International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-4, November 2019

Maximizing Savings in Electricity Bills Based on Customer's Load Profile

H Atikah, C S Tan

***Abstract:** With the high demand in electricity consumption nowadays, it is crucial for regulator and utilities to ensure sufficient energy supply to meet electricity demand. Electricity demand is influenced by several factors such as number of customers, customer behavior, working hours, weather condition and holidays. Integrating renewable energy technology as part of electricity generation for self consumption has indirectly provide an option to customer to reduce his electricity consumption from the grid and help to save his electricity bill. One of the simplest solutions to install renewable energy sources is by installing rooftop solar photovoltaic (PV). In this paper, the economic feasibility of installing solar PV is discussed based on commercial customer load profile. This paper also presents the suitable PV sizing based on the payback analysis based on customer load profile. A commercial customer in Petaling Jaya, Selangor is used as a case study for this analysis. This study indicates that customer will be able to reduce their electricity bill consumption with the integration of solar PV system on the rooftop of their building. Customer is able to save their monthly electricity up to 28% if a total solar PV capacity of 1256kW is installed. The payback from this study indicates the payback period is approximately around 9 years.*

***Keywords:** Case study, Electricity, Rooftop and Solar PV*

I. INTRODUCTION

In a deregulated electricity supply industry, reducing system peak demand will help to disproportionate system generation costs. In other words, the system generation cost is high during peak demand and vice versa. Therefore the reduction of the system peak demand will help to drive a lower generation costs and bring benefit in term of a lower customer's electricity tariff. However, this situation is hardly enjoy by any customers due to the nature of their daily activities or businesses but achievable through energy efficiency measures.

Manuscript published on November 30, 2019.
* Correspondence Author
H Atikah*, College of Graduate Studies, Universiti Tenaga Nasional, Jalan IKRAM-UNITEN, 43000 Kajang, Selangor, Malaysia.
C S Tan, Institute of Energy Policy and Research, Universiti Tenaga Nasional, Jalan IKRAM-UNITEN, 43000 Kajang, Selangor, Malaysia.

Customer's behavior change on electricity consumption is seen to be the simplest yet the hardest way to improve electricity consumption which require perseverance. This can be achieved in a more sustainable energy in the future through customer's feedback on their energy consumption based on smart metering system as highlighted in [1]. The introduction of the real-time demand response is evidence to help reducing customer's electricity bills with a better way of managing electricity consumption [3]. Two algorithms named controllable device first (CDF) and shift able class first (SCF) were developed by [3] to reduce the consumption of electricity mainly in the industry. The former algorithm has shown 25.1% in annual savings while the latter shown 25.3% in annual savings.

The time-of-use pricing is another demand response mechanism that accurately reflect electricity bill of a customer. Time-of-use pricing offers the customer a lower electricity rate during off-peak hours and higher electricity rate during peak hours. This directly helps customer managing their electricity consumption in a more efficient way. Other studies also indicate that coupling a battery energy storage system with solar PV helps to reduce electricity bills [4-8]. Study in [4] indicates that real time battery energy storage control based on its state of charge can bring savings in residential via a proposed conditions of the customer load profile and electricity rate. Researchers in [6] proposed a mixed integer Non-linear programming using python optimization modeling language to minimize the electricity cost for time-of-use and net-metering customers with energy storage. Similarly, in [7] the economic feasibility of residential behind the meter battery energy storage was discussed. The study indicates that even though battery energy storage system enables end-users to purchase energy and store it in the battery when the electricity prices is low and consume the energy later when the electricity price is high, batteries are subject to economic and functional limitations because they are degradable systems and the performance declines over time. However, a research by [8], concluded that installing a battery energy storage system may not be economically beneficial to residential in Southeast Queensland with solar PV. This is mainly due to the battery energy storage cost that exceeded the electricity savings. Most of the studies focused on peak demand shaving strategies using energy storage to maximize the cost savings [6-8].

In [9], an intelligent charging system algorithm called Smart Charge was developed and deployed for residential to lower their electricity bill. This study shows that the system deployed at 22% of 435 homes reduces the aggregate demand peak by 20%.

