A PERSPECTIVE ON DISTRIBUTED GENERATION IN MUNICIPAL NETWORKS THE REVENUE IMPACT OF SOLAR GENERATION

LEADING THE ELECTRICITY DISTRIBUTION INDUSTRY

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Abstract: This paper highlights the financial impact of rooftop embedded generation on the profitability of electricity sales, focusing on the effect of various billing tariff structures. The electricity buying and selling tariff structures applicable to most municipalities are explained and the discrepancy between profits earned during different usage periods is emphasised. The generation profile of a solar panel is presented and used to show that most solar power is produced in the standard time billing period. The effect of standard time solar generation on the municipal business is then evaluated showing that up to 60% of municipal electricity gross profits, from consumers who may install PV, are at risk of being lost. A Mitigation strategy in the form of time of use billing is presented as a viable, effective and fair solution.

Introduction

Municipalities buy electricity from Eskom on a time of use tariff and then sell that electricity onto residential consumers at a flat rate (this is the case in almost all municipalities). The time of use tariff applies different charges per kWh at different times of the day and year whereas a flat tariff charges the same rate per kWh regardless of the time of day (there is sometimes seasonal variation in flat tariffs). Profit margins on electricity will thus vary throughout the day and year. When applied, most flat tariffs result in electricity being sold at a loss during certain high demand peak periods and at a profit, of varying amount, at all other times. As such, any intervention that reduces electricity sales during high profit earning times without a significant decrease in loss-causing sales results in a potentially disproportionate decrease in gross profits.

The installation of an embedded generation system (e.g. rooftop solar photovoltaic) results in the customer purchasing less electricity during sunshine hours. These lost sales occur at a time when electricity sales are most profitable (because the Eskom ToU charges are close to their lowest at this time) and can therefore have a large impact on total gross profits. This threat is well understood by most large metros, however discussions with a number of smaller municipalities has highlighted that the finer details of energy efficiency and embedded generation on municipal gross profits is often not understood.

In the past the threat from solar embedded generation was largely insignificant due to cheap grid electricity and the high cost of residential photovoltaic systems. The large price increases approved by NERSA and implemented by Eskom and the rapidly declining cost of solar panels means that grid price parity[1] between solar PV and the utility tariffs is soon likely to be realised. Once grid price parity has been reached, the number of solar embedded generation installations will rise rapidly. Municipalities must be able to adapt to this change and need to have adequate strategies in place to reduce the potential effect this can have on the municipal business. Eventually, the growth of embedded energy sources is likely to force a change in the business models of electricity supply utilities.

In what follows, a detailed explanation of the current billing structure is provided. The electricity generation profile from solar panels is explored followed by an investigation into the profit lost due to solar embedded generation. The overall effect that solar embedded generation can have on the business is quantified followed by a proposal of potential mitigation strategies for municipalities.

> ***Note 1:*** *Throughout this paper the terms 'profit' and 'gross profit' are used to denote the selling price of electricity to the consumer minus the purchase price of electricity from Eskom. It is not intended to denote the actual profits of electricity, which would need to incorporate the true cost of supply.*

[1] Grid price parity: the point at which the levelised cost of energy from solar PV equals the utility tariff.

Electricity Tariffs

Municipalities typically purchase wholesale electricity on a time of use basis (ToU) and then sell that electricity to customers at a marked-up flat rate. This results in a variation in the gross profit margin on electricity sold at different times of the day and year. The current pricing structure can result in disproportionate changes in gross profits when sales from particular times of the day are increased, decreased or shifted. In order to understand this effect the tariff structures need to be fully understood.

Time of Use Tariff

The Eskom ToU tariff was designed to "[promote] efficient allocation", "[present a] reflective supply cost" and "incentivize desired load change" (Ramokgopa n.d). The 2014/2015 Eskom Municipal Megaflex tariff is broken down into two seasons and three tariff periods. High demand season (HD) and low demand season (LD), standard time (ST), peak time (PT) and off-peak time (OT). These periods are shown in Figure 1.

