OPTIMIZING ELECTRICITY TARIFF STRUCTURE USING ROBUST APPROACH OF GOAL PROGRAMMING AND STOCHASTIC OPTIMIZATION

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ABSTRACT: *Electricity tariff structure is one if not the only key mechanism used to allocate electricity generation and distribution costs to customers. The setting 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 customers. By considering these resources constraint factors, the objective of this study is to optimize electricity tariff structure for Peninsular of Malaysia by using a robust approach that embedded both methods of programming, namely goal and stochastic. Secondary data were utilized for the period of 2014 (last tariff revised for the next three years' period which is up to 2017). In overall, the findings 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 show that the current tariff structure may have yet to achieve their optimum level. These findings are subjected to minimize the cost of service (COS) as an objective function by maximizing the given revenue targeted. As for recommendations, it is proposed that the domestic, commercial and industrial 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 is proposed that only 1 lifeline band is applicable.*

Keywords: Electricity; Tariff Structure; Optimization; Robust

1. INTRODUCTION

The Ministry of Energy, Green Technology and Water (KeTTHA), Putrajaya on 26 December 2017 was released news on electricity tariff review in Peninsular, Sabah and Federal Territory of Labuan effective on 1st January 2018. 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. This electricity tariff schedule has been effective since 1st January 2014. The tariff was reviewed for every three years in Malaysia which means that the last revised tariff is in January 2014 until December 2017. Thus, 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 part of the cost of living among its citizen. Therefore, with this decision the consumers in Peninsular will not experience any changes in electricity charges from the gazetted period, if they consume the same amount of electricity as previously [1].

Even though currently there are no changes in the electricity tariff structure, however, the fluctuation in electricity consumption and market demand will require a revised tariff in the future. Therefore, the outcome of this study will provide a practical output to utility firms particularly for the next revised tariff, which is expected to be in the year 2021 or for any projection period as required. The simulation framework will provide an efficient and fair electricity tariff setting for all types of utility customers. These include domestic, industrial, commercial, agriculture, mining and street lighting [2]. This framework consists of the following components to be aligned with the method used, goal programming and stochastic optimization as follows:

- Tariff setting objective function, either to minimize the cost or to maximize the profit
- Alternative cost of service (COS) measure
- Deterministic and non-deterministic resources constraints
- Robust rate designed based on probability and weight
- Different scenario applied/seasonality factor/decision tree effects
- Sensitivity Analysis i.e. cross-subsidy detection
- Optimize and fair tariff based on the revenue requirement given.

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 utility customers. Next, this paper covers the discussion of research methodology, followed by the result analysis and finally the conclusion and recommendations.

2. LITERATURE REVIEWS

Tariffs and tariff structures have been changing over a period of time all over the world [3]. 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 [4]. 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 [5].

According to Yang, Chen, Wei & Chen [6], electricity is an important channel between original energy and energy consumers. Electricity price or tariff is a critical factor for the interests of all those involved in the electric power market. It also plays an important role in the sustainable development of energy and environment. Thus, the electricity tariff needs to be primarily based on an acceptable measure of costs [7]. The setting of electricity prices is different based on the energy mix for the liberalization or open market and regulated market.

Keppo & Rasanen [8] analyzed the problem of pricing of electricity tariffs in the open markets when both the customers' electricity consumption and the market price are stochastic processes. Specifically, they focused on regular tariff contracts which do not have explicit amounts of consumption units defined in the contracts. The results show that the more there is uncertainty about the customer's consumption, the higher the fixed charge of the tariff contract should be. Since the consumption uncertainties enter into the tariff prices, the analysis indicates that the deterministic standard load curves do not provide efficient methods for evaluating the customers' consumption in competitive markets.

