Innovative Computing Review (ICR)
Volume 5 Issue 1, Spring 2024
ISSN$_{(P)}$: 2791-0024, ISSN$_{(E)}$: 2791-0032
Homepage: https://journals.umt.edu.pk/index.php/ICR

Article QR

Title:	**Computational Model for Net Metering Billing Optimization Using Python for Grid Economic Stability**
Author (s):	Osama Majeed Butt, Usama Arif*, and Ali Tahir
Affiliation (s):	Institute of Electrical Electronics & Computer Engineering University of the Punjab, Lahore, Pakistan
DOI:	https://doi.org/10.32350/icr.52.04
History:	Received: June 21, 2025, Revised: July 24, 2025, Accepted: August 22, 2025, Published: December 29, 2025
Citation:	O. M. Butt, U. Arif, A. Tahir, "Computational Model for Net Metering Billing Optimization Using Python for Grid Economic Stability," *Innov. Comput. Rev.*, vol. 5, no. 2, pp. 78-86, December. 2025, doi: https://doi.org/10.32350/icr.52.04.
Copyright:	© The Authors
Licensing:	This article is open access and is distributed under the terms of Creative Commons Attribution 4.0 International License
Conflict of Interest:	Author(s) declared no conflict of interest

A publication of
School of Systems and Technology
University of Management and Technology, Lahore, Pakistan

Computational Model for Net Metering Billing Optimization Using Python for Grid Economic Stability

Osama Majeed Butt , Usama Arif*, and Ali Tahir

Institute of Electrical Electronics & Computer Engineering University of the Punjab, Lahore, Pakistan

ABSTRACT Increasing trends towards the installation of Solar Photovoltaics (PV), as a renewable source, have gained popularity with the injection of energy into the grid system. Besides its advantages, it has also raised many concerns including technical as well as economic problems. Different models of billing this 'import' and 'export' of energy units are in use to calculate charges of electricity. Grids are becoming economically unstable due to the absence of limitations or putting conditions on injection of energy by distribution generators (DGs). This is not helpful for the grid network in terms of earnings and hence, becoming difficult for distribution companies to maintain their grid. Therefore, the proposed study aimed to address these challenges by developing strategies to ensure grids' economic sustainability and distribution companies' economic sustainability. The research utilized Python for modeling and analysis, enabling accurate simulations of billing mechanisms, energy flows, and their impacts on grid economics.

INDEX TERMS distribution generator, grid, net-metering, python, solar photovoltaics

I. INTRODUCTION

The increasing global demand for sustainable energy has sparked widespread interest in photovoltaic (PV) systems, positioning them as a vital alternative to traditional energy sources [1]. As more countries are moving towards embracing solar energy, there is a growing need to develop efficient billing models that not only incentivize renewable energy adoption but also ensure long-term financial sustainability for both energy providers and consumers [2]. In countries, such as Pakistan, the energy sector is grappling with severe challenges, including high electricity tariffs, frequent energy shortages, and an unreliable power grid [3]. These issues make the transition to renewable energy sources, particularly solar power, essential for fostering economic growth and stability [4].

Net metering and net billing are two significant policy frameworks that encourage the installation of grid-connected PV systems owned by electricity consumers. These policies play a crucial role in promoting the use of renewable energy by offering consumers with incentives to generate their own electricity while remaining connected to the public grid. Under the net metering model, the electricity generated and injected into the grid by a consumer is valued at the same rate as the electricity they consume from the grid (retail price) [5], [6]. This allows consumers to offset their energy costs more effectively. In contrast, net billing values the electricity fed back into the grid at a lower rate, often referred to as the wholesale or "avoided cost" price, which is less than the rate at which energy is consumed from the grid [4], [7].

Net metering was first introduced in the United States during the 1980s and has

*Corresponding Author: usamaarifbhatti594@gmail.com

since gained widespread adoption. Nearly all U.S. states now have net metering policies in place, albeit with various configurations. Some states offer simple net metering, while others include options for buy-back, rolling credit, or a combination of buy-back and rolling credit [4]. Over time, many other countries have adopted similar net metering and net billing policies to encourage the use of solar energy [8]. These frameworks have become instrumental in the global push towards renewable energy as they offer clear financial incentives for consumers to invest in small-scale PV systems.

