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Distribution Losses in Pakistan's Power Sector and Grid Support Benefits of Distributed Solar PV

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Policy Research Institute For Equitable Development

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Introduction

The power sector of Pakistan is beset by significant transmission and distribution (T&D) losses and bill collection problems—costing the national exchequer billions of losses annually. As of 2021, the T&D losses by the state-owned distribution companies (DISCOs) reached Rs 110.4 billion—of which Rs71 billion were contributed by technical losses [3].

Consequently, despite surplus energy, power cuts are widespread, especially in the high-loss feeders. So, what are these losses? These losses are attributed to several factors. The electricity procured at the generating sites requires a series of networks before it reaches the end customer. This includes transformers, overhead lines, cables and other equipment. T&D losses denotes the power lost during the transmission of (high voltage) energy from power generation to the distribution, as well as the distribution of electricity at low voltages to the end-users. Given the intrinsic nature of distribution network of electrical power system, the amount of energy generated always differs from the amount of energy that reaches the end customer.

Overall total energy losses in power systems can be grouped by sources into technical losses and non-technical losses. The former denotes the physical losses occurred during transfer of electricity, whereas the latter refers to the unaccounted energy i.e., electricity consumed but not billed due to theft or non-metered connections.[1] A power network experiences all these types of losses (see Fig. 1) and their accountability is imperative to maintain a healthy network.

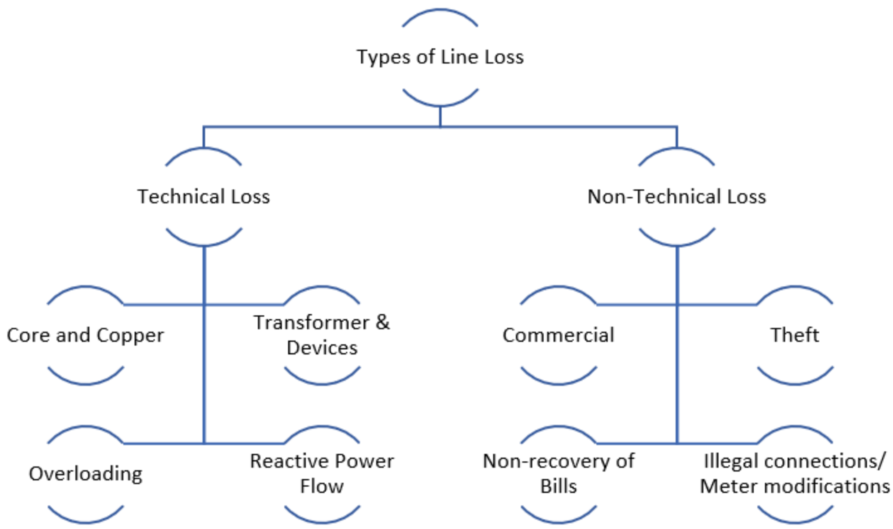

FIGURE 1: TYPES OF LOSSES IN A T&D POWER SYSTEM.

While DISCOs are at the core of longstanding inefficiencies in the power distribution sector, their consistent poor performance and breach of annual targets set by National Electric Power Regulatory Authority (NEPRA) remained a subject of policy debates. Due to the rampant and consistent poor performances by the DISCOs in terms of both technical and non-technical losses, several measures

[1] Among several other factor, length of distribution lines; size of distribution line conductors; proximity of distribution transformers to load centers; power factor of primary and secondary distribution system are major factors that adds to the line losses. Competence of technicians; fluctuation in power utilization by customer; load and no-load core losses of transformers; unequal load distribution among three phases; leaks and loss of power; overloading of lines; abnormal operating conditions; low voltages at consumer terminals; power quality of equipment etc., account for the overall technical side of distribution loss.

have been introduced in the past, which tend to either directly or indirectly improve the performances of the DISCOs (see Table.1). However, the reactive bureaucratic and entity level resistance has not resulted in inconclusive results to such discussions and we still see a fragile power distribution sector.

Performance Standards (Distribution) Rules, 2005

DISCOs are required to submit Annual Performance Reports to NEPRA, which should at least include information on system performance, consumer services performance, and plans for improvement. The performance is marked against set targets on specific parameters including T&D losses, financial recovery, planned and unplanned load shedding hours, and served consumer services complaints. Any non-compliance with the set standards has associated penalties.

Attribution of funds for T&D network improvements

NEPRA sets targets for DISCOs to contain their T&D losses under certain limits and also allows DISCOs to invest in infrastructural improvements to reduce T&D losses. From the allowed investments, DISCOs can take up projects to remove system constraints, reduce length of feeders, and introduce automated metering and preventive maintenance.

