Spectrum of Engineering Sciences
ISSN (e) 3007-3138 (p) 3007-312X Volume 4, Issue 3, 2026

FROM NET METERING TO NET BILLING IN PAKISTAN: A COMPARATIVE FINANCIAL AND TECHNICAL ANALYSIS WITH GLOBAL POLICY REVIEW

Dr. Khawaja Haider Ali[1], Ahmed Khan[2], Shah Muhammad[3]

[1]*Department of Electrical Engineering Sukkur IBA, Sukkur, Pakistan*
haiderali@iba-suk.edu.pk
[2]*Department of Electrical Engineering Sukkur IBA, Sukkur, Pakistan*
ahmedzarkhan@gmail.com
[3]*Department of Electrical Engineering Sukkur IBA, Sukkur, Pakistan*
smbajkani@gmail.com

DOI: https://doi.org/10.5281/zenodo.20328412

Keywords
Net Metering, Net Billing, Distributed Generation, DISCOs, Grid Stability, Pakistan Solar Policy, SEPCO, Total Harmonic Distortion, Feed-in-Tariff, Net Billing Tariff.

Article History
Received on 20 January 2026
Accepted on 20 February 2026
Published on 27 March 2026

Corresponding Author: *

Abstract
The exponential increase of solar power distribution in Pakistan due to the net metering (NEM) regime has caused a critical problem for DISCOs both technically and financially. This paper provides a comprehensive comparison of the proposed net billing (NEB) approach and net metering. Based on 18 months of SEPCO billing data, we quantify the increasing financial challenge faced, indicating that there is a 146% yearly increase in prosumer export income in the face of decreasing grid consumption. Avoided cost-based net billing would ensure an absence of hidden cross-subsidy payments and a reduction of up to 71–76% of prosumer compensation per counterfactual study. The technical impact of solar systems installed as a result of NEM is investigated using the three-simulation scenarios of the 132 kV Larkana grid station. As the simulation results show, voltage fluctuations, excessive harmonics, and protection miscoordination caused by NEM have made the grid more unstable. While the taking an example of Sachal Colony fault scenario revealed even higher harmonics within the rest of the grid, DG full integration resulted in 11 kV busbars exceeding 5% voltage THD, and Industrial Feeder having 7.48% voltage THD. A systematic and well-staged roadmap for the transition from net metering to net billing in Pakistan is proposed in the conclusion of this paper, which further contrasts global policies on transition as well.

INTRODUCTION

Rooftop solar PVs have brought about radical changes in the energy profile of Pakistan. This was due to the introduction in 2015 by the NEPRA legislation on net metering, which allowed consumers to offset the price of electricity by returning surplus energy to the grid at the prevailing retail prices [1]. While this strategy has proven successful for the encouragement of renewable energy, it has led to unsustainable cost shifting, with prosumers receiving high rates and their costs of grid maintenance being lower compared to non-prosumer counterparts whose bills contain the cost of transmission/distribution network maintenance and capacity charges. The prosumers export more than they consume and therefore contribute less to grid maintenance costs, leaving those who are poor and cannot afford solar panels with higher costs. There are equally important technological implications. Pakistan's distribution grid was designed based on the premise of unidirectional power transfer, where the generated electricity was fed into the loads. System reliability and security are compromised due to voltage regulation issues, harmonics, protection coordination failure, and reverse power flow caused by rapid and erratic injections of power by DGs using inverters [3].

This research presents a complete evaluation of Pakistan's transition from NEM(Net-Metering) to NEB(Net-Billing) in terms of paradigm shift. There are four major objectives, which include: (1) applying the practical data from SEPCO for conducting empirical analysis on the growing financial implications for DISCOs; (2) conducting a counterfactual analysis by estimating the prosumer income loss due to the adoption of net billing and the gain to the power sector; (3) examining the technological implications of large DG integration by conducting a three-scenario ETAP simulation of the 132 kV Larkana grid substation; and (4) deriving learnings from the international policy shifts and preparing a complete policy advisory for Pakistan's policymakers.

II. LITERATURE REVIEW

A. Net Metering vs. Net Billing: Conceptual Framework

The system of net metering, which allows consumers to balance the consumption of power from the utility grid with their export of excess energy in a ratio of almost one-to-one on the basis of kilowatt hours, was what enabled this growth. Using two-way meters to calculate the net consumption during each billing cycle, the electricity distribution network effectively became a free storage facility for solar panel owners. Because of the economic incentive involved, coupled with rising electricity prices up to Rs 37–55 per unit, the return on investment for solar panels was brought down to three years [5]. In fact, the method implicitly values the electricity sold into the network at the entire retail tariff by adding energy tariffs, capacity costs, transmission and distribution wheeling charges, among others.