In recent years, Net Energy Metering (NEM) has garnered substantial interest from a range of energy stakeholders, including regulatory authorities, utility companies, and policymakers. NEM represents an attractive investment opportunity, particularly for small-scale PV generation in the residential sector [9], [10]. This system is specifically designed for prosumers — individuals who simultaneously produce and consume energy. Furthermore, this enables them to offset the energy they consume with the energy produced by their own PV systems, such as rooftop solar panels. A key feature of NEM is the ability to consume and produce energy at different times. This feature distinguishes it from other frameworks, such as self-consumption or tax reductions for self-generated electricity.

Under NEM, the financial charge a prosumer incurs is based on the "net" amount of energy consumed and produced over a specified netting period, as outlined in the contract. If the amount of energy generated by the prosumer is less than the amount consumed (referred to as negative netting), the consumer may be charged either for the net energy used or for additional charges to cover grid-related services, such as transmission and distribution. In cases where the prosumers generate more energy than they consume (positive netting), NEM policies may allow for compensation of the excess energy at varying rates, or in some cases, no compensation at all [1].

As many countries approach grid parity — where the cost of producing solar energy becomes competitive with conventional energy sources [7] — the concept of self-consumption of PV-generated electricity is gaining considerable traction [9]. Self-consumption refers to the immediate use of the electricity generated by a consumer's PV system, typically within a 15-minute timeframe [11]. This has traditionally been the standard definition of self-consumption. However, it poses challenges for residential prosumers, whose energy production and consumption patterns often do not align.

Due to this mismatch between production and consumption, compensating prosumers for surplus energy that is fed into the grid can be a complex process. Various support mechanisms have been introduced to address this challenge, with net metering and net billing emerging as the most prominent policy solutions. These policies offer prosumers a way to earn credits or financial compensation for the excessive energy they supply to the grid, helping to reduce their overall energy costs.

At the global level, prosumers are anticipated to play a significant role in the expansion of PV installed capacity [12]. As this trend continues, many countries are shifting away from traditional Feed-in Tariff (FIT) policies, which guarantee a fixed payment for electricity produced by renewable energy sources, in favor of net metering and net billing schemes [13], [14]. These newer frameworks are seen as more sustainable and flexible, as they allow for the integration of renewable energy into the grid without placing an undue financial burden on energy providers [15].

In regulated net metering and net billing systems, the surplus electricity that prosumers feed into the grid is often rewarded with credits [16]. These credits can be applied to offset future energy consumption, providing a tangible financial incentive for individuals to invest in renewable energy systems [13]. This shift from FIT to net metering and net billing represents a broader global movement towards more efficient and consumer-friendly renewable energy policies. The success of these policies would be crucial in ensuring that the growing adoption of PV systems continues to contribute meaningfully to both environmental sustainability and economic growth.

This study proposed a billing model keeping in view the objective of encouraging distributing generators (DGs) to self-consume energy while discouraging the installation of overcapacity or beyond-need systems in order to avoid and minimize the injection of energy into the utility grid by DGs. Additionally, it would help the utility grid in having a sustainable economic situation while minimizing the liability of DGs (Solar Installations).

II. METHODOLOGY

A forecasted model was formulated to determine and analyze the economic reflection of the power grid. Using Python, advanced simulation frameworks were implemented to analyze various scenarios of energy import/export and their effects on grid economics. It was done for data processing, optimization, and visualization, while Python's flexibility allowed for detailed modeling of energy flows and billing mechanisms. This prediction was done to ease the financial pressure that could be faced by the distribution companies and utility grid due to the injection of power for domestic DGs (solar power producer residents). This model is termed as '90/10' model. As per the model, DGs would retain 90% of exported units for their own utilization, while power distribution companies would retain 10% of the total units exported by each residence each month. Furthermore, in deemed months (Nov, Dec, Jan) when utilization is less as compared to other months of the year, the share of the distribution companies for the exported units would increase to 30% of the total exported units. Additionally, a fix charge per month would be paid by each resident DG at the rate of Rs. 0.2/- per watt PV installed capacity. The tariff of 'Import' and 'Export' units will be determined based on the rates revised by the government/competent authority. Credits units (if any) for previous months would be converted and shown as credited amount after three months. The credited amount (if any) can only be used for adjustment of the bill of extra imported/used units by the consumer and cannot be cashed at any time.