Despite the provision, however, DISCOs show reluctance to take up any such projects to improve their T&D losses. The NEPRA's latest annual performance evaluation report of DISCOs further states that in last seven years, more than Rs350 billion have been allowed to DISCOs for reduction in losses, network improvement, and customer facilitation etc. However, not even 1% of T&D loss has been reduced based on overall DISCO's average.

Bifurcation/trifurcation and privatization of DISCOs

NEPRA recommends structural reforms in DISCOs to improve their performance by bifurcation and trifurcation of larger DISCOs and also privatization of DISCOs.

Distribution Franchisee Model

Distribution Franchisee (DF) Model is one of the proposed models by the past government to help DISCOs rebound their efficiency levels and reduce losses. Through this model, the DISCOs can outsource some of their functions (such as bills recovery and asset management) to private sector, without losing the ownership. Besides outsourcing, the Distribution Franchisee Model can also take forms such as input-based distribution franchisee where the DF purchases electricity from the DISCO at a predetermined rate and then takes on responsibility of billing and risk of recovery. Another form it can take is collection-based distribution franchisee in which the DF works on billing and improvement of collection.

Net metering

Net metering is a measure introduced by NEPRA in 2015, which targets not only mass adoption of renewables close to consumption end across the country but also reliefs DISCOs by reducing dependence on the grid and lowering their technical losses. NEPRA also established a framework to regulate the renewable energy-based distributed generation and net metering namely "NEPRA (Alternative & Renewable Energy) Distributed Generation and Net Metering Regulations, 2015" and amended later in 2017 (the DG and Net Metering Regulations).

The DG and Net Metering Regulations provide templates for agreement between the relevant DISCO and the Distribution Generator, generation license template between the Distribution Generator and NEPRA, *besides setting delegation of responsibilities and obligations between the Distribution Generator and the DISCOs.*

<u>Policy for development of renewable energy for power generation, 2006 (RE Policy)</u>

The RE Policy identifies the potential of distributed generation (DG) in reducing the technical losses of the transmission and distribution system. It stipulates formulation of directed policies for promotion of distributed generation to achieve economic benefits in the form of efficiency gains and losses reduction.

<u>Alternative and Renewable Energy Policy 2019 (ARE Policy 2019)</u>

The ARE Policy 2019 sets target for augmenting share of on-grid renewable energy (RE) in the country's generation capacity to at least 20% by 2025 and 30% by 2030. Any off-grid RE additions in the form of mini-grids and micro-grids are will also be considered towards achieving this target as per the ARE Policy 2019.

While the ARE Policy 2019 avoids the role of circumscribing rules around distributed generation and leaves it to the market, it stipulates measures to facilitate the promotion of distributed generation. It requires that the National Transmission & Despatch Company (NTDC)/DISCOs shall ensure provision of their distribution and transmission network for sale of electricity through mini and micro-grids and net metering and wheeling. Whereas, in case of any dispute, NEPRA will be addressing the concerns under its applicable laws.

<u>National Electricity Policy 2021</u>

The National Electricity Policy delineates a policy direction for distribution and supply end of the energy sector value chain. Reduction of DISCOs' losses and improvement of their performance is also a focus in the policy, and it requires each distribution company to create a roadmap with consultations from the Ministry of Energy. The restructuring of DISCOs is also considered as a possible option to achieve the objectives set out in the National Electricity Policy.

TABLE 1: INITIATIVES, PLANS AND POLICIES TO REDUCE LOSSES

Access to affordable, reliable, and sustainable energy is recognized as a basic human right. The distribution losses not only result in increased prices, but also long hours of revenue-based load-shedding are exercised as part of the demand-side management policies, while the consumers have to put up with these power cuts. This represents a significant challenge and has consequences to all sectors—specifically to high-loss geographical zones.

So, what could be done to improve distribution performance? Strategically sited solar photovoltaic (PV) applications and solar PV penetration in high-loss configurations offers an irresistible and necessary alternative to improve energy access (electrifying the last mile and improving reliable access to energy). It can also address the longstanding technical and inter-linked financial losses in the power sector.

In this issue of the quarterly energy monitor, we discuss in-depth the potential use of DG as a measure to address existing T&D losses, the necessary technical conditions and the regulatory environment. . The issue also covers the need for innovative business models for their successful deployment, and share few case studies from around the world for a global perspective.