On the other hand, Net-Billing (NEB) does differentiate between imports and exports. With the enactment of new Distributed Generation Regulations in February 2026, NEPRA basically abolished the net metering arrangement and adopted a new net billing scheme for all prosumers. The NAEPP rate of around Rs 9 to 11 per unit for solar power export is being provided under the revised regime, while the rate for imported electricity remains unchanged as per the retail tariffs applicable. A significant amount of debate over issues such as equity, stability, and certainty has emerged owing to the above policy measure, which has been taken through predefined procedures without the involvement of any stakeholders. In all instances of imports, the prosumer must pay the full retail rate while exports will be compensated at a different rate, which is normally lower [5]. "Avoided cost," which is the utility's savings from not having to produce or purchase that unit of power and is equivalent to the wholesale rate of energy or LCOE, is what the correct exporting compensation rate should be based on. This distinction will address any problems involving cross-subsidization and cost shifting in NEM, especially because it will ensure the prosumer pays their share of the fixed costs of the grid.

B. International Case Studies: The Global Policy Shift

Moving away from retail rate net metering schemes to those reflecting the actual worth of the distributed solar generation represents an unmistakable global trend.

Australia: The same NEB framework is found in Australia's move from premium Feed-in Tariffs (FiTs) to a regime of low market reflective export tariffs even as imports are priced at regular retail tariffs. The gradual transition, with grandfather clauses included for earlier adopters, not only protected existing investments but also put an end to an otherwise unsustainable process of cross-subsidization. Above all else, the key takeaway from the process has been the importance of stable policy and honoring contractual commitments made by early adopters [6].

Vietnam: A "gold rush" in terms of solar development, which exceeded significantly the absorbing capacity of the power grid, was triggered by Vietnam's first FiT mechanism for NEM users at 9.35 US cents per kilowatt hour. The unexpected termination of the mechanism triggered a "solar cliff effect," leading to the suspension of market activities and the erosion of investor confidence.

California, USA: As such, with the change from NEM 2.0 to Net Billing Tariff (NBT), the amount of compensation for the export of energy dropped drastically, from around 0.30/kWh under retail rates, 0.30/kWh under time-varying avoided cost, to even as low as 0.05 $0.08/kWh. To encourage self-consumption, this export compensation was accompanied by battery storage incentives, particularly to reduce peak usage in the evening, the "duck curve" being well known. The experience of California indicates that export compensation policies should be coupled with battery storage incentives.

C. Technical Impacts of Distributed Generation Integration

Numerous technical challenges are posed by the integration of high-penetration dispersed generators in distribution systems designed to accommodate passive unidirectional flows of power [9, 10]. These technical challenges have been amply discussed in the existing literature.

Voltage Regulation and Reverse Power Flow: Under the assumption that there is a gradual fall in voltage from the substation to the loads, distribution feeders are normally constructed using voltage regulating devices (on-load tap changer, voltage regulator, capacitors). However, due to generation excess and low demand in the local area, DG injection leads to a rise in voltage beyond the law [11].

Harmonic Distortion: Power electronic interfaces such as PV inverters naturally produce harmonic currents in the distribution system. While each new generation of inverters complies with IEEE 1547 guidelines, the collective operation of multiple inverters from the same feeder may cause harmonic distortion beyond the limits imposed by IEEE 519 standards at the point of common coupling [12]. Harmonic distortion causes overheating of the transformer, increased losses, nuisance protective action, and premature failures of the capacitor bank.

Protection Coordination: Direction and amount of fault currents are altered through the use of DG. Overcurrent relays for the feeders may be rendered less sensitive due to reverse power flow, leading to what is referred to as "protection blinding"—whereby the protective systems of utilities fail to detect any faults that occur further down the line. The risk of unintentional islanding, which involves isolated sections of the feeder continuing to operate via DG supply, poses the greatest danger because it could lead to equipment damage and endanger the lives of workers [13].

Transformer and Feeder Overloading: High penetration levels could lead to reverse power flow exceeding the transformer's rated back-feeding capacity, despite the fact that DG could reduce overall demand on distribution transformers during power generation hours. In addition, new thermal stresses not accounted for during the initial asset assessment due to the shift in peak loading times induced by the solar generation profile may occur [14].

III. EMPIRICAL ASSESSMENT OF DISCO OPERATIONAL DATA

A. Trend Analysis of Net Export Volumes

The amount of net exports rose considerably from October 2024 to February 2026, based on a review of SEPCO's billing. The rise in net exports was due to both lower rates on solar systems factor and the growth in solar energy production. This data is presented in Table I below.

TABLE I: Monthly Net Import and Export Volumes with Export Value Assessment

Billing Month	Net Import (kWh)	Net Export (kWh)	Export Value Assessment (Rs.)
Oct-24	462,937	2,617,778	120,146,110
Nov-24	332,306	2,529,888	119,844,128
Dec-24	396,004	1,730,477	75,011,499
Jan-25	560,048	1,905,680	83,951,413
Feb-25	833,082	2,470,046	102,676,498
Oct-25	1,490,056	5,231,919	222,841,600
Nov-25	1,687,747	6,004,440	248,243,763
Dec-25	1,383,536	5,675,771	195,399,671
Jan-26	1,183,658	6,195,500	250,936,279
Feb-26	1,609,279	5,696,118	240,261,370

There is an alarming trend that is visible when one compares similar months of consecutive years.:

- **Export Volume Growth:** There was a rise of 131% in net exports from February 2025 to February 2026, from 2.47 GWh to 5.70 GWh. Consequently, there was a rise of 134% in the financial liability of SEPCO year-on-year, from Rs. 102.7 million to Rs. 240.3 million.
- **Import-Export Disparity:** Moreover, there was an increase in the net imports, from 833 MWh to 1,609 MWh when making comparisons with February. This suggests that customers with lower baseline consumption continue to be included in the NEM program. Importantly, new recruits of prosumers are net exporters who make minimal contribution to the recovery of the fixed costs via net imports.

