# Performance of a 3-kWp grid-tied photovoltaic system in a water refilling station

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***Abstract:***
*Due to the recurring power interruptions and the increasing monthly electricity rates in Metro Manila, residents and business owners need to start using renewable energy. Solar photovoltaic (PV) is the most viable and widely available source of energy. To quantify the benefits of using solar PV systems, the performance of a 3 kWp grid-tied photovoltaic system with back-up battery bank installed in a commercial water refilling station was monitored and analyzed. The battery bank provided an uninterrupted source of energy. The calculations for the monthly savings and the potential rebates of the establishment if net metering were applied are included. Despite negative effects due to the non-implementation of the net metering scheme, the grid-tied PV system significantly reduced the monthly electricity bill by 50%. Information obtained within the 3-month duration of the study was used to make necessary modifications in the system.*

***Keywords:*** *photovoltaic system; grid-tied; savings; energy monitoring*

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## 1. Introduction

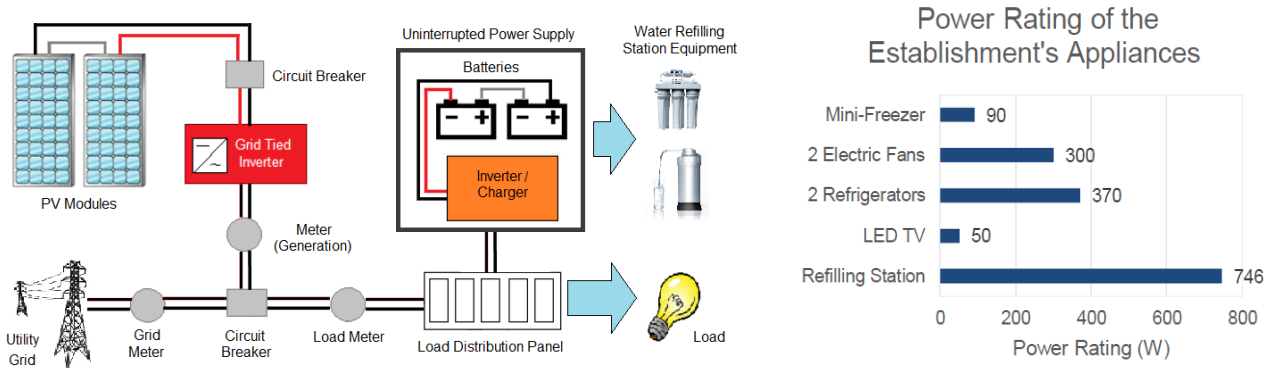
Recently, power interruptions had been prevalent sometimes lasting for hours due to insufficient supply of electricity. Metro Manila has experienced power outages, some lasting for three hours in some areas, because the system demand for power pegged at 6631MW could not be sufficiently supported by a limited supply of 6154MW, leaving the system 500MW deficient (Remo, 2012). Power interruptions can cause major problems for businesses that rely heavily on constant supply of energy. Distribution utilities such as Meralco also increase their charge per kilowatt-hour regularly. Last year, Meralco implemented an increase of 0.22/kWh for its monthly rate in June and 0.18/kWh increase in September (Cerda, 2013). With the increasing monthly rates, many people are finding it difficult to subscribe to the utility and businesses tend to increase the prices of their goods to compensate for the increase in their electricity bills.

The growth of the solar photovoltaic industry in the Philippines opens up opportunities that have a lot of untapped potential. Because of its location, the country experiences approximately 8.6 hours of direct sunlight per day during summer and an average of 5.8 hours per day for the rest of the seasons. With this, it can clearly be seen that the use of photovoltaic cells is an opportunity still waiting to bloom into its full potential.

The use of PV systems offers several benefits not just to the underserved rural communities but also to residents and businesses in urban areas. These systems can address the problems of power interruptions and the burden of a constantly increasing electricity bill. In this study, a 3 kWp grid-tied photovoltaic system with back-up battery bank utilized by a commercial water refilling station was monitored. The capacity of the installed PV system to provide enough power to sustain the business operations was investigated. Also, the unconsumed energy generated by the PV system that goes to the utility grid was determined to find out whether it is considerable for net metering. This study aims to account for the generated solar energy and the consumed energy of the establishment both from solar and from the utility grid to determine the performance of the PV system, and to calculate the savings and potential rebates from solar if the net metering scheme were implemented.

## 2. Methodology

The schematic diagram of the grid-tied PV system that was investigated in this study and the power rating of the appliances in the establishment are shown in Fig. 1. Data gathering was conducted for 3 months (May, June and July 2013) and the scope of the monthly data is based on the billing date of the utility provider. The monitoring includes recording the energy generated by the PV system, the energy consumed from the utility grid, and the total energy consumed by the establishment. These readings were obtained from the Generation Meter, Grid Meter and the Load Meter, respectively (see Fig. 1(a)).