State of the art: Distribution losses in the power sector of Pakistan

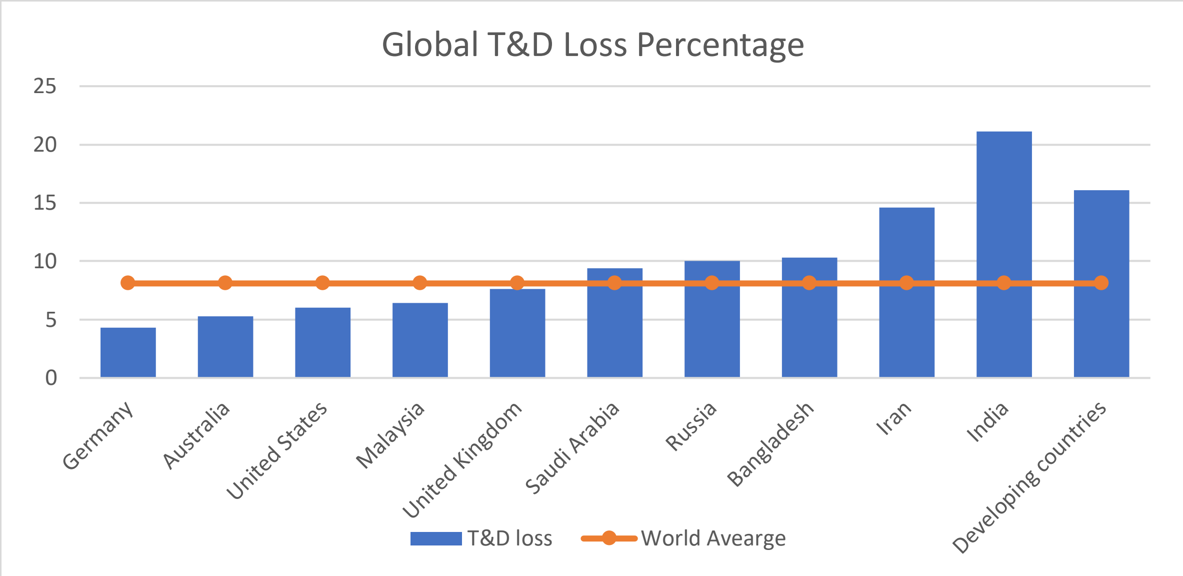

FIGURE 2: GLOBAL LINE LOSS PERCENTAGES FY 2014 (% OF OUTPUT) [1],[2]

The power systems globally are inherently bounded with grid losses[2]. The world bank reported that globally, the average global transmission and distribution loss stands at 8% [1]. Cross-country comparisons, however, do not paint a very straightforward picture where in some countries these losses are very high, while in others not so. Fig. 2 illustrates the global line losses (percentage of output)[3] and gives a general picture on loss situation worldwide.

According to government mandate of European Union, Distributed System Operators (DSOs) are responsible of reducing the losses of distribution system by 1.5% each year through prudent grid integration techniques. If the losses go beyond those specified by the regulator, DSOs have to compensate it at their own cost [5].

In the case of Pakistan, the average losses exceed 20%—costing the national exchequer billions annually. In 2020-2021, the technical losses suffered by DISCOs amount to Rs71 billion, and financial loss due to theft and low recovery reached Rs39.4 billion [3]. These losses also have been significantly contributing to the circular debt—and have adversely affected the distribution companies' profitability and quality services from past several years. Fig. 3 shows the average transmission and distribution losses encountered by Pakistan power sector since 2015, whereas Fig. 4 shows the disco-wise losses in 2021.

[2] Grid losses or energy losses in power systems are defined as the difference between the total injected energy and the total withdrawn energy in the system over a period of time.
[3] The graph uses latest data available on WDI

