# [*ELECTRICITY TARIFF COST REFLECTIVITY AND TIME OF USE TARIFF IN JAVA-BALI SYSTEM*]

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## Abstract

Electricity tariff in Indonesia, including in Java-Bali region, is set using volumetric charge or price per kWh electricity that are used by the customers with most of the tariffs are charged with flat tariff scheme and only medium voltage of commercial and industry customers that are charged with dual time tariff. On the other hand, cost of providing electricity in Java-Bali which mainly contributed by the operating cost of generators, is changing over 24-hour period due to changing mix of generators that supply the Java-Bali system over that period. To evaluate the cost reflectivity of electricity tariff in Indonesia, three parameters are being analyzed: load profile of the system and each customer segment, cost component of producing electricity, and tariff profile for each customer segment. Evaluating the correlation between electricity tariff and cost of electricity production, it is found that both simple flat-tariff scheme and peak/off-peak tariff scheme shows poor cost reflectivity with different time for overprice and under-price together with poor incentive for customer to change their energy consumption towards consumption that benefits the system. To overcome this issue, a simple time of use tariff is proposed and evaluated. It is found that the proposed simple time of use tariff can provide better cost reflectivity compared to existing electricity tariff that applied in Java-Bali system.

## Overview

Discussion about electricity tariff can be traced back to 1951 where (1) proposed a simple tariff reformation to the Great Britain electric utility. In 1961 when James C. Bonbright (2) published a book entitled Principles of Public Utility Rates, Bonbright explained several principles in determining public utility tariff including standards of reasonable rates, discussion around fair return for the utility, and proposed tariff structure. The principle of electricity tariff that are proposed by Bonbright can be summarized into three: requirement of revenue for the utility, fair distribution of costs among all customers, and optimal efficiency of resource allocation. Although Bonbright's principles remain relevant in this modern day (3), several adjustments have been proposed to complement these principles to accommodate distributed energy resources and demand side participants (4)(5)(6).

Although the principles of designing electricity tariff has been laid many years ago, electric utility still thrive to implement electricity tariff structure that satisfies all the principles. The requirement to recover sunk grid cost together with other residual costs and fair allocation to each customer still been discussed among industry practitioners and researchers (7)(8)(9)(10). Recovering revenue for generation cost is not an easy task either. The obligation of generating electricity at the exact amount of demand at all time and maintaining good quality of power delivery requires the operation of different kind of generators to operate thus impose different generation costs at different time. The challenges of transferring this time varying cost to customers lies on the available metering technology and the ability of the customers to respond to the tariff (11). Inter-temporal implication of electricity tariff where optimal investment and operation of the whole electricity industry must be considered (12) in addition to increasing disruption in electricity sector (e.g. demand response, distributed energy resources) (13) add more complication to the design of electricity tariff that makes one tariff will not fit all customers (14). Not to mention, electricity tariff is also used to drive customer behaviour by giving customer incentive to act towards certain preferable action (15).

The structure of electricity tariff implemented in modern electricity industry mainly evolves around how to charge the customer of their electricity usage, either it is based on energy (per kWh) or power consumption (per kW).

several distinct consideration that differentiate existing electricity tariff structure: spatial or the location (i.e. locational marginal pricing), temporal or the time of consumption (i.e. time of use, dynamic pricing), and volumetric or the amount of consumption (i.e. increasing/decreasing block tariff). Almost all existing tariff structure are the combination of these three considerations.

While there is vast combination of electricity tariff existed, electricity tariff in Indonesia, including in Java-Bali region, is set using volumetric charge or price per kWh electricity that are used by the customers. Even though there are several tariff classification for different groups of customers (residential, commercial, industry, social), most of the tariffs are charged with flat tariff scheme with only medium voltage of commercial and industry customers that are charged with dual time tariff which have different electricity price for peak and off peak time (16). On the other hand, cost of providing electricity in Java-Bali which mainly contributed by the operating cost of generators, is changing over 24-hour period due to changing mix of generators that supply the Java-Bali system over that period. This paper evaluate how currently applied electricity tariff reflects the cost of generating electricity in Java-Bali region and evaluate the time of use tariff scheme that are more appropriate to be implemented.

## Methods

To evaluate the cost reflectivity of electricity tariff in Indonesia, three parameters are being analyzed: load profile of the system and each customer segment, cost component of producing electricity, and tariff profile for each customer segment. Load profile for the Java-Bali system and each customer segment was obtained from the automatic meter reading data. These are used to determine how each customer segment contribute to system peak load. Cost structure of producing electricity is used to evaluate the the portion of fix and variable component of electricity production cost in Java-Bali system. The variable cost is then obtained using the generator dispatch and generator operational cost data. Both load profile and cost structure are then evaluated against the tariff incurred to each of customer segment in Java-Bali system. Cost reflectivity is then evaluated and simple more appropriate time of use tariff is then proposed.  Framework of this study is given in Figure 1.