Oprea, Bara, Cebec & Tor [9] in their study proposed a method to determine the optimum capacity of a storage device that significantly contributes to peak shaving of electricity consumption for residential consumers. The optimum capacity of the storage device is based on the solution of two minimization problems: i) payment minimization and ii) consumption peak minimization. Aside from the time-differentiated profit opportunities, there are several additional benefits of storing power and regenerating it during peak hours when the system is deficient. The most significant impact is through the reduction in the need for peak generation from high marginal cost plants having large fuel costs, such as natural gas facilities, which result in higher average electricity rates for the end user. Fuel cost reductions occur as a result of load leveling, namely using storage during off peak hours to offset a portion of the generation requirements during peak hours (Pedram Mokrian & Moff Stephen, u.d).

Thus, 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) [10, 11].

3. DATA & RESEARCH METHODOLOGY

Tariff is calculated on the basis of capacity charge (fixed cost) and energy charge (variable cost). The various components of capacity charge on which the tariff depends are returned on equity, interest on the capital loan, depreciation, interest on working capital, operation & maintenance cost, cost of secondary oil. The components of energy charge are primary fuel costs, secondary fuel oil consumption and auxiliary energy consumption. Then, all these cost components embedded into the base tariff plus the Imbalance cost pass-through (ICPT) which reflect the cost of services (COS).

In this study, the COS is become an objective function to be minimized using goal programming and 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 as shown in Figure 1.

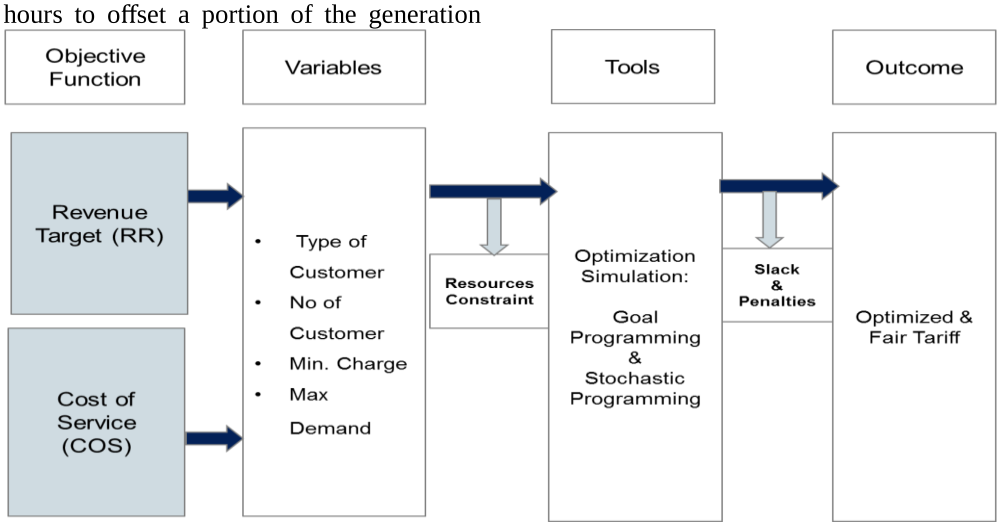

Figure 1: The Research Framework

Decision Variables

Basically, there are 6 categories of customers in the electricity tariff structure in Malaysia, namely; Domestic, Commercial, Industrial, Mining, Street lighting and Specific Agriculture [2]. 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 goal and stochastic optimization study is MYR40billion.

Next, the model for convex or minimize objective function was developed by capturing the resources constraint either for a deterministic and non-deterministic integer value(s). This element is very important to be identified 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 allows for the slack variables and penalties for 1000. The model equation is as follows:

Let, Y = tariff where is the customer category

Minimize subject to:

$$Y_{it} = \alpha_i + \sum_{j=1}^{6} \beta_j X_{i=1\ldots29,t=1}^{j6} + \sum_{i}^{29} \beta_{i=1\ldots29} X_{i=1\ldots29,t=1}^{i} + \cap Dd + \cup_{it} Charges + \sum_{it}^{5} RR + \varepsilon_{it}$$