Revenue-Expenditure Mismatch: The money spent on exporting in February 2026 (Rs. 240.3 million) is many times greater than what the revenue earned by prosumer imports can possibly be. Taking into account all duties and taxes, an average import tariff at the level of Rs. 45 per kWh would mean earning Rs. 72.4 million from imports, meaning a monthly loss of Rs. 167.9 million for this particular DISCO.

- This is a case of unfunded fixed costs that have to be distributed between all consumers. Consistent with solar power installations within DISCO operating areas, export quantities are approximately twice as large in late 2025 and early 2026 compared to those in late 2024. As can be seen from the seasonality effect, the export/import ratio in winter (November to February) is larger than that in autumn (October), implying smaller self-consumption in summer when air conditioning demand is lower. Such financial flows would also grow proportionately for more expansive DISCOs such as IESCO and LESCO, according to NEPRA, where there are the largest number of net-metering customers in the country.

B. The Capacity Charge Conundrum

This point can be seen from the following information. The energy that is not charged with the fixed cost of capacity is denoted by the "Net Export Units (kWh)" here. In terms of the regulations prevailing in Pakistan, the payment made for the fixed cost of capacity to the Independent Power Producers (IPPs) is a major portion of the total electricity charges. For instance, when a prosumer supplies 5,696 MWh in a single month, then this energy is further supplied to other consumers within its vicinity, but this prosumer cannot get anything related to the fixed cost of capacity from this energy.

Demand prediction and network planning become totally meaningless for the DISCO because of the random and unpredictable feedback from such distributed generation resources, which is derived from feeder shutdowns, load shedding schedules, local transient cloud cover conditions, and individual self-consumption patterns.

C. Counterfactual Analysis: Net Billing Implementation

A compensation amount using the NAEPP compensation rate, which was estimated to be Rs. 10 per kWh, was used on the actual export data in a counterfactual scenario to find out how much money will be minimized when net billing replaces net metering. This comparison is depicted in the last three months in Table II.

TABLE II: Comparative Compensation Under Net Metering vs. Net Billing

Month	Net Export (kWh)	Net Metering Value (Rs.)	Net Billing Value at Rs 10/kWh (Rs.)	Prosumer Revenue Reduction (Rs.)	Reduction (%)
Dec-25	5,675,771	195,399,671	56,757,710	138,641,961	71.0%
Jan-26	6,195,500	250,936,279	61,955,000	188,981,279	75.3%
Feb-26	5,696,118	240,261,370	56,961,180	183,300,190	76.3%

In the counterfactual analysis, it becomes evident that in the case of net billing at NAEPP rates, the incentive payment to producers exporting power is cut down by about 71-76% relative to the present value under net metering rates. As a result of such a reduction, the cross-subsidy inherent in the current net metering scheme through retail rates is removed. Such a drop in revenue plays a key role in the economic feasibility of the solar energy investment project, which is likely to increase the payback period by 2-3 years to around six to eight years.

As per DISCOs, the net billing system saves around Rs. 183 to 189 million monthly (data from February 2026) that would otherwise go toward uncollectable fixed costs. The total annual income retention of distribution companies as a result of implementation of the net billing system would be considerable in case the above mentioned figures are extended to the national level, where approximately 466,000 net-metering consumers exist with national average exports that far exceed SEPCO's data. It corresponds with NEPRA's objective of reducing the cost of non-solar consumers funding the fixed costs of the grid through increased tariff charges.

IV. TECHNICAL IMPACT ANALYSIS: ETAP SIMULATION OF 132 kV LARKANA GRID STATION

A. Simulation Methodology and System Description

For the determination of the technical impact of DG units' incorporation into the grid system, a comprehensive load flow and harmonic analysis were conducted for the 132 kV Larkana grid station substation through the use of ETAP version 19.0.1C. There are four 11 kV distribution feeders, namely the Industrial feeder, Jinnah Bagh feeder, Professor Colony feeder, and Sachal Colony feeder, which receive power from a 25 MVA, 132/11 kV power transformer.

Three different operational situations were modelled

- **Scenario 1 (Base Case)**: There is no tie with dispersed generation. Transformer is employed for powering all loads with the help of the 132kV transmission network.

Scenario 2 (Total DG Incorporation): Inverters are installed on four different feeders—Industrial (9.482 MW), Jinnah Bagh (1.354 MW), Professor Colony (1.764 MW), and Sachal Colony (0.664 MW). Unity power factor is being maintained by the generators. Total DG capacity is 13.264 MW.

