

Optimizing Distribution Losses through ETAP

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Abstract: High distribution system losses remain a major obstacle to efficient electricity supply in developing countries. In Bangladesh, losses exceed 10% and include both technical losses (TLs), caused by conductor resistance, transformer inefficiencies, and reactive power flow, and non technical losses (NTLs), such as theft, faulty metering, and billing errors. These losses increase operating costs, reduce revenue, and undermine energy sustainability. This paper presents a techno-economic assessment of loss-reduction strategies at the Tongi 33/11 kV substation under Dhaka Electric Supply Company (DESCO), using the Electrical Transient Analyzer Program (ETAP). Three strategies were evaluated: parallel feeder reconfiguration, capacitor bank installation, and distributed generation (DG) integration. Simulation results show that the proposed design reduces system losses from 12.12% (12.265 MW) to 6.26% (6.299 MW), nearly halving total losses. Voltage profiles improved within ± 5 % of nominal, and feeder overloads were eliminated. Economic analysis confirmed financial viability. With an investment of 216 crore BDT, annual energy savings exceeded 646 crore BDT, yielding a net profit of approximately 381 crore BDT over 15 years. The findings demonstrate that coordinated technical strategies can significantly improve both efficiency and financial performance, offering a scalable framework for utilities in Bangladesh and similar contexts.

Keywords: Distribution Systems, ETAP, Technical Losses, Economic Analysis, Distributed Generation, Capacitor Banks.

1. Introduction

Efficient distribution systems are crucial in developing countries, where rising demand and resource limitations exacerbate operational challenges. In Bangladesh, distribution losses exceed 10%, comprising technical losses (TLs), from conductor resistance, transformer inefficiencies, and reactive power—and non-technical losses (NTLs) arising from theft, metering, and billing errors [1], [2]. These losses erode utility revenue, impair service quality, and compromise long-term energy sustainability. TLs intensify feeder overloading, voltage instability, and I²R dissipation [3].

NTLs inflate tariffs, reduce financial stability, and exacerbate energy insecurity [2]. Despite initiatives by utilities such as BPDB, REB, and DESCO, losses remain between 8% and 12% [1]. Aging infrastructure, congestion, and unauthorized consumption remain persistent challenges. Several mitigation strategies have been investigated, including feeder reconfiguration, capacitor placement, and distributed generation (DG) integration [4 – 6]. Computational approaches such as Genetic Algorithms (GA), Particle Swarm Optimization (PSO), and Harmony Search have been applied to optimize feeder switching and DG placement [3], [7 - 9]. In parallel, emerging solutions such as smart substations and advanced metering infrastructure (AMI) are increasingly explored for tackling NTLs and integrating renewable DG, with ETAP-based modelling already demonstrating feasibility in Bangladesh [5], [10]. This study addresses the research gap by conducting a techno-economic assessment of loss-reduction strategies at the Tongi 33/11 kV substation under DESCO. Contributions include: (i) high-fidelity ETAP modeling, (ii) evaluation of feeder reconfiguration, capacitor placement, and DG integration, and (iii) a cost-benefit analysis confirming both technical effectiveness and financial viability as in Fig. 1.

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Framework: Losses → Mitigation → Economic Validation

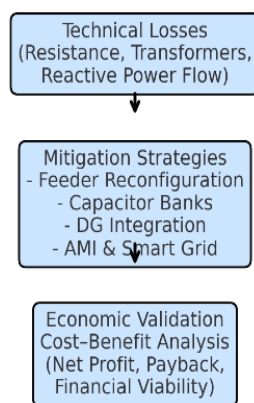


Fig. 1: Framework of the study showing distribution losses, mitigation strategies, and economic validation.