This model does not use the Time-of-use (TOU) methodology, as 'peak' and 'off-peak' tariff is not accounted for during calculations for trading import/export units. For the current study, the utility grid was considered by the University of the Punjab. Moreover, DGs (a total of 38 connections) that were connected with this power grid system were selected by using bi-directional meters.

In this study, it was observed from data collection that maximum exported units that were injected into the grid by a DG after self-consumption were 60%, while the minimum injection was 40%. Python libraries of Pandas, and Matplotlib were utilized for numerical computation, dataset handling, and result visualization. Simulation algorithms modeled different scenarios of import/export ratios (40%, 50%, 60%) to forecast the financial implications on both consumers and distribution companies. A rule-based computational model was developed to implement the 90/10 Net Metering Model. The program dynamically adjusted calculations for normal months and deemed months.

Therefore, this model was run for three scenarios of injection of units based on data collection, that is, 40%, 50%, and 60%. Additionally, the tariff was determined to be Rs.60/- for import units, while Rs.21.42/- for export units for a DG. This tariff was already set based on the current tariff rate approved by the competent authorities. Equation (i) was used for the calculation of the profitability of the normal months, while equation (ii) was used for the calculation of the deemed months, that is, Nov, Dec, Jan. Here, the deduction ratio of units increased from '10%' to '30%'. This is because during these months, the utilization pattern was seen to be low, and a greater proportion of production units was injected into the utility grid. Therefore, more percentage of the produced units was deducted to reduce the financial burden on the utility grid in terms of payback to the prosumer, and encourage the prosumer for self-consumption. A complete flow diagram for the algorithm is shown in Figure 1.

$$\sum C_{fix} + (U_{export} * 0.10 * 60) \quad \text{(i)}$$

$$\sum C_{fix} + (U_{export} * 0.30 * 60) \quad \text{(ii)}$$

Similarly, the reflection of liability for the consumer can be predicted using equation (iii) for normal months, while equation (iv) for deemed months

$$\sum C_{fix} + (U_{export} * 0.10 * 21.42) \quad \text{(iii)}$$

$$\sum C_{fix} + (U_{export} * 0.30 * 21.42) \quad \text{(iv)}$$

Here C_{fix} = fix charges, U_{export} = exported units by respective DG

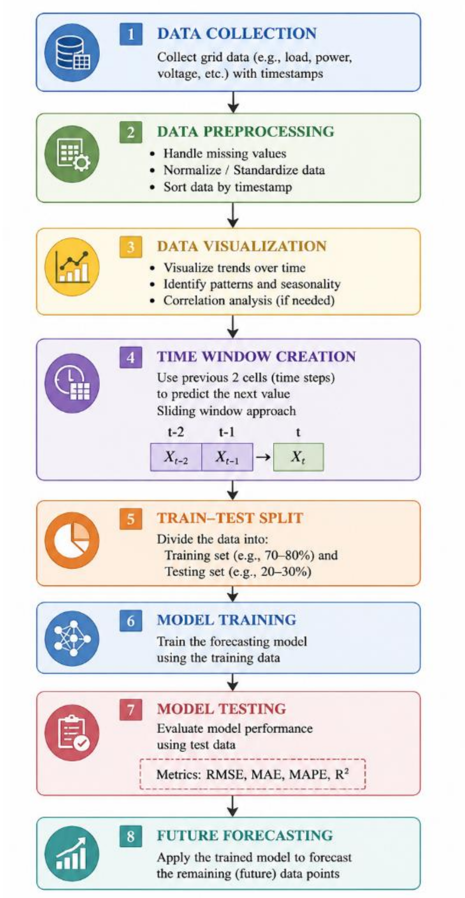

FIGURE 1. Flow Diagram of Algoritm for Forcasting of Billing Model

III. RESULTS AND DISCUSSION

The targeted sample distribution network (Punjab University) was classified into three categories based on the capacity of the installed solar system, that is, 6kW, 8kW, and 10kW. Furthermore, after analyzing the behavior of the DGs, these sites were studied on three different patterns of the total exported units to the network after self-consumption.

