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Net energy metering scheme based on time of use pricing for residents in Malaysia

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Article Info

ABSTRACT

The current Malaysia's net energy metering (NEM) scheme has been updated in 2019 that credits excess generation into the next billing month at retail rate compare to at displaced cost. The new NEM may attract more installation of solar photovoltaic (PV) system among residential customers. However, it is discovered that customers with low monthly electricity consumptions are still not benefited since their electricity cost is lower than the PV generation cost. Implementing time-of-use (TOU) pricing on NEM scheme may overcome the problem as it based on hourly energy usage. This paper compares the annualized energy cost of residential PV system under different TOU prices and NEM scheme. The results show that an optimized TOU prices as suggested in this paper may give financial benefits to all residential customers with PV system, including the one with low monthly consumption.

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1. INTRODUCTION

In Malaysia, as compared to previous feed-in tariff (FIT) scheme, net energy metering (NEM) scheme is less popular among residential customers since they only get paid if their PV generation is higher than their consumption [1]. This condition is very unlikely to happen since the electricity output from residential PV panel is commonly small due to small PV size. The customers only gain benefit from the lower electricity bill due to the lower kWh consumption (due to net consumption). In other words, net metering can avoid customers from being charged the expensive electricity tariff block. If the monthly kWh consumption of a customer is already low, NEM will not give financial benefit to that customer since them already being charged with low tariff. The work in [1-2] highlighted the disadvantage of the current NEM scheme on residential customers with low monthly energy usage. The problem can be solved by implementing time-based electricity tariff for charging the customers and rewarding PV generations.

Time-of-use (TOU) tariff is an electricity price scheme in which the customer is charged base on the time they used the electricity [3]. Basically, the price will be expensive at periods with high electricity demands and cheap at periods with low demand. The prices for those periods are pre-established and make known to the customers in advance, allowing them to adjust their electricity usage in response to such prices. In Malaysia, TOU is applied on commercial and industrial customers [4-5]. Applying TOU pricing on NEM scheme will benefit customers since the TOU prices is high at noon where the output from the PV panel is also high. Through TOU, the PV energy price can be valued more correctly [6]. However, determining the

the right TOU prices is critical as it will affect financial returns of both customers and utilities [7]. This paper will investigate the annualized energy cost of different TOU prices on residential customers under Malaysia's NEM scheme. The results will also be compared with the existing NEM 2019 scheme as well as energy cost without PV system.

2. NET ENERGY METERING SCHEME

Net energy metering (NEM) allows a consumer to generate, use and sell only the excess energy to the grid. The main objective of NEM is for self-consumption to reduce demand from the grid [8]. A bidirectional meter will be installed that able to show the direction of energy usage [9]. If the meter rotates forward, it means that the customser is getting energy from the grid. In contrary, if the meter rotates backwards, it means the customer is supplying energy to the grid. Any excess generation after billing period will be given as credits. These credit is used to offset the electricity bill [10]. The maximum roll over credits period is 12 or 24 months [11-12]. Depending on countries, the remaining credits either will be paid to customer or will be set to zero [13-14]. Indirectly, the policy has made the grid act as a very huge storage [15].

A well-designed NEM policy provides a simple, low cost, and easily administered way to deal with PV residential system. NEM overcome the complexity of Feed-in tariff (FIT) scheme that requires a contract and installation of two meters. Inflation is another disadvantage of FIT scheme, since the customers may need to pay higher electricity rate in the future but not for FIT rate paid to them [16]. NEM acts like a perfect hedge against electricity prices rise [17]. In addition, NEM able to reduce power losses [18] by allowing the customers to consume the generated energy first and only export the excess energy instead of export all the generated. It will prevent congestion in the transmission lines that causes rise in power losses. However, NEM requires longer years for return of investment compared to FIT. A study presented in [19] shows the NEM will takes 16.1 years compared to 11.5 years for FIT. Next, some countries are implementing increasing-block rate tariff, which means the electricity rate per kWh increases as the volume of consumption increases. Thus NEM will not necessarily mean a profitable investment, especially for small consumers if the first electricity tariff block is comparatively low [15].

