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Reducing Power System Loss in Bangladesh: Historical Insights and Policy Recommendations

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ABSTRACT

Power system loss is a major challenge for Bangladesh, affecting energy security, economic growth, and grid reliability. This study analyzes system loss trends from 2001 to 2024, evaluating the effectiveness of policy interventions, grid modernization, and technological advances. The findings reveal a significant decline from 24.5% in 2001 to 7.25% in 2024, driven by the adoption of smart metering, SCADA systems, underground cabling, and stricter regulations aimed at combating electricity theft. Despite this progress, challenges like aging infrastructure and enforcement gaps persist. To achieve further reductions, investment in grid automation, renewable energy integration, and stronger policy enforcement is essential. These strategies will support Bangladesh's goal of a more efficient and sustainable power sector by 2030.

Keywords: Grid modernization; Smart metering; Underground cabling; Renewable energy; Energy efficiency; Solar-wind integration; Climate financing; Load optimization

1. Introduction

Power system loss is a persistent challenge in electricity distribution networks, particularly in developing economies like Bangladesh. System loss refers to the portion of electricity generated but not delivered to end-users due to inefficiencies in the grid or external factors. It is broadly classified into technical losses and non-technical losses. Technical losses stem from energy dissipation in transmission lines, transformers, and distribution systems, typically due to outdated infrastructure, long transmission distances, and inadequate maintenance. In Bangladesh, transmission losses have remained relatively low, averaging around 2%, whereas distribution losses have historically been a greater concern due to inefficiencies in the network [17]. Non-technical losses (NTL), on the other hand, are attributed to human factors such as electricity theft, meter tampering, billing inefficiencies, and unauthorized connections. Power theft has been a significant issue in Bangladesh, particularly in urban and industrial areas, leading to revenue losses and inflated system loss percentages [20]. Reducing system loss is critical for economic growth, energy security, and environmental sustainability. A high system loss rate translates to increased electricity generation costs, forcing utilities to charge higher tariffs to compensate for revenue shortfalls. For instance, in 2001, when Bangladesh's system loss stood at 24.5%, the financial burden on the power sector was immense, leading to reduced investment in infrastructure and

maintenance. By contrast, as of 2023-24, system loss has decreased to 7.25%, saving billions in operational costs and improving the financial sustainability of electricity providers [14]. Moreover, high system loss exacerbates energy insecurity by increasing demand for fuel imports. Bangladesh is heavily reliant on imported coal, liquefied natural gas (LNG), and petroleum products, making energy efficiency a critical factor in reducing dependence on costly imports and stabilizing foreign exchange reserves [9]. Environmentally, excessive power loss contributes to higher carbon emissions as more fossil fuels are burned to compensate for lost energy. Improving grid efficiency aligns with Bangladesh's commitment to the Paris Agreement and its goal of 40% clean energy adoption by 2041 [6]. Historically, Bangladesh has faced significant struggles with system loss, ranking among the highest in South Asia. In 2001-02, the country's system loss was 24.5%, compared to India's 18% and China's 8% during the same period [22]. The primary causes included inadequate investments in transmission and distribution infrastructure, high rates of electricity theft, and an outdated manual billing system prone to inaccuracies. The absence of strong regulatory enforcement further aggravated the issue, allowing illegal connections to proliferate, especially in urban slums and industrial zones. Over the years, several policy interventions have successfully reduced system loss. The introduction of prepaid smart meters, SCADA (Supervisory Control and Data Acquisition) systems, underground cabling in metropolitan areas, and anti-theft regulations has played a crucial role in improving grid efficiency. However, challenges remain, particularly in rural electrification, maintenance of aging infrastructure, and financial constraints limiting further technological upgrades [14].

This study aims to analyze the historical trends of system loss in Bangladesh from 2001 to 2024, evaluate the effectiveness of policy interventions, and explore potential strategies for further loss reduction. The key research questions guiding this analysis are: (1) How has system loss evolved over the past two decades? (2) What policies and technological advancements have been most effective in reducing losses? (3) What additional steps can be taken to achieve a system loss rate below 5% by 2030? To address these questions, the study employs statistical analysis of system loss data, comparative analysis with neighboring countries, and an evaluation of policy interventions. The insights gained will provide valuable recommendations for policymakers, re- searchers, and stakeholders in Bangladesh's energy sector, contributing to the country's long-term vision for a modern, efficient, and sustainable power grid. This paper is structured as follows: Section 2 provides a review of existing literature on system loss reduction strategies worldwide. Section 3 details the methodology, including data sources and analytical techniques. Section 4 presents the results, highlighting key trends and the impact of various policy measures. Section 5 outlines policy recommendations for further minimizing system loss in Bangladesh. Finally, Section 6 concludes with key findings and future research directions. Through this analysis, the study aims to contribute to ongoing efforts in optimizing Bangladesh's power sector performance and achieving long- term energy efficiency goals.