Scenario 3 (Faulted/Shutdown/Loadshedding Feeder): Sachal Colony feeder was taken offline because of some fault condition. Other DGs located in Professor Colony, Jinnah Bagh, and Industrial feeders continue operating..

Harmonic spectra from the harmonic library of the ETAP program were selected for four harmonic inverter models: Inv1 and Inv3 (12-pulse, 30° phase shift), Inv2 (6-pulse, 0° phase shift), and Inv4 (12-pulse, 30° phase shift).

B. Load Flow Results and Discussion

Table III summarizes the key load flow parameters across all three scenarios.

TABLE III: Comparative Load Flow Results Across All Scenarios

Parameter	Scenario 1 (No DG)	Scenario 2 (Full DG)	Scenario 3 (Fault)
Grid Import (MW)	12.589 (Import)	−1.008 (Export)	−2.513 (Export)
Grid Reactive Power (Mvar)	6.025 (Import)	5.556 (Import)	4.504 (Import)
DG Generation (MW)	0.000	13.264	12.600
Total Demand (MW)	12.589	12.255	10.087
Transformer Loading (MVA)	13.956 (55.8%)	5.647 (22.6%)	5.158 (20.6%)
Total Active Losses (kW)	878.8	220.6	180.2
Total Reactive Losses	733.0	122.9	102.4

(kvar)			
11 kV Bus Voltage (%)	97.74	98.02	98.42

Reverse Power Flow: The reverse direction of power flow through the grid interface proves to be most significant. In the first scenario, the network takes 12.589 MW from the grid. On integrating all the DG sources, the system feeds 1.008 MW of power back to the transmission grid of 132 kV voltage level (Scenario 2). Since the excess power is fed at the higher voltage level, it becomes evident that the generation of DGs locally exceeds the overall distribution demand. With the exclusion of Sachal Colony feeder in the third scenario, the feed increases to 2.513 MW.

Reactive Power Anomaly: Significantly, while exporting active power, it still supplies reactive power (5.556 Mvar for Scenario 2). Since the inverters of the DG units are working under unity power factor conditions, they cannot supply the needed reactive power to the distribution load, as shown by the leading power factor of 0.179 at the grid interface. Losses and problems in voltage control are induced by the reactive power import through the transformer.

Voltage Profiles: Table IV presents the bus voltage magnitudes across scenarios.

TABLE IV: Bus Voltage Profile Comparison (% of Nominal)

Bus ID	Scenario 1	Scenario 2	Scenario 3	Trend
11 KV Grid Bus Bar	97.74 Marginal	98.02	98.42	Increasing
Industrial Feeder Bus Bar	89.44 Critical	100.49	100.88 Overvoltage	Over Increased
Jinnah Bagh Bus Bar	95.82 Marginal	97.62	98.02	Increasing
Professor Colony Bus Bar	96.39 Marginal	98.62	99.02	Increasing
Sachal Colony Bus Bar	95.27 Marginal	96.31 Marginal	— (Faulted)	—

Since the Industrial Feeder Bus Bar is experiencing critical under-voltage (89.44%) while three other bus bars are running under the 98% margin limit.

The introduction of distributed generation will affect voltage profiles significantly. With 9.482 MW of generation and 7.014 MW of load, the voltage level of the Industrial Feeder is increased to 100.49% (Scenario 2) and 100.88% (Scenario 3). This indicates the voltage control problem faced by the DISCOs due to unlimited distributed generation penetration, which results in a 11% change in voltage levels solely due to the addition of DG units.

Transformer Loading: Loading of apparent power of the transformer will reduce from 55.8% to 22.6%. This appears to be good, but one needs to consider the more important aspect of power flow in reverse direction. Tap changer control and protection of the transformer were not designed to operate in this condition.

C. Harmonic Analysis Results and Discussion

The most convincing evidence that confirms the quality power crisis caused by DG presence can be obtained through the harmonic load flow analysis. Voltage THD under different circumstances is analyzed in Table V below

TABLE V: Voltage THD Comparison Across Scenarios

Bus ID	Scenario 1 THD (%)	Scenario 2 THD (%)	Scenario 3 THD (%)	IEEE 519 Limit (%)	Status
11 KV Grid Bus Bar	0.00	**6.79**	**6.84**	5.0	Exceeds
Industrial Feeder Bus Bar	0.00	**7.47**	**7.48**	5.0	Exceeds
Jinnah Bagh Bus Bar	0.00	**6.89**	**6.93**	5.0	Exceeds
Professor Colony Bus Bar	0.00	**6.87**	**6.90**	5.0	Exceeds
Sachal Colony Bus Bar	0.00	**6.80**	— (Faulted)	5.0	Exceeds
BUS Bar 132 KV	0.00	0.03	0.03	2.5	Compliant

Scenario 1 provides an ideal base case, where there is no harmonic generation from any source within the distribution network when in its natural state. Each bus at 11 kV in Scenario 2 exceeds the IEEE 519 limit for voltage THD, which is 5%, suggesting that there is a serious issue regarding power quality within the network. As it has the greatest number of distributed generators (9.482 MW), the Industrial Feeder Bus Bar has the highest level of distortion, which is 7.47%.