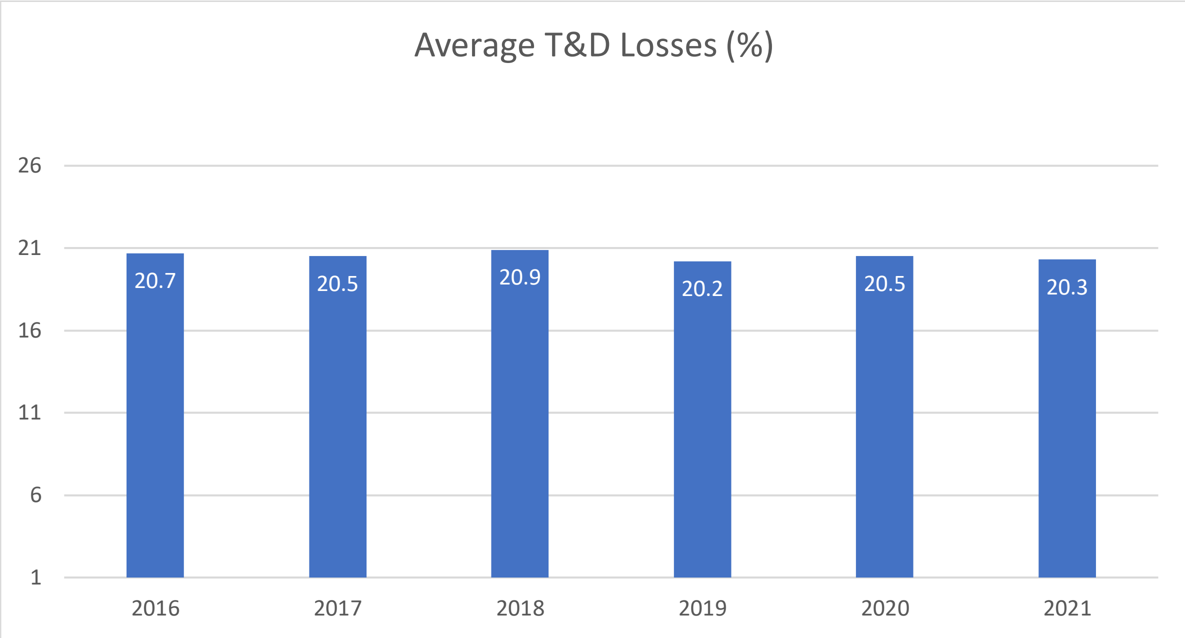

FIGURE 3: AVERAGE T&D LOSSES (NEPRA, 2021)[3][4]

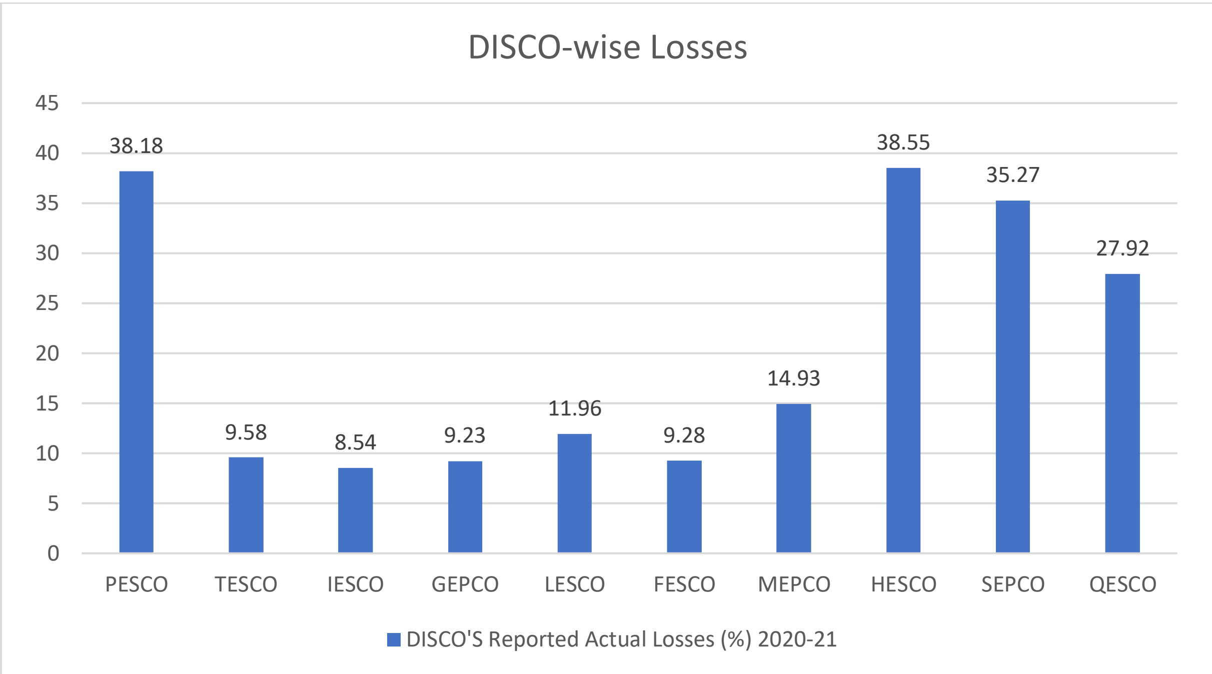

FIGURE 4: DISCO'S REPORTED ACTUAL LOSSES 2020-21 (NEPRA, 2021) [3], [4]

NEPRA has established T&D loss limits for each DISCO through consumer-end tariff evaluations. The DISCO is responsible for any losses that surpass the predetermined target losses. Fig. 5 showcases that majority utilities have breached the NEPRA allocated targets. Despite all this, the government continues to bailout distribution companies every year to keep them afloat.