2.1. NEM in Malaysia

In Malaysia, NEM was firstly introduced in 2016 replacing the FIT scheme. The scheme has been revised and a new NEM is introduced in 2019. There is small but significant difference between the NEM introduced in 2016 (refered as NEM 2016) and the one introduced in 2019. For NEM 2016, solar energy is eligible for all type of consumer. For residential, the allowable capacity is up to 12kW for single phase and 72kW for three phases. While for commercial and industrial, it is up to 1MW. The excess generation will be credited into next billing period at a displaced cost [20]. The maximum roll over period is 24 months and any surplus after 24 months will be forfeited [21-22]. The electricity bill under NEM 2016 scheme is equal to the consumption price minus the generation price in a month. While, the consumption price is equal to total consumption times with Tariff A (domestic tariff) as in Table 1 and generation price is equal to total generation times with displaced cost. For NEM 2019, the allowable customers are residential, commercial, industrial and agriculture. The excess generation will be credited into the next bill period at retail rate (Tariff A-domestic tariff) [23] as given in Table 1. The rest is still the same as NEM 2016 scheme. For NEM 2019, the calculation of electricity bill is simple. The net consumption is equal to the total consumption minus the total generation. Then, the electricity bill is calculated by multiplying the net consumption to Tariff A (domestic tariff).

Table 1. Peninsular Malaysia's electricity tariff for domestic customers

Tariff Category (kWh)	Unit price (sen/kWh)
1-200	21.80
201-300	33.40
301-600	51.60
601-900	54.60
>900	57.10

2.2. Impact of NEM 2019 on small residential customer

Even though NEM 2019 overcome some weakneses of NEM 2019, small resident customers still do not benefit from the scheme for all PV system size. The main factor is small residential customers are being charged with low electricity tariff rates. In Malaysia, residential customers are based on increasing block tariff structure as shown in Table 2. For the first 200kWh consumption, they only pay 21.8 cents/kWh. The price is comparatively low compared to the PV energy cost, thus it does not viable financially to install

the PV system that requires high capital and maintenance cost. For medium and large residential customers, which consumed more than 300kWh a month, they are paying more expensive electricity rates, which is higher than the cost of energy from the PV panel.

3. PROPOSED TOU-NEM SCHEME

The purpose of this research is to overcome the weakness of existing NEM scheme which is not benefited for small size residents by proposing the existing NEM scheme is integrated with the TOU pricing scheme. The main idea of TOU-NEM scheme is to give the residents higher returns so all the residents size will benefit from the scheme, especially for small size residents. Since TOU structure charged at higher rates on peak hours, which means in daytime, meanwhile solar energy also generated at the same time. Therefore, the solar energy will be generated and offset the bill at higher rates.

3.1. Mathematical formulation

For the NEM-TOU method, the net consumption is calculated hourly instead of monthly, where the electricity bill is then calculated on hourly basis by multiplying the net consumption of a particular hour with the time of use (TOU) tariff for that hour. If the electricity consumption is higher than generation, the net consumption will be positive and electricity bill will also be positive. It indicates the amount of electricity bill that the consumer should pay for that hour. On the other hand, if the electricity consumption is lower than generation, the net consumption will be negative and the electricity bill will also be negative. The negative sign indicates that the utility need to pay the consumer for that hour. It can be mathematically presented as follows;

$$\text{at hour 1:} \quad P_{hour\ 1}^{net} = P_{hour\ 1}^{consump} - P_{hour\ 1}^{generation}, EB_{hour\ 1} = P_{hour\ 1}^{net} \times TOU_{hour\ 1} \tag{1}$$

$$\text{at hour 2:} \quad P_{hour\ 2}^{net} = P_{hour\ 2}^{consump} - P_{hour\ 2}^{generation}, EB_{hour\ 2} = P_{hour\ 2}^{net} \times TOU_{hour\ 2} \tag{2}$$

$$\text{at hour 24:} \quad P_{hour\ 24}^{net} = P_{hour\ 24}^{consump} - P_{hour\ 24}^{generation}, EB_{hour\ 24} = P_{hour\ 24}^{net} \times TOU_{hour\ 24} \tag{3}$$

Thus, the total electricity bill for one month can be formulated as follows;

$$EB^{month} = \sum_{d=1}^{30} \sum_{h=1}^{24} \left(P_{d,h}^{consump} - P_{d,h}^{generation} \right) \times TOU_{d,h} \tag{4}$$

where,

$P_{hour\ h}^{consump}$: Electricity consumption at at hour h

$P_{hour\ h}^{generation}$: Electricity generation at at hour h

$P_{hour\ h}^{net}$: Net consumption at hour h

EB : Electricity bill

$TOU_{d,h}$: Time-of-use tariff of day d at hour h

$TOU_{d,h}$: Time-of-use tariff of day d at hour h

To simplify the problem, in this paper it is assumed that daily load profile pattern and PV output pattern are approximately the same. Thus, the total electricity bill for one year can be approximated as follows;

$$EB^{year} = \left(\sum_{d=1}^{30} \sum_{h=1}^{24} \left(P_{d,h}^{consump} - P_{d,h}^{generation} \right) \times TOU_{d,h} \right) \times 12 \tag{5}$$