In cases of 12-pulse inverters where there is incomplete harmonic cancellation, the dominant harmonic frequencies are the 11th (660 Hz), 13th (780 Hz), 23rd (1380 Hz), and 25th (1500 Hz).

D. Summary of Key Technical Findings

The ETAP simulation conclusively demonstrates that:

- **Voltage Regulation is Compromised:** Each feeder experiences overvoltages greater than 11 percentage points as a result of the incorporation of distributed generation, where the Industrial Feeder's performance changes from critical under-voltage at 89.44% to almost an over-voltage at 100.88%.
- **Reverse Power Flow is Inevitable:** The system now becomes an exporter to the 132kV grid at 13.264 MW total DG as compared to the 12.255 MW demand.
- **IEEE 519 Harmonic Limits are Universally Violated:** All five 11 kV bus stations exceed the voltage THD of 5%; the Industrial Feeder exceeds 7.48%.

4. **N-1 Contingency Exacerbates Harmonics:** N-1 Scenario Worsens Harmonics: In an already challenging operating environment, faulty feeders exacerbate power quality issues through increased harmonic clustering in the system.

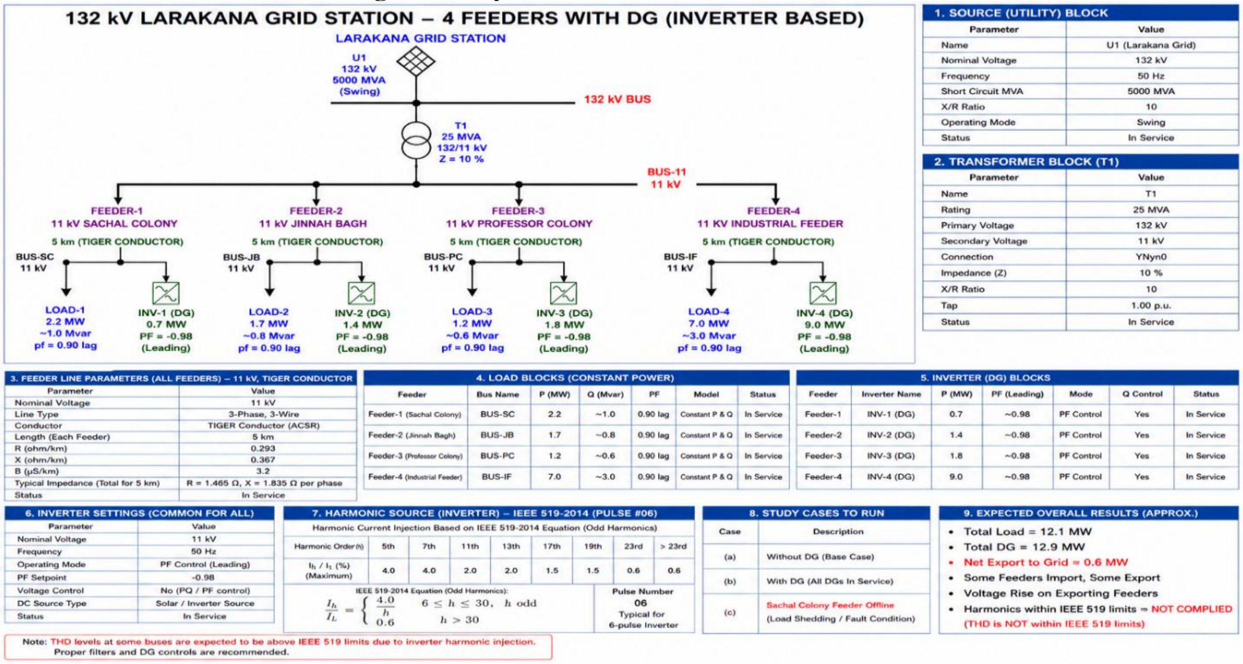

Figure 1: Figure Show ETAP-based single line diagram (SLD) of the 132 kV Larkana Grid Station integrated with distributed generation (DG) on multiple 11 kV feeders for load flow, back-feeding, voltage profile, and harmonic distortion analysis under various operating scenarios.