A. DG INSTALLED WITH 6KW SOLAR SYSTEM

Figure 2 shows the results of the proposed billing model as per the behavior and data collected from the users of 6kW DG site. According to the model, fixed charges would be implemented at Rs.1200/- per month. With 40% of exported units, an average of Rs.1600/- per regular month is earned by the grid, while in deemed months, this average is increased to 3200/- per month. Annually, a total of Rs.40000/- (approx.) is earned by the grid network with 40% exported units of the total produced. This profitability is in terms of electricity unit deduction and fixed charges. Whereas, consumers have a reflection of approximately Rs.23000/- liability annually. This profitability and liability increase to Rs.45000/- and Rs.25000/-, respectively when exported units are 50% of the total produced units after being self-consumed by DG.

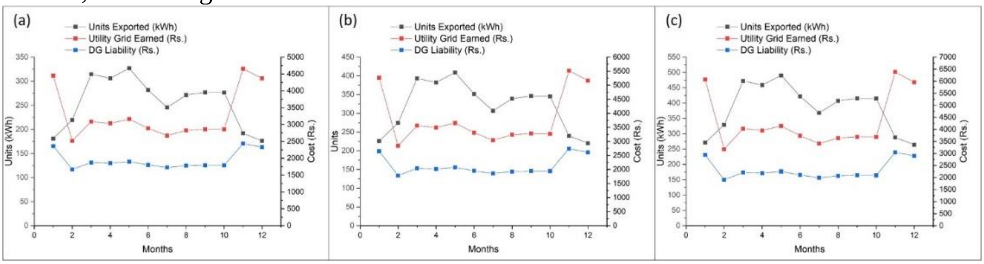

FIGURE 2. Data for units production, profitibality of the distribution network, and DG's liability of 6kW installed solar system with (a) 40% exported units; (b) 50% exported units; (c) 60% exported units

B. DG INSTALLED WITH 8KW SOLAR SYSTEM

Based on user behavior and data collected from the 8kW DG site, the results are shown in Figure 3. Under this billing model, a fixed charge of Rs.1600 per month is applied. With 40% of the total generated energy being exported, the grid earns an average of Rs.3800 per month, increasing to Rs.6000 during peak months. Annually, the grid earns approximately Rs.52000 but for the consumer, this creates an annual liability of around Rs.30000. If the exported energy rises to 50% of total generation after self-consumption, the grid's earnings increase to Rs.60000 annually, while the consumer's liability grows to Rs.35000.

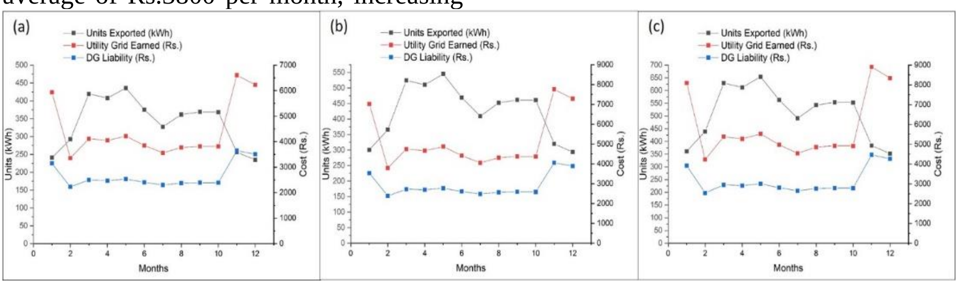

FIGURE 3. Data for units production, profitibality of the distribution network, and DG's liability of 8kW installed solar system with (a) 40% exported units; (b) 50% exported units; (c) 60% exported units

C. DG INSTALLED WITH 10KW SOLAR SYSTEM

Figure 4 summarizes the user behavior and data from the 10kW DG site. For 10kW site, fixed charges include Rs.2000 per month. Approximately, 40% of the total generated energy from 10kW system is being exported to grid which earns an average of Rs.4800 per month for the grid, increasing to Rs.7500 during peak months. Annually, the grid earns approximately Rs.65000. At the same time, the consumers face a liability of around Rs.38000. If the exported energy rises to 50% of total generation after self-consumption, the grid's annual earnings increase to Rs.76000, and the consumer's liability grows to Rs.42000. Similarly, if DG export approximately 60% of its total produced energy than grid would have a profit of Rs.85000. In contrast, DG may face a liability of Rs.46000 annually.