For a typical home the electric bill can be reduced by 10%-15% using realistic battery capacities as reported. Following the technology enhancement, various solutions were introduced to promote savings in the customer's electricity bills. Researcher in [2] has conducted study on the economic benefits and the payback periods of rooftop solar panels in Australia. The paper has highlighted several factors affecting economic benefits of rooftop solar panel including rating of the rooftop solar panel, the pattern of electricity consumption by the household, the location of the household, electricity consumption charge and feed-in tariffs (FiT) offered by the

utility. Based on the analysis carried out, the study concluded that for a typical Australian household which consumes 5,500kWh annually and 50% of the solar PV generation is for own consumption while the remaining to be exported to the utility under Fit scheme, the payback period is 5-11 years.

Load profile has been used by many researchers as an efficient, organized and systematic tool for energy tariff scheme design, planning and load management in many countries [12]. Due to diversity of customers, statistical methodology has been used for preparation of aggregated load profile. Reference in [13] compares, correlates data and analyses the results to determine the different factors that influence the load profiles which significantly varied between different occupancy types, housing data and customer behavior. There is also an alternative method to do load modeling as specified in [14] by modeling the load composition rather than actual monitoring. The main obstacle in this load modeling will be on the validation of data. Reliance on the out-of-date data is not recommended because such data sets do not necessarily accurately represent end-use load profiling. It presents a method which involves updating outdated load studies with current mean annual unit energy consumption data.

Paper in [15], describes that when customer load profile is very poor which only based on the data provided by classic meter, smart metering systems could allow electric distribution companies monitoring the electrical power conditions practically in every point of network. The load profiling methodology uses self-organization techniques to process data, identify existing load classes or patterns, classify customers according to classes and generate typical load profiles. For determination of the customer's classes, every customer must be characterized by the following primary information: daily (monthly) energy consumption, minimum and maximum loads. With detail information on the load profile, end-customers can obtain great savings in their electricity bill by reducing the energy consumption with the usage of energy efficient products and energy harvesting from solar PV.

In order to quantify the electricity bill saving, it is important to know what customer's electricity tariff is so that the monthly electricity bill savings can be determined before and after with the proposed solar PV sizing. However, saving in electricity bills depends on number of factors such as direct hours of daily sunlight, solar PV sizing and angle of the rooftop are both important, but electricity rates play the biggest role in determining how much solar PV can generate saving. The volatile nature of electricity prices is an added incentive for solar PV whereby the energy costs is locked at a constant rate with solar PV without needing to consider the variable utility rates.

This paper presents the load pattern analysis of a financial institution customer in Petaling Jaya, Selangor based on the electricity consumption monitored from the customer's meter. A solar PV system is identified as a solution to reduce electricity consumption imported from utility grid and hence provides savings to customer's electricity bill. A comparison is also made to determine solar PV sizing for the customer in terms of financial benefits and acceptable payback period.

II. METHODOLOGY

A financial institution commercial customer load profile in Petaling Jaya, Selangor was obtained and shared by Suruhanjaya Tenaga. The load profile collected is between 1st and 31st May 2018. The load profile measured at the customer's output meter has a 10-minutes interval reading. The half-hourly interval data was created based on the load profile readings. The characteristic of the customer electricity consumption of the half-hourly load profile pattern were analyzed and observed. Two weekly profiles were generated to observe the difference in operation between weeks. The average maximum and minimum customer load profile will help in determining solar PV sizing. In this paper, the solar PV sizing was based on the average maximum demand. 70% of the average maximum demand is set as the lowest solar PV capacity and increase gradually up to 100% solar PV capacity which is equivalent to the average maximum demand. The total electricity bill saving was calculated according to different solar PV sizing. The payback period was identified with different solar PV sizing based on the commercial customer load profile used. The solar PV module chosen for the analysis is shown in Table 1.

Table. 1 Solar PV Module Parameters

Maker	JA Solar
Rated Maximum Power	370W
Maximum Efficiency	18.6%
Dimensions	1993mm x 998mm x 30mm
97% nominal power for first year	

The electricity tariff for this commercial customer is Tariff B – Low Voltage Commercial Tariff and the structure is as in Table 2.