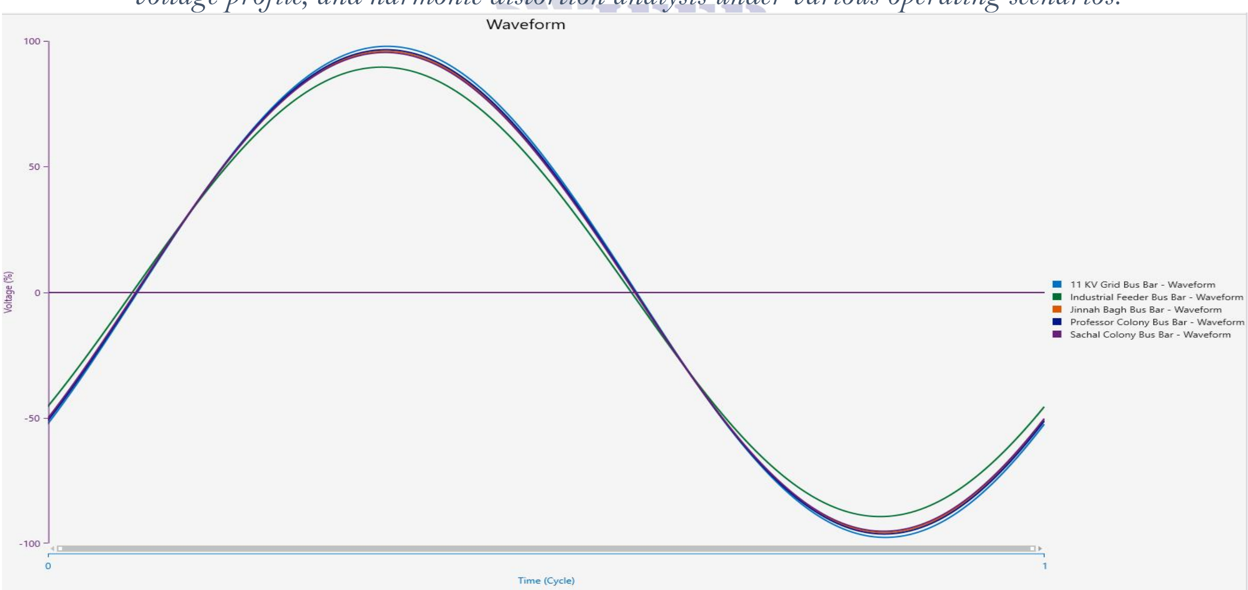

Figure 2: Shows the hormonic analysis on 11 KV Grid Bus Bar for the base case (No DG Connected)

Without having any distributed generation connected to the grid, here is the ETAP harmonic spectrum plot for the 11 kV busbar. From the graph, we can see no harmonics, which means that there are no sources of harmonics in the system by default. Unlike the scenario where distributed generation was connected, this gives us the ideal baseline.

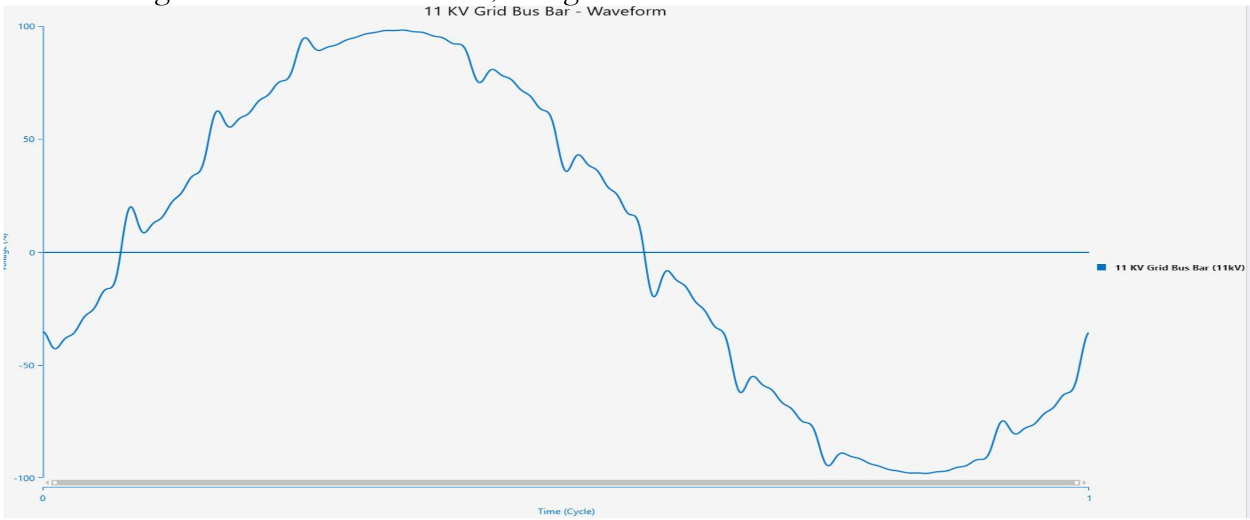

Figure 3: Shows the hormonic analysis on 11 KV Grid Bus Bar (Full DG Integration)

ETAP harmonic load flow results for Scenario 2 where all four feeders have DG installed with maximum capacity are depicted in this figure. The voltage THD results for each bus are provided; Voltage THD for 11 kV Grid Bus Bar = 6.79%, Industrial Feeder Voltage THD = 7.48%, Jinnah Bagh Feeder Voltage THD = 6.89%, Professor Colony Feeder Voltage THD = 6.87%, and Sachal Colony Feeder Voltage THD = 6.80%. All five buses of 11 kV exceed IEEE 519 voltage THD standard of 5.0%.