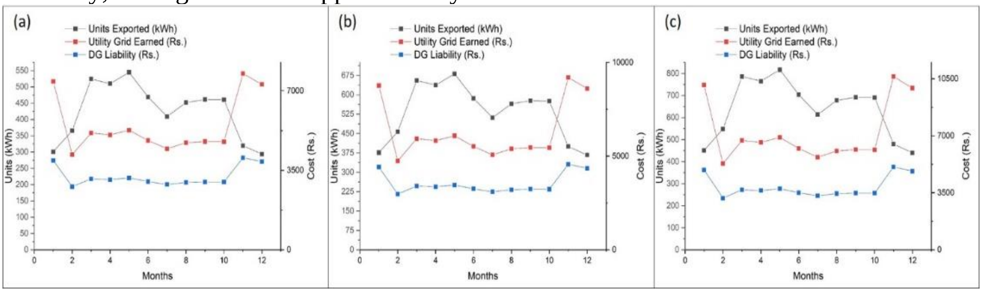

FIGURE 4. Data for unit production, profitability of the distribution network, and DG's liability of 10kW installed solar system with (a) 40% exported units; (b) 50% exported units; (c) 60% exported units

D. COMPARISON OF THE '90/10' MODEL WITH THE EXCITING MODEL

Currently, the net meter billing policy of Pakistan does not include the exporting of energy into the utility grid. According to the exciting net meter billing model, all exported units are adjusted against the imported units of the prosumer from the electrical utility network. Furthermore, surplus exported electrical units are converted into a credit amount on the fixed tariff. This results in 'zero' contribution of the electrical network provider in exported units despite providing essential electrical services. Therefore, utility grid networks have to bear all the financial and maintenance burdens. This model is eventually destabilizing the economic growth of the electrical utility grid.

The current '90/10' model is a step forward in which the electrical distribution network provider and prosumer become shareholders, and the utility grid could earn from prosumers in terms of electrical units and relieve financial stress. The current study showed that the electrical network provider could yearly earn approximately PKR 76000, 61500, and 45500 from a 10kW, 08kW, and 6kW prosumer, respectively, despite keeping its exciting tariff.

E. CONCLUSION

The billing model mentioned in this study could be beneficial for having an insight into the economic situation of the net metering billing mechanism. Moreover, it may be helpful in predicting the financial outcomes. Currently, studies show that this billing model might be helpful in earning the grid approximately 44% more than the financial liabilities to distribution generators, while no extra costs would have to be borne by the DGs. Directly, DGs would not suffer most of the cost as deduction is done in terms of energy unit. This difference in profitability and liability of utility grid and DGs is due to the difference in the unit exchange rate. Additionally, the study sought to encourage DGs to prioritize self-consumption of energy and discourage the installation of over-capacity PV systems. By achieving these goals, the study contributed to creating a more balanced and stable energy ecosystem while leveraging the computational power of Python for precision and efficiency.

Author Contribution

Osama Majeed Butt: conceptualization, writing – review & editing. **Usama Arif:** formal analysis, writing – initial draft. **Ali Tahir:** formal analysis, writing – initial draft.

Conflict of Interest

The authors of the manuscript have no financial or non-financial conflict of interest in the subject matter or materials discussed in this manuscript.

Data Availability Statement

Data supporting the findings of this study will be made available by the corresponding author upon request.

Funding Details

No funding has been received for this research.

Generative AI Disclosure Statement

The authors did not use any type of generative artificial intelligence software for this research.

REFERENCES

[1] C. E. Casillas and D. M. Kammen, "The energy-poverty-climate nexus," *Science*, vol. 330, pp. 1181–1182, Nov. 2010, doi: https://doi.org/10.1126/science.1197412.

[2] M. Moezzi, A. Ingle, L. Lutzenhiser, and B. O. Sigrin, "A non-modeling exploration of residential solar photovoltaic (PV) adoption and non-adoption," Nat. Renew. Energy Lab. (NREL), Golden, CO, USA, 2017, doi: https://doi.org/10.2172/1379469.