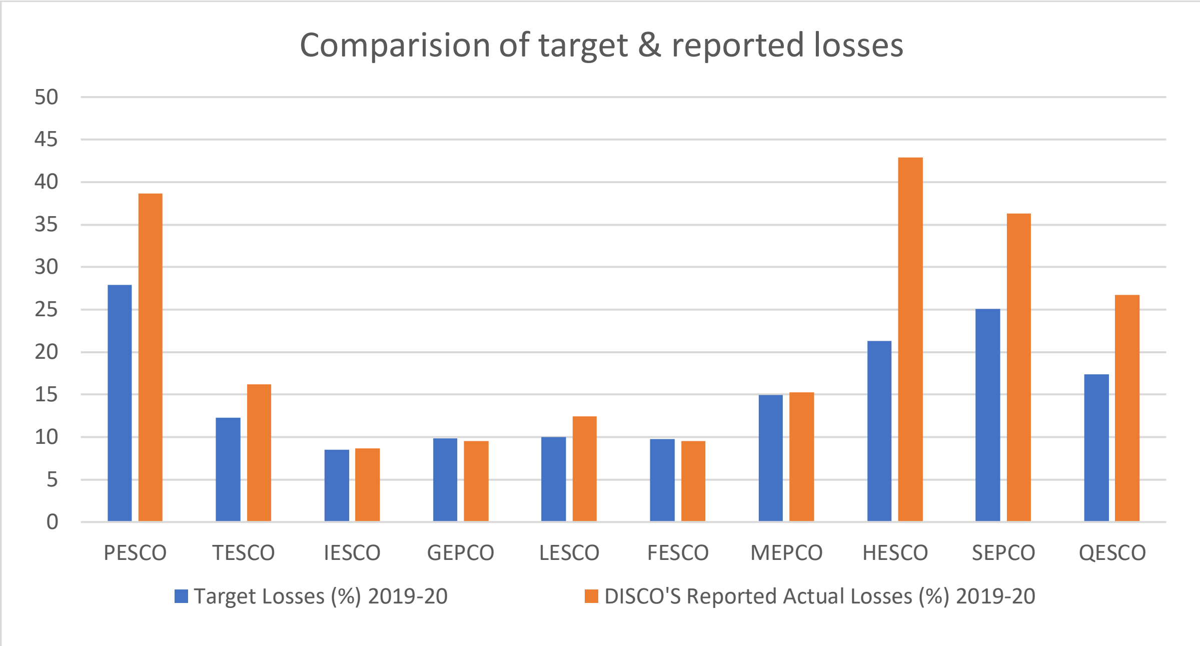

Figure 5: Comparison of Targeted & reported losses (NEPRA, 2021) [3], [4]

Most of the distribution companies in the country have T&D losses exceeding 15%, with the exception of four utilities namely Faisalabad Electric Supply Company (FESCO), Gujranwala Electric Power Company (GEPCO), and Lahore Electric Supply Company (LESCO) and Islamabad Electric Supply Company (IESCO). In 2019-20, PESCO had the highest loss rate of 38.9%, followed by SEPCO with 36.3%. The best-performing utilities i.e., FESCO and IESCO experienced losses of less than 10%. In Punjab, all DISCOS have collection rates of over 94%. However, in the case of Sindh, Baluchistan, and Khyber Pakhtunkhwa (KP), these percentages decline substantially. The financial costs associated with the imbalance in recovery ratio across all utilities is shown in Fig. 6 and Fig. 7.