V. HOW NET BILLING MITIGATES TECHNICAL RISKS

In case of DG connections, the change in billing system becomes an automatic means to regulate demand. The flood of unauthorized connections will be automatically checked by reducing the motivation to export energy since the compensation rate will be reduced from Rs. 27+/kWh retail price to Rs. 10/kWh avoided cost. This economic check will provide DISCOs the much-needed breathing space to make the necessary technological changes:

Hosting Capacity Analysis: Hosting capacity studies can be conducted by DISCOs on selected 11 kV circuits with minimum applications for DG integration so that the maximum amount of DG that can be accommodated is established without violating voltage, harmonic, or protective constraints.

Protection System Upgrade: In this case, the use of overcurrent relays is upgraded to include directional overcurrent relays that have the capacity to differentiate between forward and backward fault currents. Communication-based protection systems are also used where needed.

Advanced Inverter Functionalities: In order to enable self-regulation of voltages that eliminates the problem of voltage swings observed in the simulation, it may be required for the new installation of inverters to incorporate Volt-VAr and Volt-Watt control functions (IEEE 1547-2018 compliant).

System Strengthening Investments: Controlled DG growth allows DISCOs to plan and execute reinforcement measures like reconductoring, transformer upgradation, and harmonic mitigation through proper planning rather than reacting to crises.

Harmonic Mitigation: These issues in the IEEE 519 standards discovered from the harmonics analysis have been catered to by reducing inverter density and specifications of inverters that should exhibit low harmonic generation (preferably 12 pulse or multilevel inverters).

VI. POLICY ANALYSIS AND RECOMMENDATIONS

A. Stakeholder Impact Assessment

Table VII summarizes the advantages and disadvantages of NEM versus NEB for each stakeholder category.

TABLE VII: Stakeholder Impact of Net Metering vs. Net Billing

Stakeholder	Net Metering (Current)	Net Billing (Proposed)
Prosumer	**Advantage:** Savings on electricity bills and quick recovery within two to three years.. **Disadvantage:** Costly, and will encounter more social and regulatory opposition.	**Advantage:** Fair share grid costs enhance battery storage's economics in terms of payback. **Disadvantage:** Lowered ROI and increased payback periods of 6 to 8 years.
Non-Solar Consumer	**Advantage:** None. **Disadvantage:** The company must cover capacity costs and fixed costs by increasing rates.	**Advantage:** Less cross-subsidy, more stability, and lower tariffs in the future. **Disadvantage:** None direct.
DISCO/Government	**Advantage:** Helps to meet targets on renewable energy.. **Disadvantage:** Impossible to predict demand, unstable, inability to recover capacity costs, and loss of income.	**Advantage:** Good demand forecast, a sustainable business model, an appropriate rate of technology adoption, and proper cost allocation. **Disadvantage:** There might be the risk of stopping the solar market if the move is abrupt..

B. Phased Policy Roadmap: From Net Metering to Net Billing

A consistent, reliable, and clear strategy must be employed to ensure success during the transition process to avoid the problem of "solar cliff" experienced by Vietnam. It is recommended that the following multi-tier strategy be adopted:

Phase 1 — Short-Term (0–12 Months): Immediate Corrective Actions

1. **Grandfathering Clause:** Assert definitively that during the course of the licensing period (minimum 7 years from the date of connection), all existing net metering customers as well as those with approved applications for connection shall continue to receive their existing retail export payments.

. **Immediate Net Billing for New Applicants:** Announce the inclusion of all future projects of distributed generation within the net metering system, commencing with effect from a particular cut-off date (say 90 days from announcement), and the export incentive price being fixed at the rate of avoided cost determined by NEPRA (estimated to be Rs. 10/kWh).

. **Mandate Advanced Inverter Functions:** As per IEEE 1547-2018 standard or otherwise, revise the Distribution Code to state the requirement that Volt-VAr and frequency-watt control features be provided for all newly installed DG systems. These problems associated with voltage control and harmonics identified through the ETAP simulation have been explicitly accounted for.

Phase 2 — Medium-Term (1–3 Years): Enabling Market Transformation

1. **Time-of-Use (ToU) Net Billing:** Time-dependent export prices must be included in the net billing scheme. To specifically alleviate constraints on grid peaks, a higher export price during peak demand periods (such as between 6 pm and 10 pm) will favor west-facing solar PV systems or battery discharge.
2. **Battery Storage Incentive Program:** Provide home and business battery storage systems either a cash back reward, tax credit, or a discount rate finance option. It is the only technology that can turn the consumer into a valuable asset to the grid system by offering
3. **DISCO Hosting Capacity Maps:** The requirement that all DISCOs develop and release GIS maps, which update every quarter and show the DG connection capacity left in each 11kV feeder, is a good step towards regulation. It helps attract investment from prosumers into areas with available grid capacity.