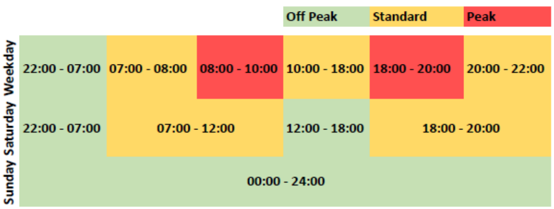

Figure 1: Chart showing Eskom Weekday Time of Use periods.

The Eskom Megaflex pricing applied to each of these periods is shown in Figure 2. There is a large difference in pricing between LD and HD periods and the price of electricity is significantly increased during PT, especially so during HD-PT. Electricity bought during HD-PT is 700% more expensive than electricity bought during LD-OT.

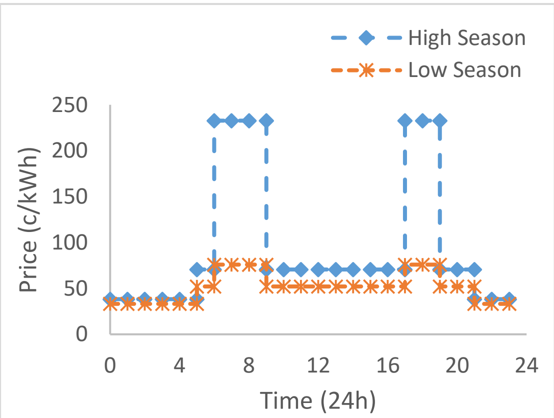

Figure 2: Breakdown of municipal tariffs per unit of energy bought and sold.

> ***Note 2**: Throughout this paper only work days (Mon-Fri) will be looked at. Weekends have no peak periods, and as such the effects of Time of use billing are amplified over this time.*

Residential Flat/Inclined Block Tariff

An inclined block tariff is designed to "make electricity more affordable to the poor" and "promote energy conservation" (Jooste & Palmer 2013). The City of Cape Town Domestic Tariff has two blocks as shown in Figure 3. This tariff applies throughout the year and does not vary with season. Any electricity purchased above 600 kWh/month is charged a 20% premium.

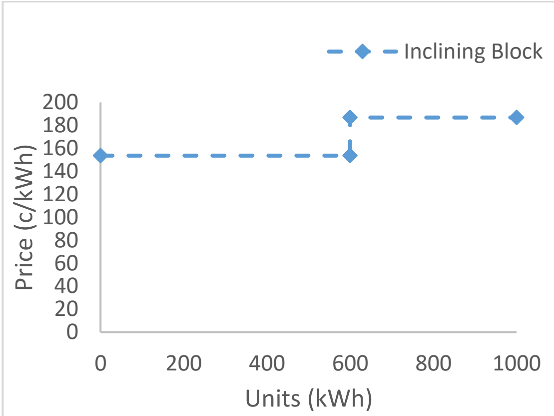

Figure 3: City of Cape Town Inclined Block Tariff 2014/2015. Obtained from the City of Cape Town website.

Gross profit realised on weekday sales

Profits are generated from electricity sales by selling electricity at a mark-up on overall cost price. Figure 3 presents an example of municipal gross profits for electricity sold at varying times of the day using a flat tariff. It can be seen that electricity is sold at a profit of varying levels throughout the day and that sales made during HD-PT incur a loss.

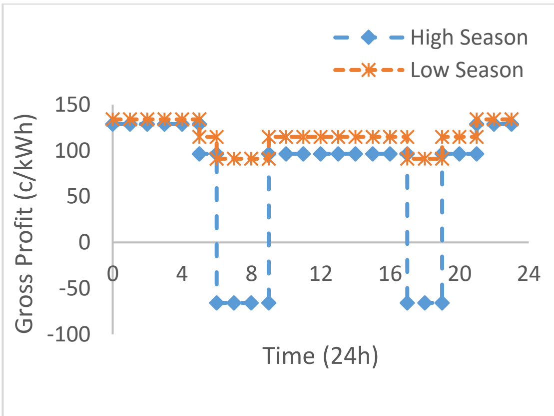

Figure 4: Municipal unit profit generated through the sales of electricity to residential customers

Customer Load profile

An average load profile for the City of Cape Town is presented in Figure 5. There are two clear daily demand peaks that occur at around 8am and 8pm corresponding to the pre- and post-work peak periods.