2. Literature Review

2.1 Technical Approaches to Loss Reduction

Early work on reconfiguration used branch and bound algorithms [6], but computational complexity limited scalability. Fuzzy multi objective optimization improved flexibility [2]. Recent computational intelligence methods GA, PSO, and Harmony Search, demonstrated effective performance for feeder reconfiguration and capacitor allocation [3], [7–9]. Optimizing capacitor placement has been shown to significantly reduce reactive losses [4]. More recently, ETAP-based studies confirmed that coordinated deployment of capacitors and DG units can cut losses by over 50% in South Asian distribution feeders [10].

2.2 Distributed Generation (DG) Integration

DG, particularly renewable sources, is widely recognized for improving voltage profiles and reducing losses when optimally sited [3]. Recent applications of PSO in African networks achieved meaningful loss reduction indices [11], while European studies combining GA and PSO reported up to 50% reduction through optimized DG allocation [12]. Classic studies on DG placement and sizing using multi-objective GA further underscore the importance of intelligent optimization [17].

2.3 Smart Substations and Non-Technical Loss Mitigation

Smart substations, integrating IoT, SCADA, and AMI technologies, have recently been modelled for

Bangladesh, showing improvements in efficiency and resilience [5]. Machine learning applied to AMI data has enhanced anomaly detection and electricity theft prevention in smart grids worldwide [13]. Advanced capacitor optimization methods [14], renewable integration studies [15], and resilience analyses of substations [16] highlight the evolving toolkit for reducing both TLs and NTLs.

2.4 Research Gap

Although global research confirms the benefits of reconfiguration, capacitor placement, and DG integration, practical validation in Bangladesh remains scarce. Few studies combine ETAP simulations with detailed economic analysis for real substations. Furthermore, smart-grid-enabled NTL reduction strategies remain underexplored in Bangladesh. This study addresses these gaps by presenting an integrated ETAP based modeling and techno-economic framework for the Tongi 33/11 kV substation.

3. Materials and Methods

This study employed the Electrical Transient Analyzer Program (ETAP) to model and simulate strategies for reducing both technical and non-technical losses in a real-world distribution network. The selected case study was the Tongi 33/11 kV substation under Dhaka Electric Supply Company (DESCO), which supplies residential, commercial, and industrial loads in northern Dhaka

3.1 Substation Modeling in ETAP

The Tongi substation was modeled in ETAP to represent its existing configuration, including:

- Incoming 33 kV feeders from transmission supply,
- Primary busbars,
- Step-down power transformers (33/11 kV), and Outgoing 11 kV feeders to load centers.

Fig. 2, illustrates the existing substation configuration, where several feeders and buses are heavily overloaded, as indicated by the red color. These overloads contribute to significant technical losses and voltage drops.

3.2 Methods of Reducing Technical Losses

Three technical strategies were evaluated through ETAP simulations:

3.2.1 Methods of Reducing Non-Technical Losses

Since ETAP cannot directly simulate non-technical losses (NTLs), mitigation strategies were assessed qualitatively. Proposed measures included:

- Deployment of Advanced Metering Infrastructure (AMI) and tamper proof meters,
- Routine inspections and replacement of defective meters,
- Consumer awareness campaigns regarding electricity theft, and
- Strengthened regulatory enforcement for unauthorized connections.

3.3 Simulation Scenarios

Five simulation scenarios were conducted:

- Base Case (Existing System): Current network with no compensation.

- Feeder Reconfiguration Case: Addition of parallel feeders.
- Reactive Power Compensation Case: Capacitor banks installed at feeders.
- DG Integration Case: DG units placed at major load centers.
- Combined Case (Proposed Design): Application of all three strategies.
- For each scenario, ETAP simulations generated bus voltage profiles, feeder loading data, and active/reactive loss calculations.

3.1 Results from ETAP Simulations

Fig. 3, shows the proposed ETAP model with all overloads eliminated, indicated by the black color. The combined case demonstrated the most effective results.