Since the electricity bill is calculated for 25 years, the present cost will take in consideration [24]. Assume that the discounted value is 6% every year [25]. It can be mathematically presented as follows;

$$\text{at year 1:} \quad EB_{year\ 1} = \text{Electricity bill in one year} \times \frac{1}{1.06^0} \tag{6}$$

$$\text{at year 2:} \quad EB_{year\ 2} = \text{Electricity bill in one year} \times \frac{1}{1.06^1} \tag{7}$$

$$\text{at year 25:} \quad EB_{year\ 25} = \text{Electricity bill in one year} \times \frac{1}{1.06^{24}} \tag{8}$$

Thus, the total electricity bill for 25 years can be formulated as follows;

$$EB^{25\ years} = \sum_{n=1}^{25}[\ (\sum_{d=1}^{30}\sum_{h=1}^{24}(P_{d,h}^{consump} - P_{d,h}^{generation}) \times TOU_{d,h}) \times 12\ ] \times \frac{1}{1.06^{n-1}} \tag{9}$$

Therefore, the annualized cost for the total electricity bill under proposed TOU-NEM scheme for 25 years can be formulated as follows [26];

$$Cost_{TOU-NEM}^{annualized} = EB^{25\ years} \times 78.227 \times 10^{-3} \tag{10}$$

3.2. Optimized TOU-NEM formulation
The objective is to maximize the cost savings to ensure the small residents able to reduce the electricity bills. Therefore, the objective function can be written as follows;

$$Max\{Cost\ Savings\} \tag{11}$$

where the cost saving can be formulated as follows;

$$Cost\ Savings = Cost_{existing}^{annualized} - Cost_{TOU-NEM}^{annualized} - Cost_{PV}^{annualized} \tag{12}$$

Therefore, the objective fuction can be written as follows;

$$Max\{Cost_{existing}^{annualized} - Cost_{TOU-NEM}^{annualized} - Cost_{PV}^{annualized}\} \tag{13}$$

Since annualized cost of existing tariff ($Cost_{existing}^{annualized}$) and PV cost ($Cost_{PV}^{annualized}$) are constant, therefore, to maximize the cost savings, the annualized cost of TOU-NEM ($Cost_{TOU-NEM}^{annualized}$)should be smallest possible. Therefore, the objective function can be written as follows:

$$Min\{Cost_{TOU-NEM}^{annualized}\} \tag{14}$$

4.   CASE STUDY
In this paper, the TOU structure is based on Malaysia's enhanced time of use (ETOU) tariff. Under this scheme, there will be three time zones energy charges; i) peak, ii) mid-peak and iii) off-peak rates. The rates will be applied on a daily basis including weekends for year-round. The off-peak rate starts from 10pm to 8am, while mid-peak rate has two different time from 8am to 11am and 5pm to 10pm. The peak rate starts from 11am to 5pm. The load profile of small residential customer with 2kWp PV system in [27] is used. Table 2 shows the TOU prices limits between maximum and minimum for four TOU schemes. For TOU 1, the minimum TOU price has been set at 5 cents. While, the value of 10 cents, 15 cents and 20 cents have been set for TOU 2, TOU 3 and TOU 4 respectively. The mid-peak rate value is exactly between peak and off-peak rates. The equality constraint annualized cost of existing tariff and TOU rates (without PV) has been set to get the optimized TOU rates result.

Table 3 shows the optimized TOU rates results from (14). For TOU 1, the rate for off-peak period is 10 cents, while mid-peak is 11 cents and peak is RM1. Meanwhile for TOU 2, the off-peak rate is 20 cents, the mid-peak rate is 22 cents and the peak rate is 90 cents. Under TOU 3 tariff, the rate on off-peak period is 30 cents, 33 cents at mid-peak and 80 cents at peak period. For TOU 4 tariff, the rate on off-peak period is 40 cents, while on mid-peak is 44 cents and on peak is 70 cents.