With deterministic resources constraints on:

X1 = 0.218

RR= MYR40billons

And, non- deterministic resources constraints for:

X2 >= X2

X3 >= X2

X4 >= X3

X5 >= X4

CR>= RR

TS = COS

AT <=TU

DeviationPCT<=DeviationLimit

COS_Eq = COS

Where;

X1…..Xn = 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 UpperLimit/Unbound

PCT = Percent

Eq = Equation

4. RESULTS & DISCUSSION

The result of goal programming on the customer electricity tariff reported in Table 1. From the given COS value, the targeted RR for MYR 40billion can be achieved up to MYR39,999,999,984.11 by considering the slack and penalties in the robust system. Means, the goal and stochastic programming indicate that only -MYR15.89 in the overall objective function and this value is closed to fully optimize for the current year.

Based on Table 1, on average, the first lifeline band for domestic customers as represented by Domestic_200 is a deterministic value, thus the result was shown no changes for the optimized tariff. The value for this tariff level is maintained in their structure for a MYR0.218 /kWh energy consumption due to the special rate offered by utility firms as the chart on what was mandated by the energy regulatory bodies.

However, next lifeline tariff shows that the value is increasing to MYR0.334 which indicates higher than the optimized value at MYR0.256 significant difference. As for the next 3 lifeline bands tariff, the optimized tariff only captured at MYR0.32 with a difference at 38 percent to 44 percent. Suggesting that, there have chances for the utility firms or electricity regulatory bodies involved to charge at minimizing level this group of domestic customers, much probably at the optimized rate for MYR0.320 perkWh.

Table 1: Current and Optimized Tariff Structure based on Customer Categories (2014-2017)

Customer Category	Optimized Tariff	Current Tariff (Effective as at 1st January 2014)	Difference RM	Difference %
Domestic_200	0.218	0.218	-	0%
Domestic_300	0.256	0.334	(0.078)	-23%
Domestic_600	0.320	0.516	(0.196)	-38%
Domestic_900	0.320	0.546	(0.226)	-41%
Domestic_high	0.320	0.571	(0.251)	-44%
Commercial_B_200	0.440	0.435	0.005	1%
Commercial_B_high	0.502	0.509	(0.007)	-1%
Commercial_C1	0.400	0.303	0.097	32%
Commercial_C2_Peak	0.353	0.365	(0.012)	-3%
Commercial_C2_OffPeak	0.353	0.224	0.129	58%
Industrial_D_200	0.335	0.38	(0.045)	-12%
Industrial_D_high	0.375	0.441	(0.066)	-15%
Industrial_E1	0.335	0.296	0.039	13%
Industrial_E2_Peak	0.375	0.355	0.020	6%
Industrial_E2_OffPeak	0.375	0.219	0.156	71%
Industrial_E3_Peak	0.354	0.337	0.017	5%
Industrial_E3_OffPeak	0.335	0.202	0.133	66%
Mining_F	0.357	0.381	(0.024)	-6%
Mining_F1	0.357	0.313	0.044	14%
Mining_F2_Peak	0.357	0.313	0.044	14%
Mining_F2_OffPeak	0.357	0.172	0.185	107%
StreetLight_G_Maint	0.250	0.305	(0.055)	-18%
StreetLight_G_NoMaint	0.250	0.192	0.058	30%
StreetLight_G1	0.250	0.208	0.042	20%
Agriculture_H_200	0.343	0.39	(0.047)	-12%
Agriculture_H_high	0.343	0.472	(0.129)	-27%
Agriculture_H1	0.343	0.351	(0.008)	-2%
Agriculture_H2_Peak	0.343	0.365	(0.022)	-6%
Agriculture_H2_OffPeak	0.343	0.224	0.119	53%

Notes: All the tariff values are denoted in unit per MYR cent/kWh.
**The current tariff values for each of the customer categories are based on TNB Tariff Book effective on 1st January 2014.*

As regards to the commercial customers, out of 5 lifeline bands, the result shows that there are 2 tariffs as represented by Commercial_B_high and Commercial_C2_peak have a small difference which is at the variance of 0.007 to 0.012 per kWh or percentage decrease nearly at an optimized level from 1 percent to 3 percent respectively. This result is significantly different with the increase at enormous value from 1 percent to 58 percent. It was justified that the utility firms still make lower electricity tariff charges as compared with the proposed optimized tariff.