Table. 2 Electricity Tariff Structure

Consumption	Unit	Rates
For the first 200kWh (1 – 200kWh) per month	sen/kWh	43.50

For the next kWh (201kWh onwards) per month	sen/kWh	50.90
The Minimum Monthly Charge	RM	7.20

Output generated from the solar PV is calculated according to Equation (1)

$$E = A \times R \times H \times PR \quad (1)$$

E = Output generated, W
A = Total area in square meter, m^2
R = Efficiency
H = Irradiance, W/m^2
PR = Performance ratio {97%}

To obtain the payback period, this paper has made reference to a report produced by International Renewable Energy Agency (IRENA) on the average total installed cost of solar PV systems [11]. In this study, it is assumed that the average total installed cost of solar PV systems is approximately 1600 USD/kW in 2018. Simple payback period is calculated using Equation (2).

$$Payback\ period, years = \frac{Total\ Solar\ PV\ Installed\ Costs}{Annual\ Savings} \quad (2)$$

III. RESULTS AND DISCUSSIONS

Figure 1 shows the daily commercial customer's load profile usage between Monday and Sunday between 1st – 7th May 2018. It indicates that the commercial customers started its operation as early as 6.00 am and end at 6.00 pm then the electricity consumption gradually decreasing to a minimum by 10.30 p.m. The minimum electricity consumption for this commercial customer ranging between 300kW and 530kW and it occurs during weekend. On average, the consumption is about 400kW on Saturday and Sunday. The load pattern summarizes that the daily maximum demand varies between 1000kW and 2000kW during operations i.e., office hours. The weekdays load consumptions show a flat consumption for duration of 12 hours during weekdays. Based on the load pattern, it shows that the commercial building does not operating during weekend and holiday seasons.

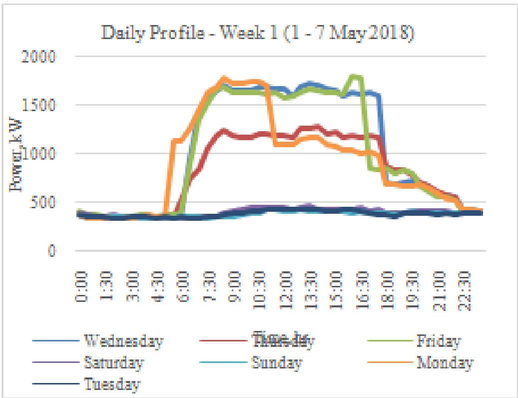

Fig. 1 Customer's Load Profile Week 1

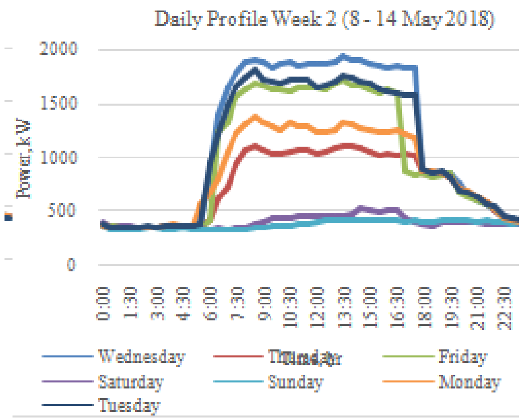

Fig. 2 Customer's Load Profile Week 2

Figure 2 illustrates a similar load pattern profile as shown in Figure 1 for week 2 between 8th – 14th May 2018. It also indicates that there's no significant difference in operation's time during weekdays and weekend between week 1 and week 2. On normal operation days, Wednesday and Monday/Thursday shows the highest and the lowest electricity consumption respectively each week. Based on the load consumption recorded, the average maximum dan minimum demand of the commercial customer is 1795kW and 340kW respectively. Solar PV is designed based on the customer's load pattern and maximum demand. In this paper, multiple solar PV sizing are simulated to achieve the maximum savings. The solar PV sizing are calculated based on the customer's daily average maximum demand as depicted in Table 3.

Table. 3 Solar Photovoltaic (PV) Sizing based on Average Maximum Demand

Percentage (%) of average Maximum Demand	Solar PV Capacity (kW)	Percentage (%) of average Maximum Demand	Solar PV Capacity (kW)
10	180	60	1,077
20	359	70	1,256
30	539	80	1,436
40	718	90	1,616
50	898	100	1,795

Monthly average solar irradiations on the horizontal surface in Petaling Jaya were obtained from [10]. The maximum value of solar irradiation is 16.99 MJ/m2/day and the minimum value recorded is 14.54 MJ/m2/day. The annual average solar irradiation in Petaling Jaya is 15.82 MJ/m2/day. Therefore, the maximum value of solar irradiation is used to calculate the maximum output generated from the solar PV as shown in Figure 3.