**(a)** **(b)**

**Fig. 1** (a) Schematic of the grid-tied PV system installed in the commercial water refilling station and (b) the power rating of the appliances in the establishment.

From the three energy meters, the following relationships can be derived:

(1) Since net metering is not implemented, and with a digital meter, the excess energy from solar going to the grid is considered "consumed" by the grid meter. Therefore, the grid meter then gives the energy consumed from the grid $G_C$ and the excess energy from solar $S_E$.
(2) The load meter accounts for the energy consumption from solar $S_C$ and from the grid $G_C$.
(3) The excess energy from solar can be calculated by subtracting $S_C$ from the generated solar energy $S_G$, where $S_G$ is obtained from the generation meter .

The consumption from solar can be determined through the following calculations:

Grid meter = $G_C + (S_G - S_C)$, therefore $S_C = G_C + S_G$ – Grid Meter (1)

$G_C$ = Load meter – $S_C$, therefore, $S_C$ = (Load Meter – $S_C$) + $S_G$ – Grid Meter (2)

Rearraging, we get (Eq. 1) $S_C$ = ½ (Load Meter + $S_G$ – Grid Meter).

The grid consumption is determined from (Eq. 2) $G_C$ = Load Meter – $S_C$ and the excess energy from

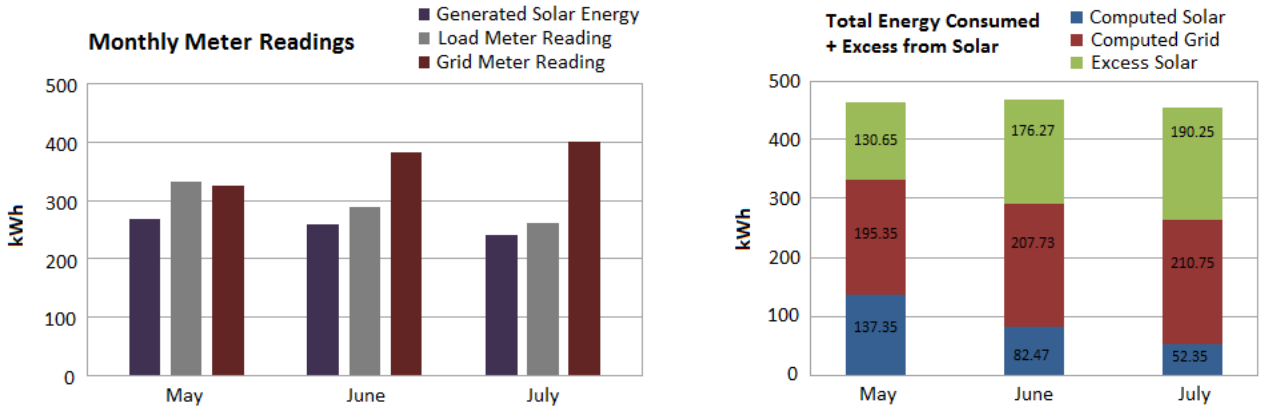
$$S_E = S_G - S_C \quad (3)$$

The cost of electricity $P_{DU}$ from the Distribution Utility (DU) and potential rebate $R$ from net metering were computed by multiplying the $G_C$ and $S_E$, respectively, with the price per kilowatt-hour. The price of electricity from the grid between May and July 2013 varied between Php 10.10 – Php 10.76 per kWh with an average of Php 10.39 per kWh, while the net metering rate is based on the DU blended generation cost (Ocampo, 2013). When this study was conducted, the net generation cost was at Php 5.4951 per kWh. From this, the monthly electricity bill *MEB* if with net metering was calculated using