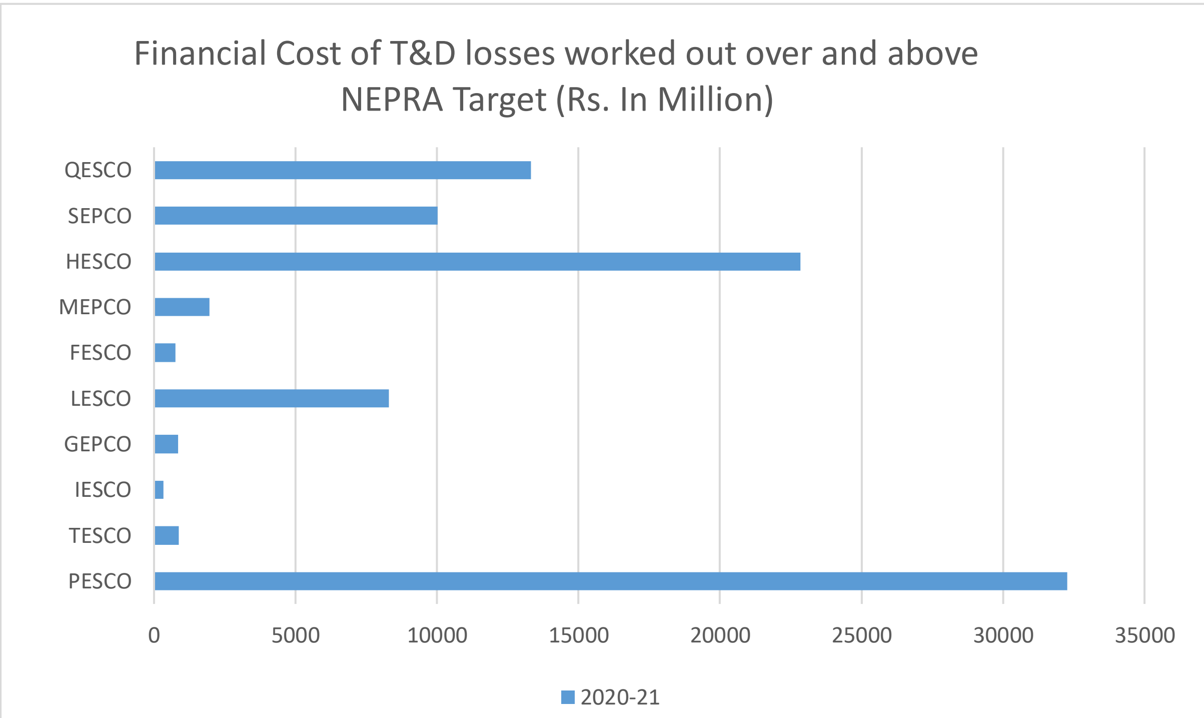

Figure 6: Financial Costs of T&D Losses across Utilities (NEPRA, 2021) [3], [4]

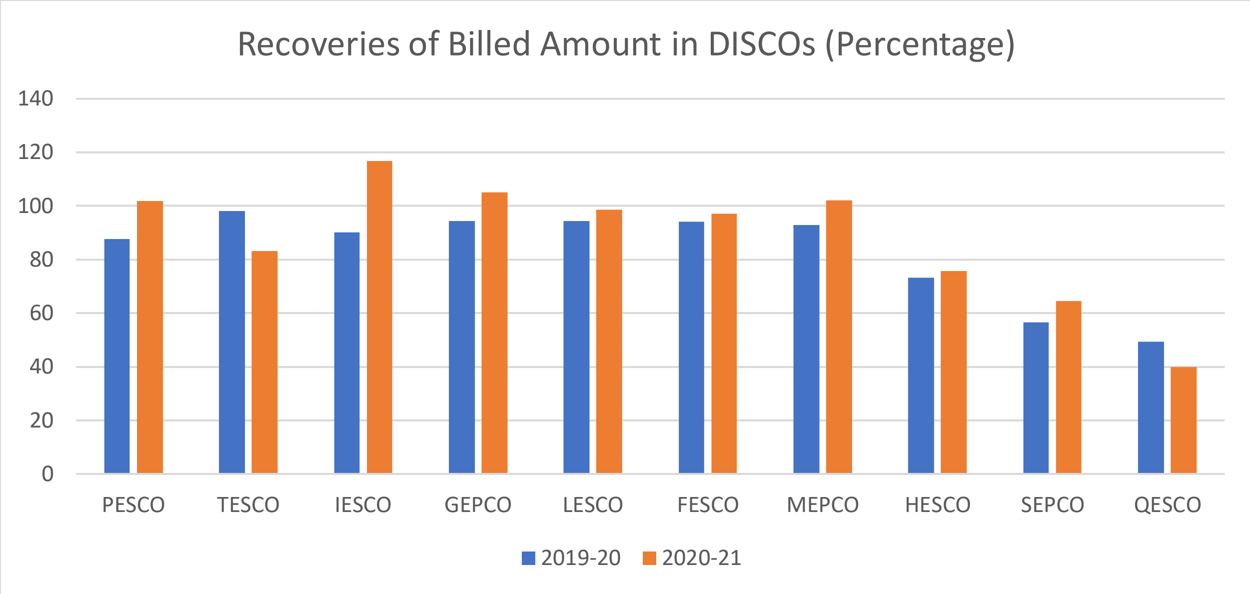

Figure 7: Recoveries of Billed amount in DISCO (NEPRA, 2021) [3], [4]

Strategic sited solar PV growth: Novel approach for loss reduction

Line losses are key performance indicators for global power systems. Controlled power losses ensure greater energy efficiency and security of supply. [4] Electrical line losses occur as current flows through long distance high-voltage transmission lines, often miles and miles across the country.

The solution is to either control the resistance or control current of the line to keep the losses at minimum levels. The former method requires costly measures, such as replacing or adding equipment at the grid and along the T&D lines. Whereas, current can be reduced by decreasing the congestion (burden) on the T&D line through generating energy at the consumption point by employing energy generation technologies such as solar PV systems.

A more economic and novel approach for reducing T&D losses is to change 'how and when' we use power. If the load is to serve by generating sources located at consumer's premises such as solar PV on rooftop of the house or building, this will reduce the burden on the grid i.e. relieve the congestion on distribution lines. These local generating sources can provide many values in terms of cost savings and loss reduction to the utilities. Because of less burden on the grid, the grid maintenance and upgradation can be delayed to a later time and thereby increasing the longevity of the power system. In this way, PV at consumption site is supporting the grid (grid-support PV) by decreasing the magnitude of line losses. So overall, solar-PV grid support can improve distribution system reliability as well as defer transformer and transmission line upgrades and equipment maintenance intervals.

[4] For instance, the energy losses in the low and medium voltage distribution lines in European countries vary from 2% to 13.5%, with respect to total energy injection.