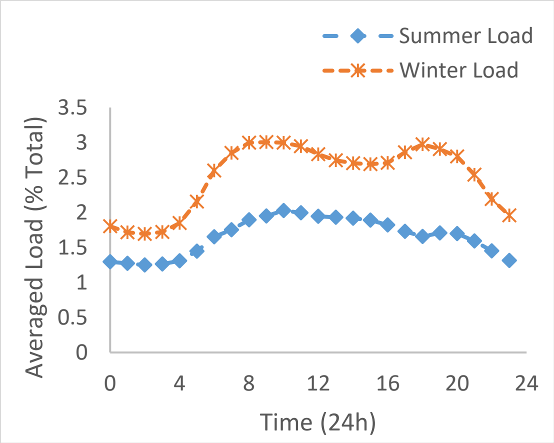

Figure 5: Summer and Winter Load Profiles for the City of Cape Town. Load is represented as a percentage of the total energy consumed for that day. Data from City of Cape Town (CoCT Electrical Department). Shows mixed consumption load including residential and commercial.

Electricity revenue structure

Applying the relevant municipal purchase price tariffs to the load profile reveals an electricity cost of sales profile. This shows the municipal expenditure on electricity at each point in the day as presented in Figure 6. In this figure the load is represented as the percentage of total energy cost to the municipality for that day. Analysis of this data reveals that for this example load profile approximately 40% of the total cost of sales is incurred during HD-PT which only makes up 14% of the total energy purchase.

Similarly when gross profit margins are applied to the load profile a gross profit profile is developed. The gross profit profile for this example shown in Figure 7 confirms that profits are made outside of PT, with 50% of total gross profit coming from ST sales

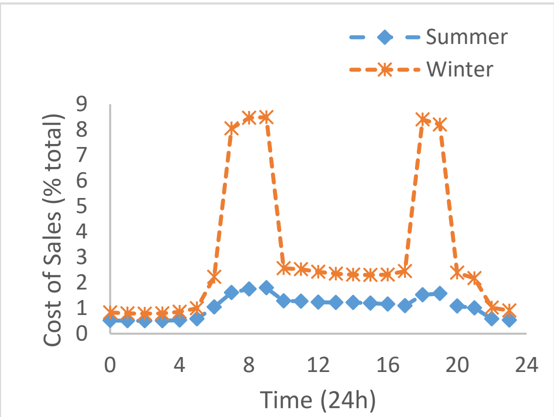

Figure 6: Municipal cost of sales throughout the day. Cost is shown as a percentage of the total daily expenditure.

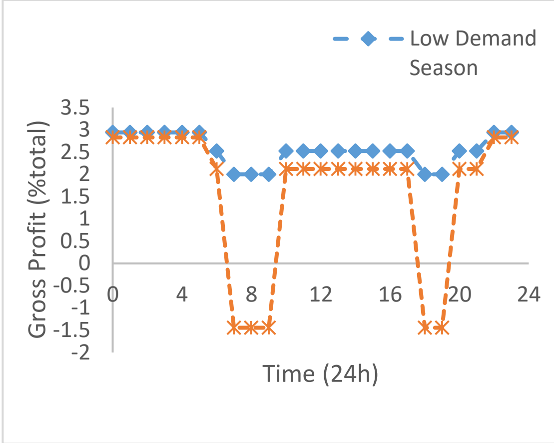

Figure 7: Municipal gross profits earned throughout the day.