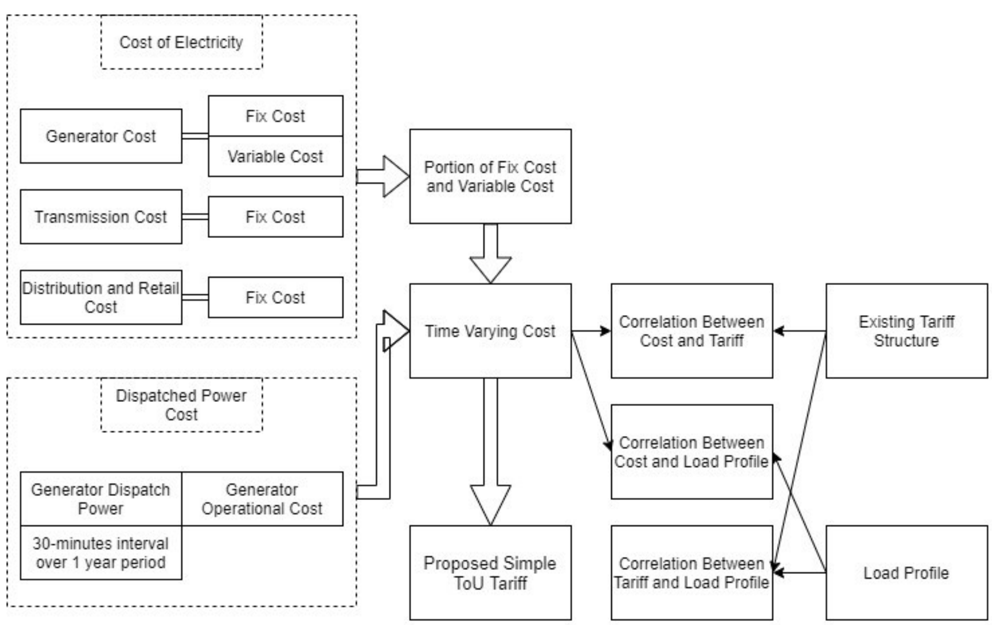


Figure 1. Framework of this study

## Results and Discussion

Evaluating the correlation between cost of electricity production and system load profile, we found that electricity production cost is in strong correlation with the system load profile as shown in Figure 2.

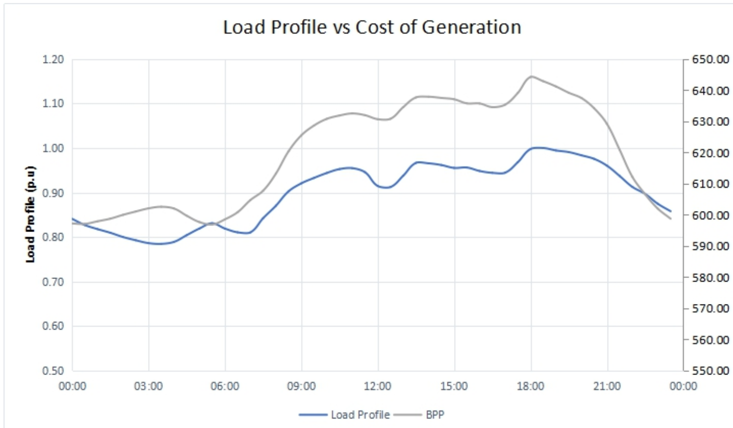


Figure 2. Correlation of load profile and cost of generation

The R-Squared value for these two variables is calculated to be 0.95. The correlation of cost of generation and load profile for each customer segment also evaluated. The R-Squared value for residential, industry, and business customers are 0.37, 0.81, 0.93 respectively and visualize in Figure 3.

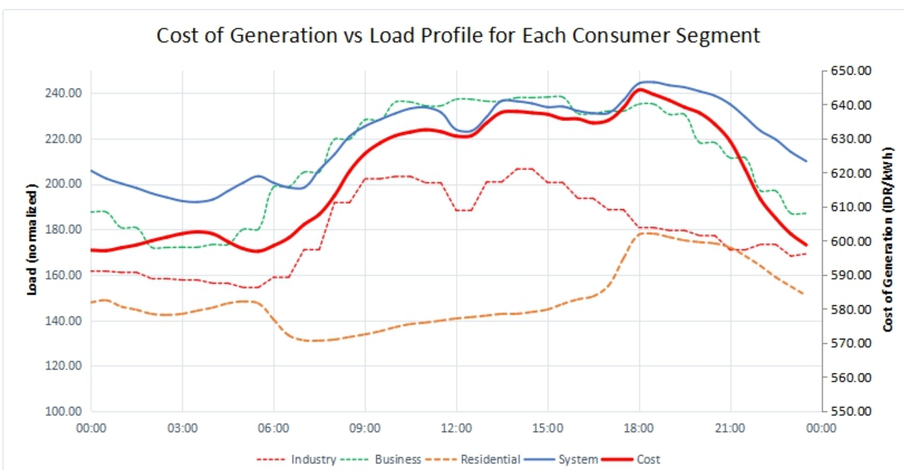


Figure 3. Cost of generation vs load profile of the system and each consumer segment

From load profile evaluation we noticed that Java-Bali system has two peak load occurrence, daytime peak and evening peak. Comparing this with per-segment customer load profile, we can see that the daytime peak is mainly caused by commercial and industrial customer while evening peak load is mainly caused by residential load. The profile of electricity production cost also conform with the occurrence of peak load, although not significantly different between the cost of production at peak load time and off-peak load time.