Next, as for the industrial customers, there are 2 lifeline bands as represented by the first 2 of the tariffs shown below than optimized level (that is in between 12 percent to 15 percent). However, the other next 5 lifeline bands were shown inverse result; means the current tariff charges is below than the optimized tariff from 5 percent to 71 percent.

With respect to the mining and street lighting customers which have 4 and 3 lifeline bands in their tariff structure respectively indicate similar result pattern whereby there are only first lifeline tariff have a decrease value at 6 percent and 18 percent respectively. From the result, mining_F2_offpeak had shown an increase in optimization result up to 107 percent. This dramatically changes might be influenced by the non-deterministic factors such as too small in a number of this customer and electricity demand for consumptions belongs to this range.

Contradicted results are shown for special agriculture customers whereby only last lifeline band as represented by H2_offpeak have yet be optimized. This can be seen from the current tariff is at MYR0.224 compared with optimized tariff proposed at MYR0.343 with the difference value of MYR0.119 perkWh. The other lifeline bands for this customer have shown a percentage difference between 2 percent until 27 percent suggesting that the tariff still can be further revised.

The result of the optimized tariff as compared to current tariff than was illustrated using the graph as represented in Figure 2. The overall pattern shows that both current and optimized tariff have an increasing growth pattern as highlighted by the exponential line. However, this growth rate is too small which is in between almost 0.5 percent to 1.5 percent only. It means that in average the tariff charges are quite fair to all respective customers even still yet under optimized.