PV generation

In order to determine the impact that solar embedded generation will have on the gross profits from electricity sales, the generation profile of the solar panels needs to be known. Photovoltaic electricity production is directly related to the irradiance level of sunshine. The study below focuses on the effect of PV generation, but similar results will be found from any distributed energy source (e.g. solar hot water) that has its primary effect during sunshine hours.

PV Irradiation/Generation Profile

A normalized irradiation profile for Cape Town is shown in Figure 8. Up to 87% of total energy is generated during ST (between 9am and 6pm). A small amount of electricity is generated during PT and no electricity is produced during OT. Significantly more electricity is produced during LD than during HD.

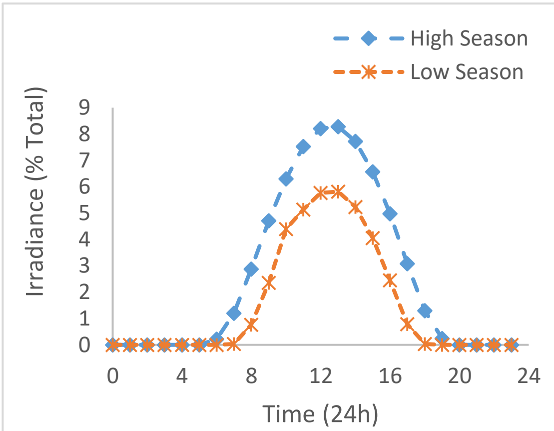

Figure 8: Graph showing irradiance/generation profile of a Solar Panel in Cape Town during summer and winter

Embedded Generation Impact

Given the electricity gross profit profile (Figure 6) and photovoltaic generation curve (Figure 7), the effect that solar embedded generation has on municipal gross profits can be calculated. Solar embedded generation only affects profits that were earned during sunshine hours. As such only OT gross profits are unaffected by solar embedded generation. OT gross profits account for 40% of the total gross profit earned, leaving 60% of electricity gross profit at risk of being impacted by solar embedded generation.

Note 3*: Photovoltaic panels have low output during HD-PT and thus offer little direct benefit in reducing municipal load during this time. While it is possible to optimise photovoltaics for HD-PT production to some extent, it is unlikely that this will have a significant effect. Solar embedded generation should therefore not be considered as a peak load reduction method, unless other actions such as customer load shifting or energy storage are undertaken.*

Overall effect on gross profits generated

Embedded generation systems are expensive at present and would typically only be installed by high-end customers. These customers consume electricity from the most expensive residential inclined block tariff and thus even a small reduction in sales from these customers can result in a big loss of highly profitable sales. Figure 9 and Figure 10 show the change in gross profits when a solar embedded generation system is installed in an average large consumer household.

The effect of solar embedded generation on municipal profits is best demonstrated with an example. Example 1 presents a quantitative illustration of how this would affect a typical large household in terms of lost gross profits to the municipality.

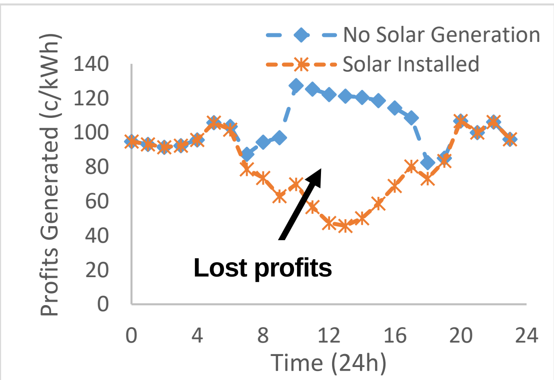

Figure 9: Low demand (summer) unit profits generated with and without solar embedded generation.