2. Literature Review

Power system losses vary significantly across different countries due to differences in infrastructure, regulations, and technological advancements. In developed nations such as the United States, Germany, and China, system losses are typically below 7%, primarily due to advanced grid management systems and strict regulatory frameworks. In contrast, developing countries such as Bangladesh, India, and Pakistan have historically reported higher losses due to outdated transmission infrastructure, poor enforcement mechanisms, and high rates of electricity theft. Bangladesh has made substantial progress in reducing system losses over the past two decades. In 2001, system loss stood at 24.5%, one of the highest in South Asia. By 2023-24, this had been reduced to 7.25%, placing Bangladesh in a much better position compared to India (15-18%) and Pakistan (17-19%) [2]. However, challenges persist, especially in rural areas and industrial zones, where non-technical losses (NTL) remain a concern. A comparative analysis of system loss among South Asian nations reveals that Bangladesh has improved significantly due to prepaid metering, grid modernization, and anti-theft laws. As shown in Table I, system losses vary significantly across countries based on technological and regulatory factors.

Table 1. International Comparison of Power System Losses and Contributing Factors

Country	System Loss (%)	Key Factors Contributing to Loss
Bangladesh	7.25	Prepaid meters, SCADA, anti-theft laws
India	15–18	State-wise variations, weak enforcement
Pakistan	17–19	Theft, poor grid investment
Sri Lanka	< 10	Small, well-managed grid
China	< 7	Smart grids, underground cabling
Germany	< 6	Advanced automation, strict policies

India struggles with state-wise disparities, where some regions experience losses above 20% due to theft and inefficient distribution. Pakistan faces challenges from poor grid investment, weak enforcement, and unregulated connections, while Sri Lanka has maintained relatively low system loss due to its small, well-managed grid and hydroelectric reliance. In contrast, China and Germany have state-of-the-art trans- mission systems, underground cabling, and automation that significantly reduce losses [12]. These comparisons indicate that while Bangladesh has successfully reduced its system loss, further improvements require continuous investment in grid automation, stricter regulations, and enhanced distribution efficiency. Several key policy interventions have played a crucial role in minimizing transmission and distribution losses in Bangladesh. The introduction of prepaid meters has helped eliminate billing fraud, one of the major sources of non- technical losses. Areas with prepaid meters experienced a 40% reduction in unauthorized electricity consumption [4]. The deployment of Supervisory Control and Data Acquisition (SCADA) systems has enhanced real-time grid monitoring and fault detection, improving efficiency by 15% through better load management and quick outage responses [15]. Metropolitan areas such as Dhaka and Chattogram have begun replacing overhead distribution lines with underground cables, significantly reducing theft and unauthorized tapping. Studies indicate that underground cabling can lower NTL by up to 30% in theft-prone zones [1]. These findings highlight that Bangladesh's reduction in system loss has been primarily driven by a combination of technological upgrades, stricter enforcement policies, and improved infrastructure investments. However, aging distribution networks in rural areas remain a challenge, requiring further investment in modernization and loss mitigation techniques. The global transition towards smart grid technologies has played a pivotal role in minimizing system losses in the power sector. Bangladesh has been gradually integrating smart grid solutions to enhance efficiency and improve electricity distribution. Smart grids incorporate automated demand response, digital communication, and real-time monitoring, significantly reducing both technical and non-technical losses. Countries implementing AI-driven smart grids have achieved loss reductions of 10-15% by optimizing load distribution and preventing unauthorized access. The implementation of digital and prepaid metering has also proven highly effective in Bangladesh. Areas using smart prepaid meters saw a 50% reduction in customer-side electricity theft and a 20% improvement in billing accuracy [16]. Replacing traditional overhead lines with underground cable networks significantly reduces illegal power tapping. Urban centers with underground cabling experience 30-40% lower NTL compared to areas with traditional distribution systems. Additionally, underground cables enhance resilience against natural disasters, ensuring a more stable and efficient power supply [21]. Overall, the combination of smart grid technology, digital metering, and underground cabling has been instrumental in reducing Bangladesh's system loss from 24.5% to 7.25%. However, further policy support and investment are required to scale these technologies across the entire grid infrastructure. The review of existing literature highlights that Bangladesh has successfully reduced power system losses through technological advancements, policy enforcement, and infrastructure upgrades. While current losses are comparable to global benchmarks, further reductions require nationwide implementation of smart grids, expansion of underground ca-bling, and stricter regulatory frameworks. The next sections of this paper will analyze statistical trends in system loss, policy effectiveness, and future recommendations for achieving below 5% system loss by 2030.