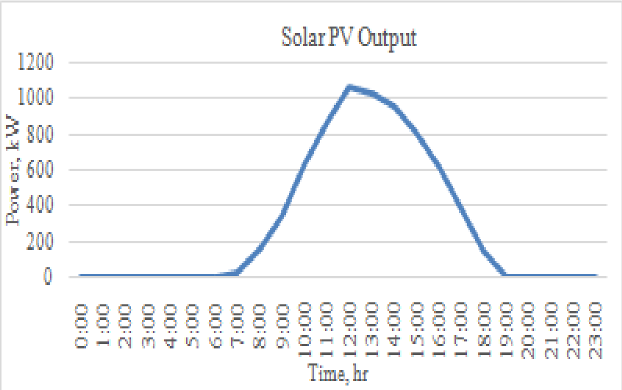

Fig. 3 Solar PV Output Generated

Figure 4 illustrates the customer's load profile during normal operation and total solar PV output generated with a varying percentage (%) of average maximum demand between 70% and 100%. The solar PV output is calculated using Equation (1) based on the maximum irradiation value in Petaling Jaya. The energy generated from solar PV will use, hence translated into savings in customer's electricity bill.

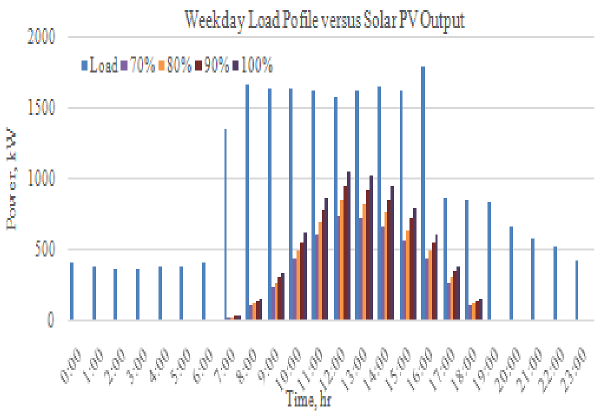

Fig. 4 Weekday Load Profile versus Solar PV Output

Figure 5 shows the customer's load profile during weekend whereby the load demand recorded is low. Eventually, there is an excess of energy generated from solar PV system during midday. The load consumption between 10.00 a.m and 4.00 p.m can be utilized based on the energy generated from the proposed solar PV system.

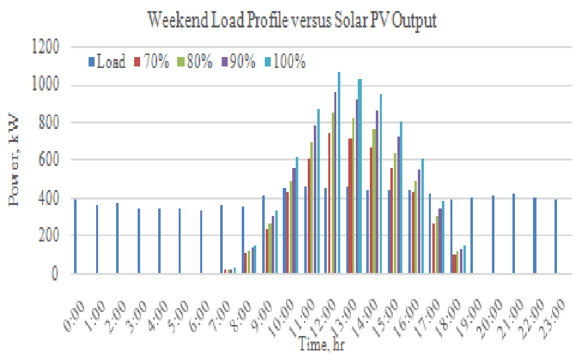

Fig. 5 Weekend Load Profile versus Solar PV Output

Figure 6 shows the annual savings calculated with different solar PV sizing in percentage of maximum demand of the customer under the study. The results obtained from the analysis shows that solar PV generated with different sizing (capacity) can help customer to save up to 28% in monthly bill if a total capacity of 1256kW solar PV is installed. It is known that larger PV capacity will result in greater electricity bill savings. However, the solar PV capacity to be installed is constraint off by the existing rooftop size. The payback period of this study is around 9 years for this case study based on the customer's maximum demand.