$$MEB = P_{DU} - R \quad (4)$$

## 3. Results and Discussion

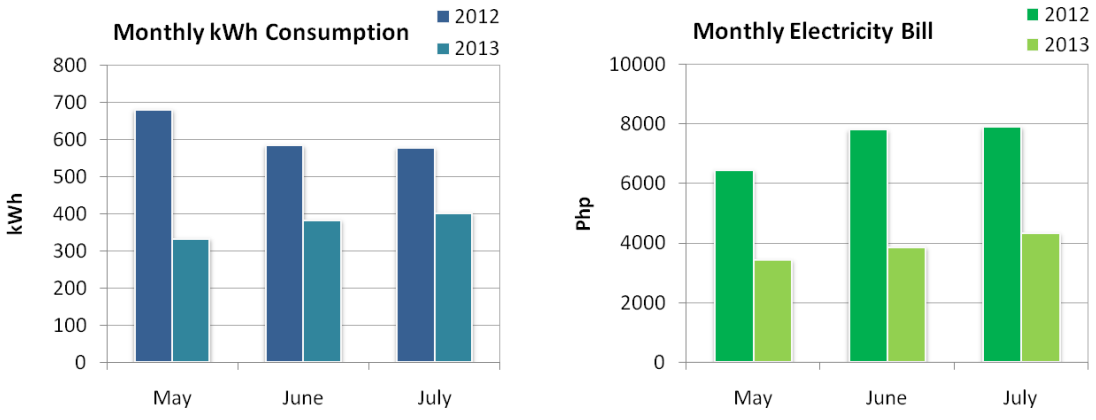
The meter readings during the months of May, June and July, the total energy consumed as calculated using the equations derived previously are shown in Fig 2. Without net metering, the effect of excess solar energy going to the utility grid is observed in Fig 2(a). The establishment's energy consumption during the 3 months decreased as indicated by the load meter reading. However, the grid meter reading increased considerably. This means that during peak sun-hours, most of the solar energy went to the grid and this contributed to the "consumption" as recorded by the grid meter. Using Eq. 3, the excess solar energy from the PV system was found to have increased during this period despite the slight decrease in generated solar energy, see Fig 2(b). Scheduling of activities requiring the use of electricity during peak sun-hours can address this problem. The calculated total energy consumption: computed solar and computed grid, determined using Eq. 1 and Eq. 2, respectively, is consistent with the total energy consumed by the establishment as recorded from the load meter.




**(a)** **(b)**

**Fig. 2 (a)** The meter readings during the months of May, June and July, and **(b)** the computed energy consumed from solar and from the grid together with the excess energy generated by the solar PV system.

The Year-Over-Year comparisons are shown in Fig 3. The figure shows a significant drop in the energy consumption and monthly electricity bill with the solar PV system in place. The increase in the electricity rates from Php 9.46 to Php 13.37 in 2012 is very evident in the opposite trends of the graphs. Fig 3(a) shows a decrease in kWh consumption between May and June, whereas the corresponding monthly electricity bill in Fig 3(b) increased.




**(a)** **(b)**

**Fig. 3** The Year Over Year comparison of **(a)** the energy consumption in kWh and **(b)** the monthly electricity bill of the establishment.

Moreover, the monthly electricity bill can be reduced further. In Fig 4, the comparison between the 2013 monthly electricity bill, the computed consumption from the grid (Utility), the savings from solar consumption and the rebate from excess solar generation if the net metering scheme were implemented are shown. Also in the graph is the monthly electricity bill *MEB* of the establishment if with net metering as calculated using Eq. 4. The solar PV system can generate energy to off-set the grid consumption of the establishment. If implemented, the net metering can provide rebates for excess generated solar energy that can further reduce the monthly electricity bill.

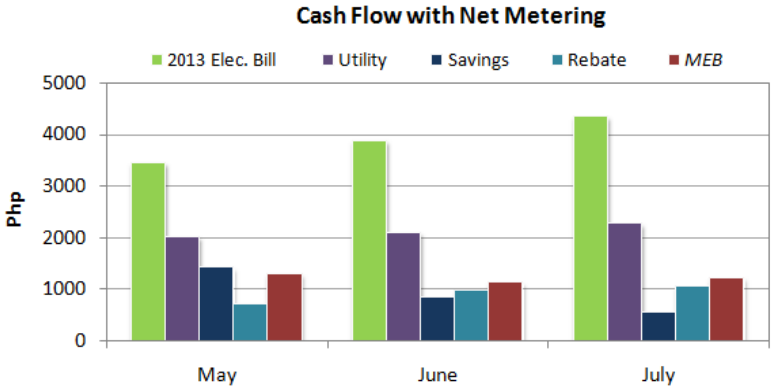



**Fig. 4** Comparison between the 2013 Monthly Electricity Bill and the computed Monthly Electricity Bill, Savings and the potential rebate from excess solar energy if the net metering were implemented.

The owners of the water refilling station, however, opted to divert the excess solar energy by providing a connection between their establishment and their nearby house since applying for the net metering will incur additional expenses on their side. In effect, their household load can be powered by solar during peak sun-hours and can substantially reduce the excess solar energy which contributes to their monthly electricity bill.

## 4. Conclusion

The 3 kWp solar PV system provided an uninterrupted source of energy and significantly reduced the monthly electricity bill of the water refilling station by at least 50% despite the setback brought about by the non-implementation of the net metering scheme. If the net metering scheme were to be implemented, the generated solar energy will earn the establishment rebates equal to the blended generation charge of the DU. This can further reduce the monthly electricity bill and improve the duration of return-on-investment.

## 5. Acknowledgement

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