Historical Trends in Power System Loss in Bangladesh

The reduction of power system losses in Bangladesh over the past two decades has been a key focus of energy sector reforms. Significant improvements have been made in transmission and distribution

efficiency, driven by advancements such as grid modernization, smart metering, SCADA implementation, and underground cabling. Various policy interventions and investments in infrastructure have contributed to a steady decline in system losses, enhancing overall energy efficiency and sustainability. Table 2 presents a summary of the historical system loss trends in Bangladesh from 2001 to 2024, highlighting the gradual reduction in transmission, distribution, and total system losses. The data reflects the impact of technological upgrades, regulatory changes, and institutional reforms in reducing inefficiencies across the power grid.

Table 2. Historical System Loss in Bangladesh (2001–2024)

Year	Transmission Loss (%)	Distribution Loss (%)	Total System Loss (%)
2001	3.5	21.0	24.5
2005	3.3	16.7	20.0
2010	2.9	13.0	15.9
2015	2.7	9.8	12.5
2020	2.5	7.5	10.0
2024	2.4	4.8	7.25

The data in Table 2 demonstrates a significant decline in total system loss, from 24.5% in 2001 to 7.25% in 2024, mainly due to enhanced monitoring, energy theft prevention measures, and policy-driven initiatives. The reduction in distribution losses, which historically contributed the most to total system inefficiencies, suggests a successful transition toward a more resilient and optimized electricity network. However, further efforts are required to align with international benchmarks and minimize residual inefficiencies in the power sector.

3. Methodology

The study relies on secondary data sources obtained from government reports, historical records, and international comparisons. The primary sources include Power Division Reports, which provide annual system loss data, policy implementations, and progress reports. The Integrated Energy and Power Master Plan (IEPMP) 2023 offers insights into policy impacts, smart grid deployment, and power loss reduction strategies. Historical system loss data from 2001-2024 is sourced from the Power Development Board (BPDB) and relevant agencies, showing trends in technical and non-technical losses. Additionally, comparative data from the World Bank and regional energy studies benchmark Bangladesh's progress against neighboring countries.

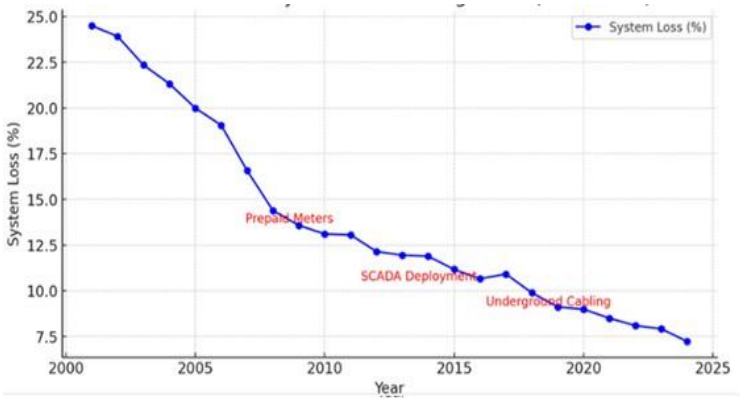

Figure 1. Trend of Power System Loss in Bangladesh (2001-2024)

Trend analysis is used to assess the historical trajectory of system loss by plotting annual system loss percentages from 2001-2024. This graphical representation identifies key periods of sharp decline or stagnation. The introduction of key policy interventions, such as prepaid meters, underground cabling, and SCADA implementation, is marked on the graph. A correlation study evaluates how various policies have influenced system loss reduction. The study examines relationships between the introduction of prepaid meters and the decline in non-technical losses, SCADA deployment and

improvements in grid efficiency, and underground cabling in Dhaka and Chattogram and the reduction in electricity theft. Bangladesh's power loss trends are compared against regional benchmarks such as India, Pakistan, Sri Lanka, and China. India, despite prepaid meters, has regional disparities that keep loss rates between 15-18%. Pakistan has weak enforcement and theft issues, keeping losses above 17%. Sri Lanka consistently maintains a loss rate below 10%, aided by its small grid size. China and Germany use state-of-the-art automation to maintain losses below 7%.