[3] O. M. Butt, M. Mohsin, R. Irfan, H. Ashfaq, and K. Habib, "A comparative simulative study to determine controller schemes of static var compensator (SVC) for stability of power system," *Mehran Univ. Res. J. Eng. Technol.*, vol. 44, pp. 1–12, 2025, doi: https://doi.org/10.22581/muet1982.0195.

[4] M. Irfan, Z.-Y. Zhao, M. Ahmad, and M. C. Mukeshimana, "Solar energy development in Pakistan: Barriers and policy recommendations," *Sustainability*, vol. 11, Feb. 2019, Art. no. 1206, doi: https://doi.org/10.3390/su11041206.

[5] M. Alrbai, L. Al-Ghussain, S. Al-Dahidi, O. Ayadi, and S. Al-Naser, "Techno-economic assessment of residential PV system tariff policies in Jordan," *Utilities Policy*, vol. 93, p. 101894, 2025, doi: https://doi.org/10.1016/j.jup.2025.101894.

[6] S. A. Sadat and J. M. Pearce, "Techno-economic evaluation of electricity pricing structures on photovoltaic and photovoltaic-battery hybrid systems in Canada," *Renew. Energy*, vol. 242, 2025, Art. no. 122456, doi: https://doi.org/10.1016/j.renene.2025.122456

[7] M. Asim *et al.*, "Opportunities and challenges for renewable energy utilization in Pakistan," *Sustainability*, vol. 14, 2022, Art. no. 10947, doi: https://doi.org/10.3390/su141710947.

[8] J. Khan and M. H. Arsalan, "Solar power technologies for sustainable electricity generation—A review," *Renew. Sustain. Energy Rev.*, vol. 55, pp. 414–425, Mar. 2016, doi: https://doi.org/10.1016/j.rser.2015.10.135.

[9] M. Alipour, H. Salim, R. A. Stewart, and O. Sahin, "Residential solar photovoltaic adoption behaviour: End-to-end review of theories, methods and approaches," *Renew. Energy*, vol. 170, pp. 471–486, May 2021, doi: https://doi.org/10.1016/j.renene.2021.01.128.

[10] O. M. Butt, T. M. Butt, M. H. Ashfaq, M. Talha, S. R. S. Raihan, and M. M. Hussain, "Simulative study to reduce DC-link capacitor of drive train for electric vehicles," *Energies*, vol. 15, June 2022, Art. no. 4499, doi: https://doi.org/10.3390/en15124499.

[11] M. F. Aziz and N. Abdulaziz, "Prospects and challenges of renewable energy in Pakistan," in *Proc. IEEE Int. Energy Conf. (ENERGYCON)*, Dec. 2010, pp. 161–165, doi: https://doi.org/10.1109/ENERGYCON.2010.5771667.

[12] R. Zafar, A. Mahmood, S. Razzaq, W. Ali, U. Naeem, and K. Shehzad, "Prosumer based energy management and sharing in smart grid," *Renew. Sustain. Energy Rev.*, vol. 82, pp. 1675–1684, Feb. 2018, doi: https://doi.org/10.1016/j.rser.2017.07.018.

[13] B. Knopf, P. Nahmmacher, and E. Schmid, "The European renewable energy target for 2030—An impact assessment of the electricity sector," *Energy Policy*, vol. 85, pp. 50–60, Oct. 2015, doi: https://doi.org/10.1016/j.enpol.2015.05.010.

[14] A. S. Alahmed and L. Tong, "Integrating distributed energy resources: Optimal prosumer decisions and impacts of net metering tariffs," *ACM SIGENERGY Energy Inform. Rev.*, vol. 2, pp. 13–31, 2022, doi: https://doi.org/10.1145/3555006.3555008.

[15] P. Benalcazar, C. Andrade, and W. Guamán, "Prosumer policy options in developing countries: A comparative analysis of feed-in tariffs, net metering, and net billing for residential PV-battery systems," *Polit. Energet.*, vol. 28, pp. 77–98, 2025, doi: https://doi.org/10.33223/epj/202801.

[16] L.-M. Li, B. Yuan, P. Zhou, and X. Zhou, "On the role of net metering and time-of-use pricing in distributed renewable energy adoption: A review and policy insights," *Energy Sci.*, vol. 2, no. 1, Jan. 2026, doi: https://doi.org/10.1142/s2972379526300014.