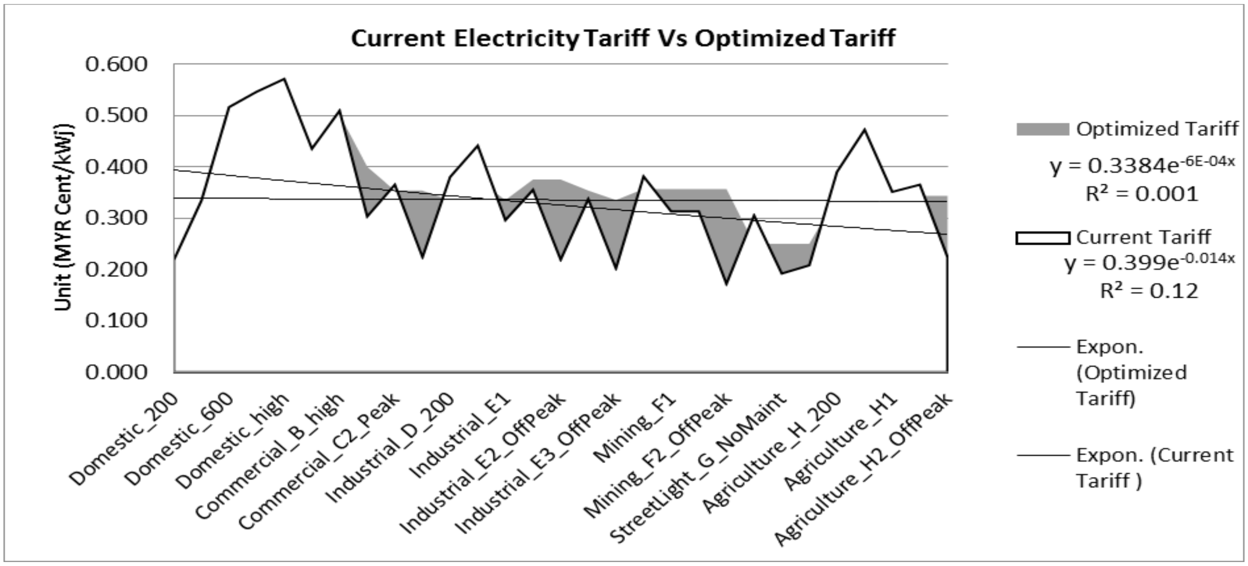

Figure 2: Current Electricity Tariff Vs Optimized Tariff by Customer Categories

5. CONCLUSIONS

The main objective of this project is to produce an efficient and fair tariff setting simulation framework using goal programming as well as a more robust technique of stochastic approach. The simulation framework will be able to deal with the multiple objectives of real-world business decision making process including optimizing electricity tariff for different types of electricity users. 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. It is notable, however, due to confidentiality of the information, this project utilized data that are available publicly that may have imposed some variance to the actual data. Nonetheless, it is important to highlight that the generation of this optimum tariff setting simulation framework will provide an avenue for TNB and related parties to relook and evaluate the current structure of Malaysian electricity tariff.

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6. REFERENCES

[1] KeTTHA (2017). Kadar taraf elektrik kekal. Available at: https://www.hmetro.com.my/mutakhir/2017/12/296987/kadar-taraf-elektrik-kekal

[2] Tenaga Nasional Berhad (TNB) Tariff Book (2014). Available at: https://www.tnb.com.my/assets/files/Tariff_Rate_Final_01.Jan.2014.pdf

[3] Mumo, M., Saulo, M. & Kibaara. (2015). Integrated Electricity Tarrif Model for Kenya. International Journal of Energy and Power Engineering. Special Issue: Electrical Power Systems Operation and Planning. Vol. 4, No. 2-1, 2015, 95-98.

[4] Rodrı´guez Ortega, M. P. & Pe´rez-Arriaga, J. I. (2008). Distribution network tariffs: A closed question?. Energy Policy 36, 1712–1725.

[5] Passey, R., Haghdadi, N., Bruce, A. & MacGil, I. (2017). Designing more cost reflective electricity network tariffs with demand charges. Energy Policy 109, 642–649.

[6] Yang, Y., Chen, W. Wei, L. & Chen, X. (2018). Robust optimization for integrated scrap steel charge considering uncertain metal elements concentrations and production scheduling under time-of-use electricity tariff. Journal of Cleaner Production 176, 800-812.

[7] Malko, J.R. & Swensen, P.R. (2008). Some Lessons Learned: Electricity Costing and Pricing. The

Electricity Journal, p.1040-6190 . doi:/10.1016/j.tej.2007.12.005.

[8] Keppo, J. & Rasanen, M. (1999). Pricing of electricity tariffs in competitive markets. Energy Economics, 21. p.213-223.

[9] Oprea, S.V., Bara, A., Cebec, M.E. & Tor, O.B. (2017). Promoting peak shaving while minimizing electricity consumption payment for residential consumers by using storage devices. Turkish Journal of Electrical Engineering & Computer Sciences, 25, p.3725 – 3737. doi:10.3906/elk-1606-152

[10] Mohd Saad, N., Mohamed Yusof, N.Y., Mamat, M.N., Abdullah, Z., Mat Husin, N. & Ibrahim, J. (2018a). A Review of Tariff Efficiency Mechanisms for Malaysian Electricity Distribution Firm. 4th International Conference on Engineering, Technology and Management 2018 (ICETM 2018) in Singapore on 26th-28th January 2018.

[11] Mohd Saad, N., Abdullah, Z., Mohamed Yusof, N.Y., Mat Husin, N. , Mohayiddin, A.L. & Mohd Arshad, M.T. (2018b). A Goal Programming Approach to Peninsular of Malaysia Electricity Tariff Structure. 3rd International Conference on Basic & Applied Sciences in Korea on 20th-22th April 2018.