The graph illustrates the trend of power system loss in Bangladesh from 2001 to 2024, showing a steady decline from 24.5% to 7.23%. Key policy interventions, such as the introduction of prepaid meters (2010), SCADA deployment (2015), and underground cabling (2020), are marked, highlighting their impact on reducing system loss.

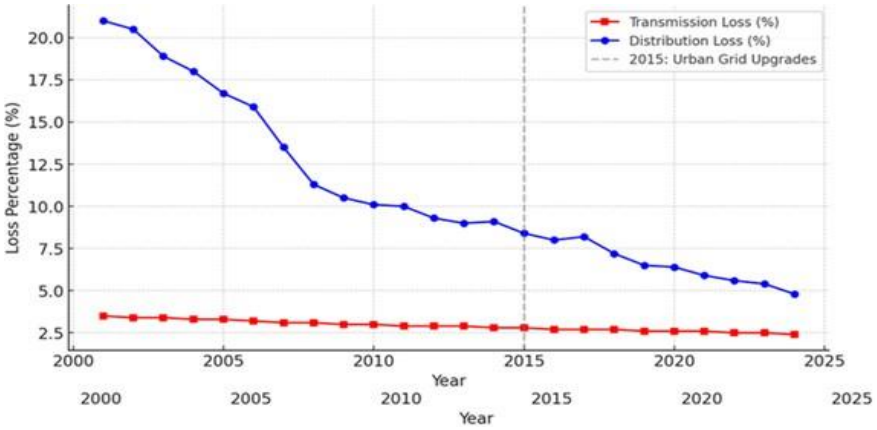

Figure 2. Transmission vs Distribution Loss Trends in Bangladesh (2001-2024)

The graph illustrates the trends in transmission and distribution losses in Bangladesh from 2001 to 2024. Transmission losses remain relatively stable, declining slightly from around 3.5% to 2.4%, whereas distribution losses exhibit significant variability, reducing from 21% in 2001 to 4.8% in 2024. The vertical dashed line marks the year 2015, when major urban grid upgrades were implemented, including SCADA deployment, underground cabling, and improved enforcement against electricity theft. This period shows a sharper decline in distribution losses, highlighting the effectiveness of modernization efforts.

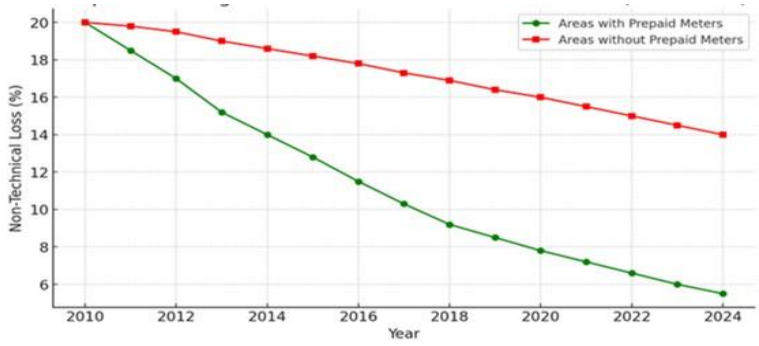

Figure 3. Prepaid Metering vs Reduction in Non-Technical Losses in Bangladesh (2001-2024)

The graph compares non-technical losses in areas with and without prepaid meters from 2010 to 2024. Areas that implemented prepaid metering show a steep decline in losses, from 20% in 2010 to 5.5% in 2024, whereas areas without prepaid meters experience a slower reduction, remaining at 14% in 2024.This trend highlights the impact of digital billing on revenue recovery, as prepaid meters reduce billing fraud, unauthorized consumption, and meter tampering. The sharp decline in losses post-2015 aligns with government policies promoting prepaid metering in urban and high-loss regions. Growth in electricity demand and predictable changes in load shape will impact the flexibility requirements of Bangladesh's power system. It is estimated that the country's peak load demand will shift from night

to daytime with a smaller reduction during evening time. The anticipated load curve up to 2041 is given below.