Phase 3 — Long-Term (3+ Years): Full System Integration

1. **Distribution System Operator (DSO) Model:** The DISCOs ought to evolve to become Active Distribution System Operators rather than the passive role they have been playing until now. This will involve establishing platforms within the market where ancillary services (voltage management, frequency regulation, and reactive power) can be offered by the battery-equipped prosumers with smart inverters.
2. **Dynamic Export Limits:** Develop an operating envelope system that allows DISCOs to notify smart inverters on restrictions on exporting power at times of emergency situations in the grid system, while allowing unrestricted exports at other times to maximize distributed generation. Equity for prosumers will be assured by compensating them for lower energy consumption.
3. **Harmonic Mitigation Standards:** Set limitations on mandatory contributions to harmonics by each inverter and at each connection point using data from research projects, such as those carried out for the Larkana grid. These limitations will be enforced using type testing certification criteria.

VII. CONCLUSION

In Pakistan, the transition from net metering to net billing is a much-needed structural change for a tariff structure which is now, quite frankly, unsustainable, unjust, and risky from a technical standpoint rather than being anti-solar. An indisputable empirical demonstration of an unsustainable financial trend where export obligations keep rising every year without any contribution to grid fixed costs is found in the SEPCO billing figures. Based on counterfactual analysis, net billing using avoided costs will eliminate between 71% and 76% of the embedded cross-subsidy.

The qualitative technical data lacking in the policy discussion is delivered through the ETAP simulation analysis of the 132 kV Larkana grid substation. It becomes evident that all the 11 kV buses studied in this paper are beyond the IEEE 519 standards for harmonic distortion due to complete DG integration, with voltage THD on the bus with the highest DG penetration rate being at 7.48%. The N-1 contingency analysis demonstrates how faults on feeders affect power quality under stress operating conditions, leading to concentration of harmonics in the rest of the network.

Clearly defined lessons can be derived from international experiences, ranging from California's net billing system coupled with energy storage to Vietnam's abrupt change in policy to the gradual process followed in Australia. The three essential elements of a successful transition include the predictability of policies, grandfathering of existing projects, and the integration of storage with export compensation.

The current scenario in Pakistan stands at a critical juncture, with the current trajectory for net metering unjust to consumers without solar PV installations and not economically viable for DISCOs. Data obtained from technical reports clearly indicates the imminent threat posed to the power quality and reliability of distribution networks due to excessive DG growth. The phased approach to the adoption of an optimal DSO framework as proposed herein offers a clear way forward to a sustainable distributed generation paradigm.

REFERENCES

[1] National Electric Power Regulatory Authority (NEPRA), "Net Metering Regulations for Solar PV and Wind Energy Systems," S.R.O. 716(I)/2015, Islamabad, Pakistan, Sep. 2015.

[2] T. Ahmed and A. A. Sheikh, "Impact of net metering on the financial health of electricity distribution companies in Pakistan," *Energy Policy*, vol. 158, p. 112567, Nov. 2021.

[3] F. Katiraei and J. R. Aguero, "Solar PV integration challenges," *IEEE Power and Energy Magazine*, vol. 9, no. 3, pp. 62–71, May–Jun. 2011.

[4] A. Poullikkas, "A comparative assessment of net metering and feed-in tariff schemes for residential PV systems," *Sustainable Energy Technologies and Assessments*, vol. 3, pp. 1–8, Sep. 2013.

[5] NEPRA, "Proposed Amendment to Net Metering Regulations: Net Billing Mechanism," Consultation Paper, Islamabad, Pakistan, 2024.

[6] Clean Energy Council, "The Future of Solar Energy in Australia," CEC Policy Paper, Melbourne, VIC, Australia, 2021.

[7] M. D. P. Nguyen, N. Ha-Duong, and A. Minh, "Vietnam's solar power boom: Drivers, challenges and policy implications," *Energy Research & Social Science*, vol. 70, p. 101762, Dec. 2020.

[8] California Public Utilities Commission, "Decision Adopting Net Billing Tariff," Rulemaking 20-08-020, Decision 22-12-056, Dec. 2022.

[9] IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces, IEEE Std 1547-2018, 2018.

[10] R. A. Walling, R. Saint, R. C. Dugan, J. Burke, and L. A. Kojovic, "Summary of distributed resources impact on power delivery systems," *IEEE Trans. Power Delivery*, vol. 23, no. 3, pp. 1636–1644, Jul. 2008.

[11] P. M. S. Carvalho, P. F. Correia, and L. A. F. M. Ferreira, "Distributed reactive power generation control for voltage rise mitigation in distribution networks," *IEEE Trans. Power Systems*, vol. 23, no. 2, pp. 766–772, May 2008.

[12] IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems, IEEE Std 519-2014, 2014.

[13] H. H. Zeineldin, E. F. El-Saadany, and M. M. A. Salama, "Impact of DG interface control on islanding detection and non-detection zones," *IEEE Trans. Power Delivery*, vol. 21, no. 3, pp. 1515–1523, Jul. 2006.

[14] K. D. McBee and M. G. Simoes, "Evaluating the long-term impact of a continuously increasing PV penetration on distribution transformers," *IEEE Trans. Industry Applications*, vol. 50, no. 3, pp. 2165–2173, May–Jun. 2014.