are computed with the actual data of the Libyan system in only one year for 2006.

Thus, to achieve the objective of the study, the cost of services is become an objective function to be minimizing using stochastic optimization. In this method, combining both meanings of stochastic optimization can generalize deterministic methods for deterministic problems. These deterministic variables also be together with non-deterministic variables as resources constraints to produce an optimize tariff outcome for each of the scenarios analysis.

Decision Variables and Objective Function

In peninsular of Malaysia, 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). Under these 6 categories of customers, there are a total of 29 lifeline bands derived from 5 for domestic, commercial and specific agriculture respectively and 7 for industrial, 4 for mining and 3 for street lighting. Therefore, this study assumes that the average tariff for all these customers in Peninsular of Malaysia is at MYR 0.3853 per kWh and the estimated revenue requirement for the purpose of these robust programming consists of stochastic optimization study is MYR40billion for the current year and MYR42billion for the next year.

Next, the model for convex or minimize objective function was developed by capturing the resources constraint either for deterministic and non-deterministic integer value(s) are applied as previous studies. But, the extension model for developed to capture the scenarios analysis which is important for the utility firms to make a predictions and forecast targeted revenue where necessary. This element is very important be identify in the model to allow the robustness of the system in capturing the tariff setting with the inbound and outbound limited. Besides that, the model also allow for the slack variables and penalties for 1000.

Under uncertainty conditions, the proposed strategies (named smart) outperform other theoretical benchmarks, such as deterministic, flexible and inflexible approaches. The two-stage stochastic optimization model increases the robustness of the energy bids by incorporating the uncertainty of flexible in the optimization process. This reduces the net cost of the aggregator, namely the regulation costs. The smart strategy places lower quantities of demand and supply bids than the deterministic strategy almost all days. This behaviour is due to two reasons: (i) The stochastic nature of the optimization model adopted by the smart strategy, which in-corporates the uncertainty of the net consumption through multiple scenarios, and (ii) The imbalance cost term in the objective function, which values the uncertainty of the net consumption (Iria, Soares & Matos, 2018). Thus, the research framework for this study is as follows:

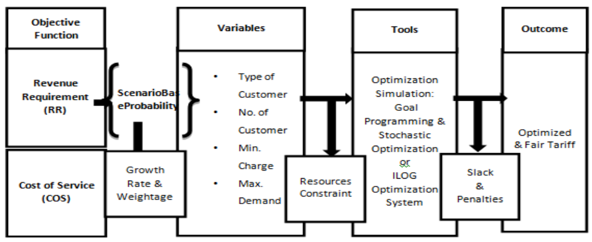

Figure 1: The Research Framework on Scenarios Based Weight age and Probability of Growth Rate

In this research framework model illustrated by Fig. 1, the goal programming and stochastic optimization approach was utilized to achieve an optimized and fair tariff structure for the utility customers. In terms of objective function, these models allowed two objectives Functions at one time. In this case there are representing by Revenue Requirement (RR) and Cost of Service (COS). The slack and penalties are introduced in this model to minimize the deviation limit from the objective function. Here, the slack represent a variable that is added to an inequality constraint to transform it into equality. While, the penalty method replaces a constrained optimization problem by a series of unconstrained problems whose solutions ideally converge to the solution of the original constrained problem. The unconstrained problems are formed by adding a term, called a penalty function, to the objective function that consists of a penalty parameter multiplied by a measure of violation of

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the constraints. The measure of violation is nonzero when the constraints are violated and is zero in the region where constraints are not violated. The scenario analysis capture the demand and customer growth rate based on different rate of probability and weightage. In addition, this model can also be used to forecast the following years' tariff structure based on the revenue requirement growth.

Therefore, the development of the model equation for the goal programming and stochastic optimization is as follows:

Let Y = tariff where is the customer category

Minimize subject to:

$$Y_{it} = \alpha_i + \sum_{j=1_j^{6\beta}} .X^{j6}_{i=1....29,t=1} + \sum_{i}^{29} + \beta_{i=1...29}X^{i}_{i=1...29,t} + \cap Dd\ Growth, Customer\ Growth\ x\ weightage$$
$$+ \cup\_itCharges + \sum\_it\text{^}5RR + \varepsilon\_it$$

Where;

$\forall Y_{it}$= Scenario; $1 \ldots\ldots\ldots n$,

n=3.