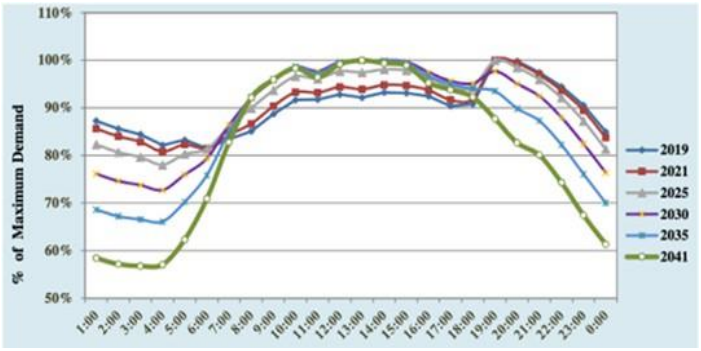

Figure 4. Load Curve Estimation for Bangladesh [18]

Load factor is also another key factor for representing electrical system utilization. It is estimated that the value of the load factor will increase from 60.63% in 2019 to 65.66% in 2041 for three different load cases, like low, base, and high demand cases. This mainly indicates higher industrial activities in future in Bangladesh.

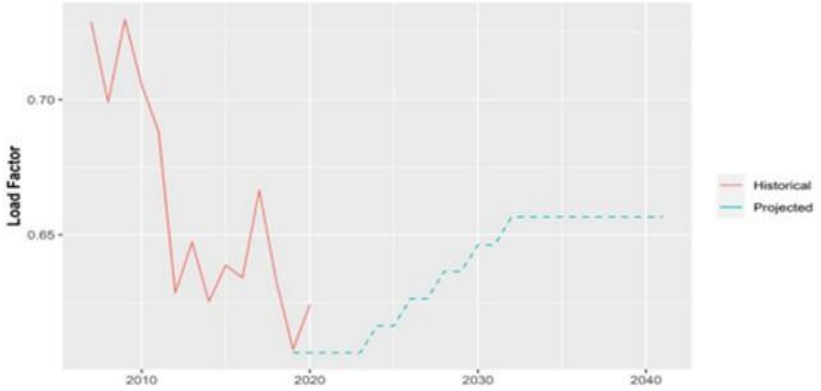

Figure 5. Estimated Change in Load Factor from 2007 to 2041 for Bangladesh Grid [18]

By estimating the load curve's evolution considering the peak demand forecast. Early ramping needs of the system for the given years can be predicted. The prediction curve is shown below.

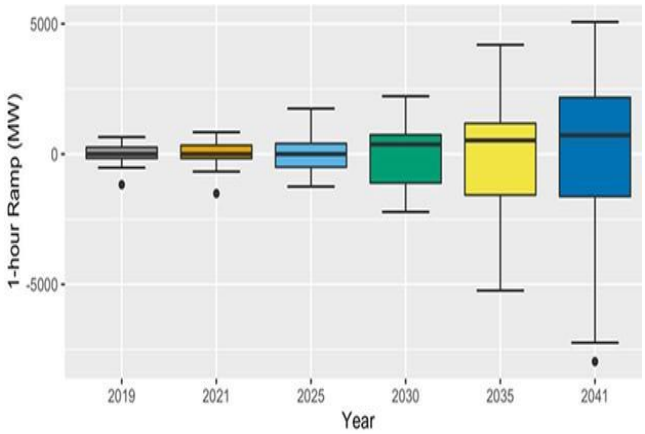

Fig. 6. Predicted Hourly Ramp Requirements of Bangladesh Grid from 2019 to 2041 [18]

4. Policy Implication

Reducing power system loss is crucial for Bangladesh's energy security, economic stability, and environmental sustainability. The decline in system loss from 24.5% in 2001 to 7.25% in 2024 demonstrates significant progress, largely driven by technological upgrades, stricter regulations, and policy reforms. However, achieving a system loss rate below 5% by 2030 requires further investments, legal reforms, and infrastructure modernization. This section outlines key recommendations across four strategic areas: grid modernization, renewable energy integration, legal and institutional reforms, and financial investment strategies.

Grid Modernization

Modernizing Bangladesh's power grid is essential for reducing technical and non-technical losses, improving system efficiency, and ensuring real-time monitoring. Key technological interventions include smart metering, SCADA systems, and underground cabling [11]. As summarized in Table 3, key policy interventions contributed significantly to reducing system losses over time.