Table 2. TOU inequaity constraint prizes for the optimization problem

TOU	Min	Max
TOU 1	0.05	0.9
TOU 2	0.10	0.9
TOU 3	0.15	0.9
TOU 4	0.20	0.9

Table 3. Optimized TOU prices for 24 hours

Type	Hour	TOU 1	TOU 2	TOU 3	TOU 4
Off- peak	0	0.0500	0.1000	0.1500	0.2000
	1	0.0500	0.1000	0.1500	0.2000
	2	0.0500	0.1000	0.1500	0.2000
	3	0.0500	0.1000	0.1500	0.2000
	4	0.0500	0.1000	0.1500	0.2000
	5	0.0500	0.1000	0.1500	0.2000
	6	0.0500	0.1000	0.1500	0.2000
	7	0.0500	0.1000	0.1500	0.2000
Mid-peak	8	0.2942	0.2852	0.2762	0.2672
	9	0.2942	0.2852	0.2762	0.2672
	10	0.2942	0.2852	0.2762	0.2672
Peak	11	0.5385	0.4704	0.4024	0.3344
	12	0.5385	0.4704	0.4024	0.3344
	13	0.5385	0.4704	0.4024	0.3344
	14	0.5385	0.4704	0.4024	0.3344
	15	0.5385	0.4704	0.4024	0.3344
	16	0.5385	0.4704	0.4024	0.3344
Mid-peak	17	0.2942	0.2852	0.2762	0.2672
	18	0.2942	0.2852	0.2762	0.2672
	19	0.2942	0.2852	0.2762	0.2672
	20	0.2942	0.2852	0.2762	0.2672
	21	0.2942	0.2852	0.2762	0.2672
Off-peak	22	0.0500	0.1000	0.1500	0.2000
	23	0.0500	0.1000	0.1500	0.2000

Figure 1 shows the annualized cost for NEM2019 and various TOU-NEM schemes. The annualized cost for system without PV is included as a benchmark to compare the other schemes. From the figure, if no PV is installed, the annualized energy cost is RM 981.32. The NEM 2019 produces the cost at RM 1,171.58 higher than existing tariff which means the resident will suffer a loss 19.39% by investing in NEM2019. While, TOU-NEM 1, 2 and 3 produce lower than existing tariff at RM 927.85 and save at 5.45%. At the same time, TOU-NEM 4 produce higher than existing tariff at RM 1,056.36 (loss 7.65%) but lower than NEM2019. It can be seen that TOU-NEM 1, 2 and 3 give the same result since under the current NEM scheme, any excess generation will be credited into the next bill at a maximum roll over period of 24 months and any surplus after that will be forfeited. If the excess generation is paid by the utility, the annualized cost for NEM2019 and various optimized TOU-NEM schemes are lower as given in Figure 2. It could be said that TOU-NEM 1 produces the lowest cost at RM 637.98 and save 34.99% followed by TOU-NEM 2 and 3 at RM 777.44 (save 20.78%) and RM 916.90 (save 6.57%) respectively. Only NEM-TOU 4 produce higher cost than existing tariff at RM 1,056.36 (loss 7.65%). The results show that the proposed TOU-NEM scheme able to lower the annualized cost compared to existing tariff. Since the TOU structure will charge higher rates at peak hours, therefore it gives the advantage for PV generation that will generate at peak hours. Based on result, small resident able to get benefit from the proposed TOU-NEM scheme.
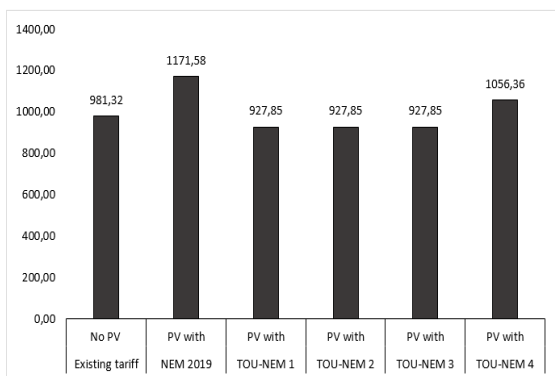

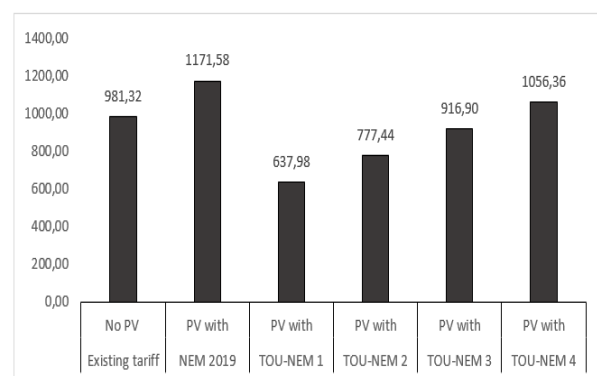Figure 1. Annualized cost for different scheme (given as credits-24 months roll over period period)

Figure 2. Annualized cost for different scheme (get paid for energy excess)

5. CONCLUSION

The results presented in this paper have proved that by implementing TOU pricing on the current NEM scheme may reduce the annualize electricity cost of small customers that install PV system. It overcome the imperfection of the current NEM scheme that only benefitted large customers. Also, through TOU the generation price of PV system can be valued more correctly compare to the current flat price.

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