With deterministic resources constraints on:

X_1 =0.218

RR=MYR40billons

Penalties =1000

And, non- deterministic resources constraints for:

$X_2 >= X_2$

$X_3 >= X_2$

$X_4 >= X_3$

$X_5 >= X_4$

$CR >= RR$

$TS = COS$

$AT <= TU$

Deviation PCT<=Deviation Limit

$COS\_Eq = COS$

Where;

$X_1 \ldots\ldots X_n$ = Lifeline bands for each of j=6

CR = Calculated_Revenue

RR = Revenue_Requirement

TS = Tariff Surplus

COS = Cost of Services

AT= Average Tariff

TU = Tariff Upper Limit/Unbound

PCT = Percent

Eq = Equation

4. Empirical Results And Discussion

Fig. 2 shows the pattern of the tariff structure for each of the scenarios. It indicates similar pattern with the current optimized tariff. However, by considering the demand and customer growth rate in the scenario 1,2 and 3, the value of R squared significantly increased from 7.24 percent to 8.39 percent and 9.2 percent respectively. Meaning that, the demand and customer growth was around 7 to 9 percent explained the variations in the tariff structure changes. Besides, the line of growth pattern also response with linear line to this entire scenarios pattern which seem reacted not much different. Nonetheless, from Fig. 3, it can be seen that the exponential line growth has been patterned the scenario analysis, however, at very small percentage between 0.1 percent to 1.2 percent changes. This pattern can't be analyzed in further detail since it just gives an overall picture on the influenced of the demand and customer growth towards optimized tariff structure. The detail of the results is tabulated in Table 1.

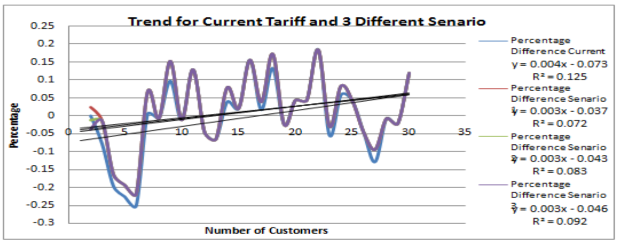

Figure 2.The Trend for Current Tariff and 3 Different Scenarios based on Demand and Customer Growth

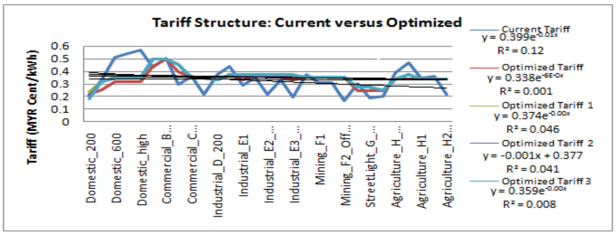

Figure 3.Current versus Optimized Tariff Structure

The result of goal programming & stochastic optimization and ILOG optimization to the customer electricity tariff reported in Table 1. Based on the Table 1, the domestic customer_200 kWh usages shown a similar result of optimized tariff with current which is at MYR0.218 per kWh. However, if the demand and customer growth are increased at 0.8 percent and 1 percent as shown in scenario 1 respectively, then the optimized tariff become MYR0.242 per kWh at percentage difference of 2.41. Even though, the demand growth increases to 1.5 and 2 percent and maintain for customer growth in scenario 2 and 3 respectively, the optimized tariff decreases at 1.23 to 3.80 percent respectively. The result also postulated that, for the other range of lifeline bands in domestic customers, in overall, there are no percentages in different among these scenarios.

With respect to the commercial customers, the scenarios analysis show that there are only 3 lifeline bands were optimized as compare to the 4 lifeline bands for the current optimized tariff relative to the actual are 5 lifeline bands. In overall, the commercial customers shows that 3 out of 5 lifeline bands of tariff is not fully optimized or charged at lower rate, for instance; Commercial_B_200, Commercial_C1 and

Commercial_C2_offpeak. Then, with regards to the industrial customer tariff structure, the first 2 lifeline bands shows that the value for optimized tariff is lower than the current tariff. The percentage also indicate similar trend to all these 3 scenarios much probably the growth of customer is too little which resulted in no changes in tariff structure optimization.

Next, analyzing on the mining customers tariff structure, it shows that the optimized current tariff just indicated 1 lifeline band as compared to 4 levels that are currently setting. Based on the stochastic optimization result by considering all the 3 scenarios, the lifeline bands indicate similar results and fixed at only 1 level. Inversely shown by streetlight and specific agriculture customers whereby both were revealed that the optimized tariff for stochastic based scenarios is only 2 lifeline bands as compared to only 1 lifeline bands for the optimized current tariff structure. Implying that, the smaller percentage or small changes in growth rate either in demand and number of customers doesn't give a big impact to the electricity tariff structure in Peninsular of Malaysia with subject to this 2 resource constraints.