So, the two-fold advantages of DG solar penetration are:

(a) Energy loss savings i.e., savings realized by reducing load and resistance on the lines.
(b) Capacity loss savings, realized by decreasing the need for capital upgrades via reducing peak loads on distribution, transmission, and generation system equipment.

A higher renewable energy penetration level hence raises the likelihood of reducing energy losses due to proximity of PV systems to load centers and thereby acts as a grid-support tool.

Case study for technical loss mitigation: India [6]
In India, more than 450 million people are un-electrified because they either reside in rural areas or are far away from the main grid. Voltage imbalance, uncertainty of power supply, inadequate generation, and ageing power transmission infrastructure are among the major factors contributing towards high electric losses. The line losses in India are very high as compared to other countries i.e., 20%-40%. In 2021, the Indian power sector incur loss of 90,000 crore Indian rupees along with the debt of 67,917 crore Indian rupees. Power at distribution level is the weakest link in the supply chain of country's power system, due to poor infrastructure and operational inefficiencies. The line loss situation was aggravated to such an extent that the Arunachal Pradesh state experienced aggregated transmission and dispatch loss (AT&C) of 56%, while the billing efficiency was 45%. These losses hinder the investment opportunities that are required for improving the power quality, necessary for creating a renewable energy-ready environment. During the last two decades, India has played a proactive role in overcoming this problem by incorporating high volumes of RE generation. Solar PV currently covers 8% of their energy demand, while wind energy is dominating by 70%. The adoption of RE has always been an important policy agenda in India. For this purpose, various schemes prevailed, including the Special Incentives Package Scheme (SIPS), Renewable Purchase Obligation (RPO), and tax amnesties. These reforms help mitigate the high-energy loss in India's conventional power system. In Delhi, the involvement of private sector (including RE Independent Power Producers) at distribution level, brought down the technical and commercial losses from 55% (in 2002) to 9% (in 2019). Among many operational reforms in different states of India, the most noted one is separation of agricultural and non-agricultural feeders, with the encouragement of up-taking the solar pumps. This significantly reduced the technical losses and energy procurement cost in these states. The distribution companies are mandated to meet the RE purchase obligations (RPOs) annually. The prevailing Rooftop Solar Programme (RTS) in India helps in minimizing the distribution losses, while also benefits the bulk consumers (commercial and industrial) in cost optimization and relieve them from cross-subsidy. Under RTS, they can procure solar energy from third party developers. The same scheme is also applicable to regular consumers, where they can get benefit from net-metering. Distribution companies balance supply and demand within their specified balancing areas as well as trades energy between regions to increase the energy flow efficiency. This helps to cope the intermittent nature of solar energy. Among many other line loss reduction initiatives, the Green Energy Corridor Programme supports the uptake of RE by upgrading the power lines. There are 14,000 micro-grids and over 20 lac solar homes in rural and far fetch areas. In India, several physical and institutional reforms are initiated including National electricity policy 2021, ancillary service market regulation, and market based economic dispatch with an investment of 3,00,000 crore Indian rupees. It is expected that these reforms would open the pathways for grid modernization (smart-grids) and new business models.

Case study of aggregated technical and commercial loss mitigation: Brazil [7]
The federal energy planning company of Brazil studied the impact of solar PV in the country. Brazil reached electrification rate of 99.5% in 2013. The balance between energy generation and utilization points out 20% losses with 116.3 TWh energy loss. Although Brazil belongs to an upper middle-income country, its line loss percentage is close to the line loss average of low-income countries. About 5% of the total incoming energy into the distribution grid is lost on the account of fraud and theft. This amount is sufficient to meet the energy needs of 7.9 million households individually. These non-technical losses generate high financial losses, overloading and degradation of the distribution grid, and raise bills for consumers to compensate losses. In 2014, the monetarily value of these non-technical losses are more than 1.26 billion euros, while in 2017, they amount to 2.3 billion euros. The progress in PV system installation had transformed the consumers into prosumers, and offered a great economic benefit for economically challenged communities. The Brazilian Electricity Regulatory Agency reported a case study that states that the installation of 161 solar systems can generates almost 1 billion euros in investment by 2023, while benefiting 130.5 million euros to credit agents in the form of loan interests. The consumers can save 405 million euros in electricity bills. Most importantly, Brazil can save technical loss of about 185 GWh and the social benefit will be job creation on 4000 citizens. PV systems has social benefits too, as it can lead to the creation of local co-operatives, earnings through net-metering, reduced maintenance of utilities, discouragement of illegal connections, while also benefiting from the reliability and quality of energy supply.

By diffusing the PV system, we can reduce not only the line loses, but also increase grid resilience, lower generation costs, and reduce requirements to invest in enhancing generation capacity, which results in capacity saving of the power system infrastructure.