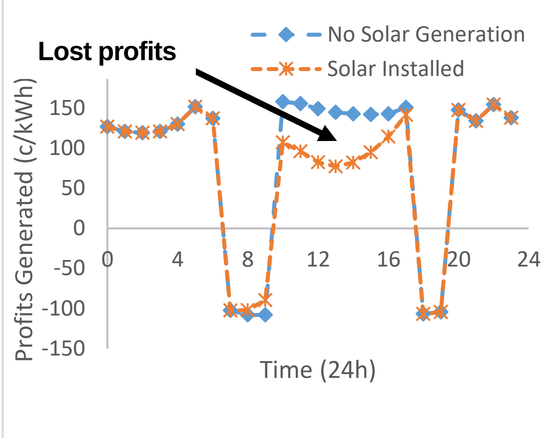

Figure 10: High demand (winter) unit profits generated with and without solar embedded generation

Example 1: Given the installation of a 1.5 kW peak PV system on a household that uses an average of around 1 000 kWh of electricity a month. The municipality stands to lose an average of 270 kWh per month of sales from the Block 2[2] electricity tariff. The lost sales occur predominantly during standard time and are equivalent to about R330 of lost gross profits. This represents a 25% decrease in total gross profits earned from this household.

What can be done

Municipalities can take a number of steps to mitigate the impact of solar embedded generation on electricity gross profits. Legislation can be used to prevent customers from installing solar embedded generation, or a monthly solar embedded generation tariff can be charged. These actions may however be considered punitive and may result in an increase in illegal solar embedded generation connections. A solution that modifies consumer electricity pricing to reflect the cost price (e.g. from Eskom) could be considered the most fair. Residential Time of Use billing with a fixed service and connection charge is the implementation of this tariff structure.

Effect of Residential ToU Tariff

A basic analysis of the effect of a residential ToU tariff on the impact of solar embedded generation was carried out. This analysis compares the revenue lost based on a flat tariff, compared to that with a revenue neutral ToU tariff (total revenue on ToU tariff does not differ from that of flat tariff for the same consumption). This analysis does not include any load shifting from the user, which would add additional complexities, but is generally seen as beneficial to the municipality. The reduction in unit gross profits in HD season due to solar embedded generation for a flat tariff and a ToU tariff are compared in Figure 11.

[2] Block 2 is the higher tariff in the inclined block tariff used in this example.

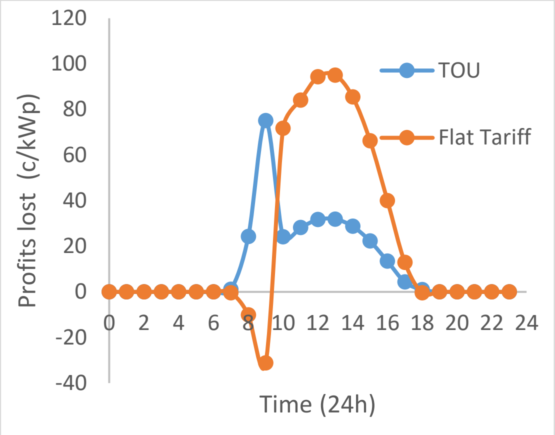

Figure 11: Comparison between unit profits lost due to PV for a flat and residential time of use tariff

While the ToU tariff results in a small loss for the duration that PV produces during PT, for the major portion of the day the loss is significantly decreased. On weekends there is no peak, and thus even an even greater loss reduction is realised. Again using the scenario presented in Example 1 the overall gross profit losses are now reduced by approximately 40%, bringing the total loss down to around 10%.

Note 4: *A change in tariff structure will affect the financial model of solar embedded generation for a customer. This may result in fewer customers installing PV which may have an impact on the local economy.*

Conclusion

The asymmetrical buying and selling prices of electricity results in different levels of gross profit being generated from the sales of electricity on an hourly and seasonal basis. Electricity is sold at a loss during high demand peak time and for a large gross profit during low demand standard and peak time. Solar embedded generation produces most of its energy when gross profit margins are greatest and hence can have a potentially disproportionate effect on kWh sales lost vs gross profits lost. Time of Use billing is explored as a mitigation strategy and is shown to have a positive impact in protecting municipal revenue.

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