Comparing electricity tariff and cost of electricity production, both simple flat-tariff scheme and peak/off-peak tariff scheme shows poor cost reflectivity with different time for overprice and under-price. As can be seen from Figure 4(a) electricity tariff imposed for residential customer which is flat tariff does not reflect the cost of producing electricity in Java-Bali system. We can see that there is time period where the cost of production is higher than electricity tariff and vice versa. In addition to that, customers have no idea of the high production cost period and no incentive provided for customer to reduce their usage at this period which in turn can inflict financial loss for PLN if customers increase their usage at this time period. On the other hand, Figure 4(b) shows comparison between electricity tariff and cost of production for industrial customers. While, the electricity tariff give a hint on high production cost at certain period (17.00 - 22.00) which is known as the peak load time, but it can be seen that the tariff at that period is significantly higher than the electricity production. This may create sense of inequality between industrial customers and residential customers. Quantifying the correlation between electricity tariff and cost of production, the R-Squared value are 0.0 and 0.5 for flat tariff and peak/off-peak tariff respectively which confirm the non reflectivity of tariff and production cost.


Figure 4. Tariff and cost of production for (a) residential customer and (b) industrial customer

To improve the cost reflectivity of electricity tariff, a simple time of use tariff that better reflect the production cost is designed and proposed. Based on the production cost of Java-Bali system, we propose two time period of tariff: high-tariff time (09.00 - 21.00) and low tariff time (21.00 - 09.00). The tariff for each time period is examined using three alternative as shown in formula below:

Alternative 1:

$$High-tariff = FixCost + AverageOperationalCost(09.00-21.00)$$
$$and$$
$$Low-tariff = FixCost + AverageOperationalCost(21.00-09.00)$$

Alternative 2:

$$High-tariff = FixCost + MaxOperationalCost(09.00-21.00)$$
$$and$$
$$Low-tariff = FixCost + AverageOperationalCost(21.00-09.00)$$

Alternative 3:

$$High-tariff = FixCost + MaxOperationalCost(09.00-21.00)$$
$$and$$
$$Low-tariff = FixCost + MinOperationalCost(21.00-09.00)$$

The three alternatives are then evaluated based on how they affect the customer spending and PLN's revenue when the customers increase or decrease their electricity consumption both at low-tariff period and high-tariff period. Using this evaluation method, it is found that the third alternative shows superior performance compared to other alternatif in terms of the ability to give incentive to customers to lower their energy consumption at high-tariff period or increase their consumption at low-tariff period in addition to ensuring PLN's revenue not to be harmed. Figure 5 shows the proposed tariff compared to the electricity production cost for residential customers.

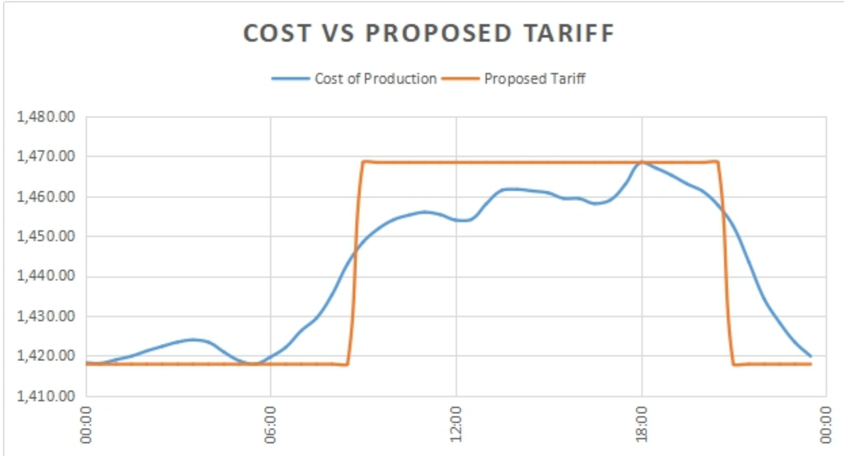


Figure 5. Production cost vs proposed tariff

Evaluating the correlation with cost of electricity production, the proposed tariff show better cost reflectivity compared to existing tariff with R-Squared value of 0.92.

## Conclusions

From this study we can conclude that current electricity tariffs that are implemented in the Java-Bali region, both simple flat tariff scheme and peak/off-peak time tariff, poorly reflects the cost of electricity production. Residential customer which contribute to the increase of electricity production cost at evening peak time need to be considered to apply time of use tariff scheme, rather than currently applied simple flat tariff. Implementing the proposed simple time of use tariff can provide a more cost reflectivity and thus give customer incentive to shift their electricity usage that can drive down electricity production cost at peak time period. Further study on tariff with different scenario of load consumption of customers and behind the meter generation is still need to be conducted to provide a more cost reflective, fair and just tariff for all the customers.

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