Table 1: Electricity Tariff Structure Optimization

Customer Category	Current Period (2014-2017)		Next Regulatory Period (Expected to be in year 2022 onwards)			
	* No changes in Tariff for 2018-2021)		Scenario 1 (Dd Growth at 0.8% & Customer Growth at 1%)	Scenario 2 (Dd Growth at 1.5% & Customer Growth at 1%)	Scenario 3 (Dd Growth at 2.0% & Customer Growth at 1%)	
		Goal & Stochastic				**ILOG**
	Current Tariff	*Optimized Tariff*	*Optimized Tariff 1*	*Optimized Tariff 2*	*Optimized Tariff 3*	*Optimized Tariff*
Domestic_200	0.218	0.218	0.242	0.206	0.180	Similar Results
Domestic_300	0.334	0.256	0.320	0.320	0.320	
Domestic_600	0.516	0.320	0.352	0.352	0.352	
Domestic_900	0.546	0.320	0.352	0.352	0.352	
Domestic_high	0.571	0.320	0.352	0.352	0.352	
Average	-	-	-	-	-	**0.320**
Commercial_B_200	0.435	0.440	0.502	0.502	0.502	Similar Results
Commercial_B_high	0.509	0.502	0.502	0.502	0.502	
Commercial_C1	0.303	0.400	0.456	0.456	0.456	
Commercial_C2_Peak	0.365	0.353	0.353	0.353	0.353	
Commercial_C2_OffPeak	0.224	0.353	0.353	0.353	0.353	
Average	-	-	-	-	-	**0.471**
Industrial_D_200	0.38	0.335	0.335	0.335	0.335	Similar Results
Industrial_D_high	0.441	0.375	0.375	0.375	0.375	
Industrial_E1	0.296	0.335	0.375	0.375	0.375	
Industrial_E2_Peak	0.355	0.375	0.375	0.375	0.375	
Industrial_E2_OffPeak	0.219	0.375	0.375	0.375	0.375	
Industrial_E3_Peak	0.337	0.354	0.375	0.375	0.375	
Industrial_E3_OffPeak	0.202	0.335	0.375	0.375	0.375	
Average	-	-	-	-	-	**0.356**
Mining_F	0.381	0.357	0.357	0.357	0.357	Similar Results
Mining_F1	0.313	0.357	0.357	0.357	0.357	
Mining_F2_Peak	0.313	0.357	0.357	0.357	0.357	
Mining_F2_OffPeak	0.172	0.357	0.357	0.357	0.357	
Average	-	-	-	-	-	**0.357**
StreetLight_G_Maint	0.305	0.250	0.275	0.275	0.275	Similar Results
StreetLight_G_NoMaint	0.192	0.250	0.275	0.275	0.275	
StreetLight_G1	0.208	0.250	0.250	0.250	0.250	
Average	-	-	-	-	-	**0.250**
Agriculture_H_200	0.39	0.343	0.343	0.343	0.343	Similar Results
Agriculture_H_high	0.472	0.343	0.378	0.378	0.378	
Agriculture_H1	0.351	0.343	0.343	0.343	0.343	
Agriculture_H2_Peak	0.365	0.343	0.343	0.343	0.343	
Agriculture_H2_OffPeak	0.224	0.343	0.343	0.343	0.343	
Average	-	-	-	-	-	**0.343**

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

5. Conclusion

Goal programming and stochastic as well as ILOG produces an efficient and fair electricity tariff setting by revealing the similar results even though ILOG is more powerful software operate by instructed command. Both simulation framework approach are able to deal with the multiple objectives of real world business decision making process including optimizing electricity tariff for different types of electricity customer efficiently, whereby it can captures all 16 lifeline bands covers for 6 types of users. Moreover, ILOG optimization system can produce the average tariff for each of the customers that easily to compare with the COS.

Preliminary findings of the framework show the existing average tariff rate for different types of electricity users may have yet to achieve its optimum level as the optimization model produce slightly higher rates than current tariff. In addition to that, the small changes in demand growth and customer growth across the scenarios don't significantly change in the electricity tariff structure. This implying that, the electricity tariff structure should not be revised regularly or yearly and might be consistent with currently practice by utility firm and regulatory in Malaysia whereby they revised the electricity tariff for every three years is considered safe but not yet optimized. This is consistent with the result revealed by this study whereby the current tariff and next year tariff in the optimizing model doesn't change much and some of the lifeline bands are just to remain. According the studied scenarios also postulated that there is not much impact to the customers except for domestic, however it still charges at the reasonable tariff setting by conveying the COS element.

Overall, the analyses provide a scientific justification on number of lifeline bands that can be allocated for each type of customers in order to optimize the tariff structure at the targeted revenue requirement. The analyses also provide a basis for a utility provider to further revise the tariff structure and ensure a fair tariff distribution between different types of customers. Thus, it is important to highlight that the generation of this optimum tariff setting simulation framework will provide avenue for TNB and related parties to relook and evaluate the current structure of Malaysian electricity tariff.

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