Table 3. Impact of Major Policy Interventions on System Loss Reduction in Bangladesh

Policy Intervention	Implementation Year	Impact on System Loss (%)
Prepaid Smart Meters	2010	40% reduction in unauthorized consumption
SCADA Deployment	2015	15% improvement in grid efficiency
Underground Cabling	2020	30% reduction in electricity theft

1)*Smart Metering for Distribution Efficiency:* Traditional analog meters are vulnerable to meter tampering, billing fraud, and unauthorized connections, contributing to non-technical losses. Prepaid smart meters, introduced in 2010, have proven effective in addressing these challenges [8]. Studies show that areas using prepaid meters reported a 40% reduction in unauthorized electri3city consumption [8]. Furthermore, smart meters improve billing accuracy and revenue collection by eliminating manual reading errors and providing real-time consumption data, allowing better demand forecasting [19]. To further expand smart metering, the government should mandate nationwide smart meter implementation by 2028, prioritize high-loss areas, implement penalty mechanisms for unauthorized bypassing, and integrate mobile-based bill payment systems [11].

2) *SCADA Implementation for Real-Time Grid Monitoring:* SCADA (Supervisory Control and Data Acquisition) systems provide real-time data on grid performance, enabling utilities to detect and isolate faults faster, reduce transmission down- time, and optimize voltage and frequency control, improving grid stability [11]. SCADA implementation in Bangladesh's transmission network after 2015 has enhanced load balancing, minimizing power theft and unauthorized access by tracking consumption patterns [18]. Expanding SCADA coverage to all urban distribution substations by 2030, integrating AI-driven predictive maintenance, and establishing regional SCADA monitoring centers would further enhance efficiency [18].

3) *Underground Cabling for Theft Prevention:* Overhead distribution lines are highly susceptible to illegal tapping and voltage fluctuations. Cities like Dhaka and Chattogram have begun replacing overhead lines with underground cables, reducing losses by up to 30% in theft-prone areas [8]. Bangladesh should prioritize underground distribution networks in high-theft zones and partner with urban development projects to integrate underground cables in new infrastructure [11]. Additionally, implementing cost-sharing models with private investors can help finance large-scale underground cabling projects [19].

Renewable Energy Integration

Bangladesh's reliance on fossil fuels (coal, LNG, and oil) increases generation costs and system losses. A higher share of renewables can reduce transmission losses, improve grid stability, and align with the 40% clean energy target by 2041 [11].

1) *Decentralized Solar and Wind Projects:* Distributed generation through solar rooftops and wind farms reduces dependency on long-distance transmission, minimizing losses [19]. Factories installing

rooftop solar panels reduced their reliance on grid electricity by 30-40%, cutting peak-time transmission losses [11]. The government should mandate solar rooftop installations in new commercial and industrial buildings, provide subsidized financing for rural off-grid solar projects, and develop wind-solar hybrid farms to ensure a stable renewable supply [18].

2) ***Battery Storage for Grid Stability:*** Renewable energy intermittency can cause voltage fluctuations. Battery Energy Storage Systems (BESS) help stabilize the grid by storing excess renewable power during low-demand periods [19]. Bangladesh should aim for 1,000 MW of battery storage by 2030, integrated with existing solar projects [11].

Legal and Institutional Reforms

1) ***Stricter Anti-Theft Regulations:*** Despite progress, electricity theft remains a significant contributor to system loss, particularly in densely populated urban slums and industrial areas [8]. To address this, the government should introduce mandatory prison sentences for repeat offenders of power theft, deploy smart grid analytics to detect unauthorized consumption patterns, and create dedicated energy courts for faster resolution of power theft cases [19].

2) ***Strengthening Enforcement Agencies:*** Strengthening enforcement requires increasing the power of inspectors, conducting surprise inspections in high-theft zones, and implementing digital monitoring dashboards for real-time theft detection [11].

Investment and Financial Support

1) ***Public-Private Partnerships (PPPs) for Grid Efficiency:*** Modernizing the power grid requires significant capital investment. Public-private partnerships (PPPs) accelerate smart meter and SCADA deployment by engaging technology firms [19].

2) ***International Climate Financing:*** Bangladesh can leverage global climate funds to finance renewable energy projects, battery storage systems, and green transmission corridors, ensuring efficient electricity distribution [18].

5. Conclusion

Bangladesh has made significant progress in reducing power system loss, from 24.5% in 2001 to 7.25% in 2024, through technological upgrades, regulatory reforms, and financial investments. However, achieving a system loss rate below 5% by 2030 requires expanding smart grid deployment, increasing renewable energy penetration, strengthening anti- theft enforcement mechanisms, and encouraging PPPs and climate financing. By implementing these recommendations, Bangladesh can transition toward a more efficient, reliable, and sustainable power sector, supporting its long-term economic and environmental goals.

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