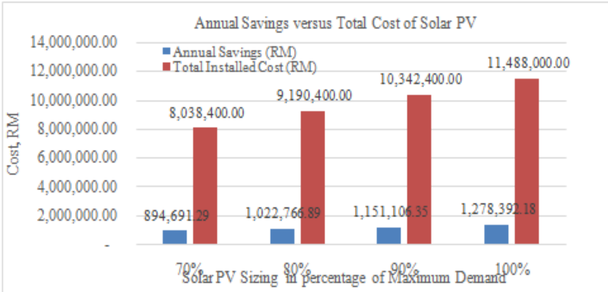

Fig. 6 Total Annual Savings and Installed Costs

IV. CONCLUSIONS

This study indicates that customer will be able to reduce their electricity bill consumption with the integration of solar PV system on the rooftop of their building. Customer is able to save their monthly electricity up to 28% if a total solar PV capacity of 1256kW is installed. The payback from this study indicates that the payback period is approximately around 9 years. The integration with battery storage is not consider in this paper. Inclusion of battery energy storage may help to save in electricity bill by selling back the excess energy to utility. More details study on the dynamicity of the load profile coupled with solar PV and battery energy storage will provide a better understanding of the electricity bill savings in long run.

ACKNOWLEDGEMENTS

The authors are grateful and appreciative to Suruhanjaya Tenaga for sharing data on customer load profile for the study. Any opinions, findings and conclusions expressed in this paper are from the authors and do not necessarily reflect the views of the Suruhanjaya Tenaga, Universiti Tenaga Nasional or the Institute.

REFERENCES

1. Zhifeng. Qiu, Geert. Deconinck, "Smart Meter's Feedback and the Potential for Energy Savings in Household Sector: A Survey", April 2011.
2. Muhammad Hayat, Farhad Shahnia, Ali Arefi, Herbet Iu, Tyrone Fernando, "Comparison of the Economic Benefits and the Payback Periods of Rooftop Solar Panels in Australia", 2017.
3. N.Y.Olawuyi, M.F.Akorede, E.Femi, A.A.Ayeni, R.G.Jimoh, "Real-time Demand Response Algorith for Minimising Industrial Consumers Electricity Billing", 2017.

4. Huangjie Gong, Oluwaseun Akeyo, Vandana Rallabandi, Dan M.Ionel, “Real-time Operation of Smart Homes with PV and Battery Systems under Variable Electricity Rate Schedules and Transactive Power Flow”, October 2018.
5. Travis Simpkins, Kate Anderson, Dylan Cutler, Dan Olis, “Optimal Sizing of a Solar-Plus-Storage System for Utility Bill Savings and Resiliency Benefits”, 2016.
6. Tu A.Nguyen, Raymond H.Byrne, “Maximizing the Cost-savings for Time-of-use and Net-metering Customers Using Behind-the-meter Energy Storage Systems”.
7. Ahmed Zurfi, Ghaidaa Albayati, Jing Zhang, “Economic Feasibility of Residential Behind-the-meter Battery Energy Storage Under Energy Time-of-use and Demand Charge Rates”, November 2017.
8. Dan Hui Tang, Dr.Daniel Eghbal,”Cost Optimization of Battery Energy Storage System Size and ycling with Residential Solar Photovoltaic”.
9. Aditya Mishra, David Irwin, Prashant Shenoy, Jim Kurose, Ting Zhu, “SmartCharge: Cutting the Electricity Bill in Smart Homes with Energy Storage”.
10. Abdul Majeed Muzathik, Wan Mohd Norsani bin Wan Nik, Khalid bin Samo, Mohd Zamri Ibrahim,”Reference Solar Radiation Year and Some Climatology Aspects of East Coast of West Malaysia”, 2010.
11. IRENA, “Renewable Power Generation Costs in 2014”.
12. Union of the Electricity Industry, “Metering Load, Metering Load Profiles and Settlement in Deregulated Markets”, March 2000.
13. Abidur Rahman, Syed Ishraq Chowdhury Arnob, “Developing Load Profile for Domestic Customers of Dhaka City through Statistical Prediction”, 2016.
14. C.M. Colson, M.H. Nehrir, “An Alternative Method to Load Modelling for Obtaining End-Use Load Profiles” 41st North American Power Symposium, 2009, 4-6 Oct 2009, pp 1-5.
15. D. Gerbec, S. Gasperic, I. Smon, F. Gubina, “An Approach to Customers Daily Load Profile Determination”, 2002.
16. Gheorghe Grigoras, Ovidiu Ivanov, Mihai Gavrilas, “Customer Classification and Load Profiling using Data from Smart Meters”, 2014.