Organization models for higher distributed generation (DG) penetration

New radical technologies such as solar are interlinked with a set of mainstream processes—including regulatory, technical, and financial—which play a critical role in stimulating and preventing their dissemination. Following this insight, the ownership and delivery models surrounding micro-generation are also changing significantly. Innovative market-oriented business models are emerging as a powerful tool to stimulate DRE—principally drawing on strategic networking and cooperative strategies (mediating between the production and the consumption side of niche technologies) aimed at alleviating the multi-dimensional obstacles hampering socio-technical transition (see Table. 2).

Market and social barriers	**Price distortion**	**Unaccounted costs of externalities in energy pricing**
	The 'hassle factor'	Higher transaction costs of gathering information/Perceived inconvenience of installing the technology.
	Split incentives	When the investor who pays for the upfront costs for Renewable Energy Technology is not the same person who reaps the benefits of the technology (for example in rental properties).

	Supply constraints	Proper RET markets not developed: technology/services unavailability.
Technical Barriers	Lacking know-how	Limited know-how on design and development, installation, operation, and maintenance of the technology.
Regulatory barriers	Bureaucratic hassle	Cumbersome/lengthy processes of availing technology licenses.
Financial barriers	Low (or no) returns on investment	Lower cost of traditional energy technologies.
	Upfront costs	Higher installation cost.
	Difficult access to finance	Cumbersome/lengthy processes of getting access to external capital for financing RET.
Information failures	Awareness gap	General lack of awareness on RET.
	Lack of information on financing	Limited know-how on financing options available for investment in RET.
	Lack of knowledge by installers	Knowledge gap/limited professionals at installation stage.

TABLE 2: BARRIERS SURROUNDING ADOPTION OF NEW RE TECHNOLOGIES.

Compared to dealer models, 'fee for service' business models are also increasingly associated with overall larger economies of scale—such as regulatory efficiency, technology durability, information asymmetry, and overall reduction of customer transaction cost. Most importantly, these models center upon customers' needs—premised around optimizing strategies aiming at best meeting end-users needs. These models also provide equal opportunities to customers who may not have financial resources and are otherwise unable to install the technology—a major barrier associated with developing countries. Besides, additional services such as extended warranties, consultancy, free advice, and maintenance services further reduces adoption barriers, perceived performance risks and uncertainties. So overall analyzing, hospitable institutional/business models provide the much needed 'protective space and enabling environment' for the configuration and development of new technologies.

Bangladesh is a leading example where coupling of the PV technology to a viable business model 'Infrastructure Development Company Ltd' (IDCOL) resulted in its extensive uptake among customers—more than 9% of the country's total population—which is one of the highest share globally. IDCOL is a public-private partnership initiative characterized by easy loans for the end-users, and highly standardized services in the entire value chain [8].

Likewise in India, rooftop PV reached 14% of the country's total installation in 2018, supported by a mix of CAPEX and OPEX models facilitating dissemination of the technology [9]. So we could see that a new wave of supportive frameworks, business, and finance models are playing an important role in stretching prosumerism and catalyzing the bottom-up transition. However, Pakistan is not only characterized by absence of such emerging models but also the literature reflects very poorly on this 'absence' as the major preventing factor substantially slowing down the otherwise immense potential held by 'bottom-up energy transition' in the country.

Conclusion

In Pakistan, the electricity losses contribute to substantial amount of wasted resources—making the country's grid very fragile. While the country has long been seeking a strategy to minimize these losses, the decade old problems in relation to technical and financial losses in power sector as well as energy access gap continues, while traditional intervention solutions have been at the root of the ongoing unsustainable trajectory.

An overlooked discourse in the energy debates is how the optimal placement of distributed generation (DG) applications such as solar photovoltaic (PV) applications can provide many values to a transmission and distribution system. In addition to clean energy procurement and resource indigenization, energy generation close to the end users is now seen as novel solution for reducing losses. These applications could play an instrumental role in loss reduction experienced by electric utilities—including both technical and non-technical losses by potentially deferring transformer and transmission line upgrades, equipment maintenance interval extension, and distribution system reliability improvement. So, loss minimization, reliability, sustainable energy provision, and clean and cheap energy—all could be achieved with a well-chose DG network. These applications do not only offer insulation from the immense transmission and distribution losses but also an escape from the capacity payment trap that Pakistan is locking itself into it.

This, however, needs a realistic action plan based on significant stakeholder support, alignment of national and provincial electricity and energy policies and planning, a facilitative and enabling environment, and consolidated changes at each stage of the energy value chain. Hence, it is necessary to have a sustainable and profitable business strategy and detailed regulation plan for strategic sited solar PV growth.

The government should undertake reforms for higher efficiency of the distribution sector on priority basis. For any desired transition, a deep analysis is needed on how innovative business models could be aligned with broader bottom-up energy investment to ensure that DG uptake among communities is not further delayed.

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