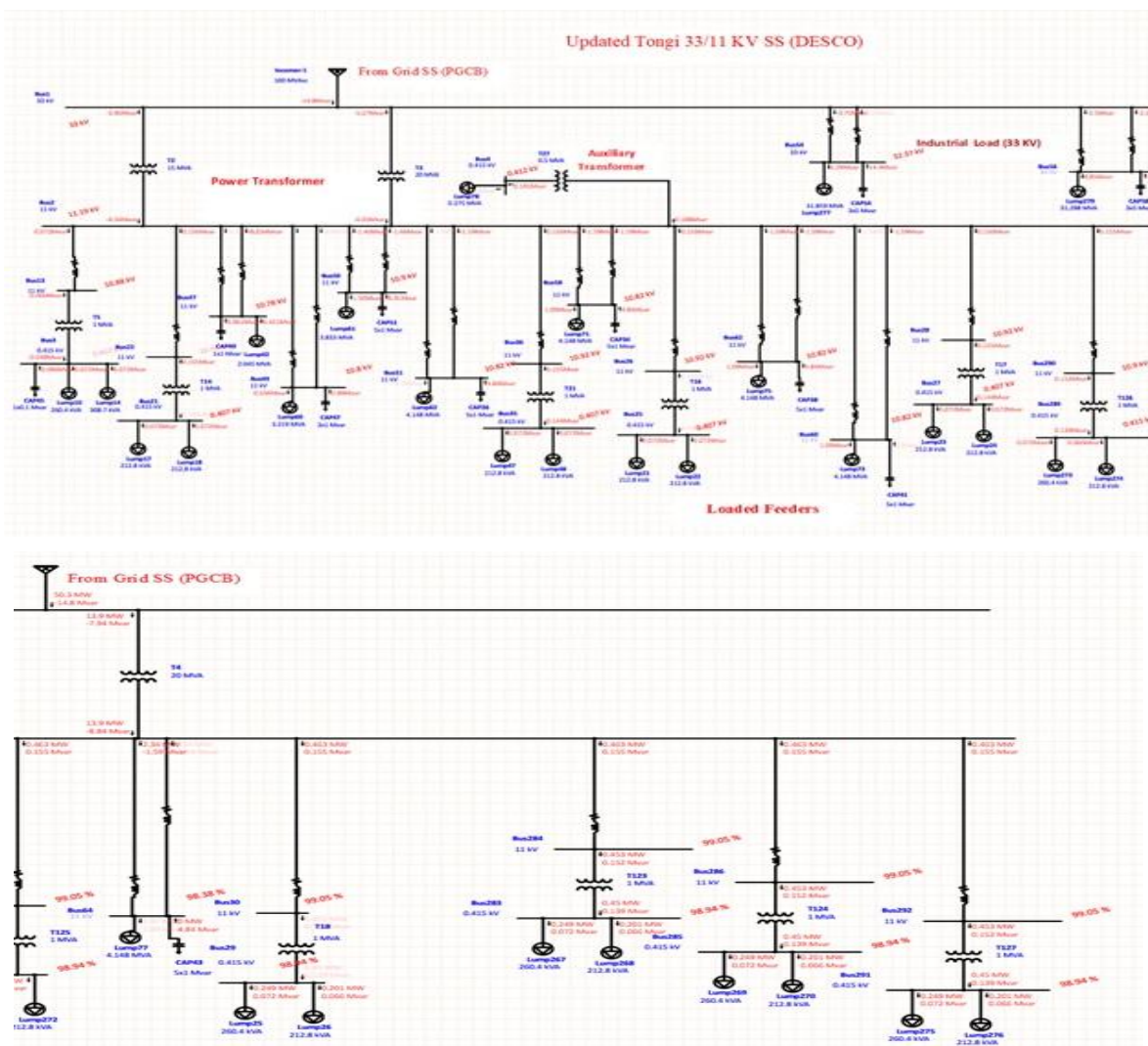


Fig. 3: ETAP simulation of Tongi 33/11 kV substation after applying loss-reduction strategies.

The system loss decreased from 12.12% (12.265 MW) in the base case to 6.26% (6.299 MW) in the proposed design, representing nearly a 50% improvement as shown in Fig. 4.

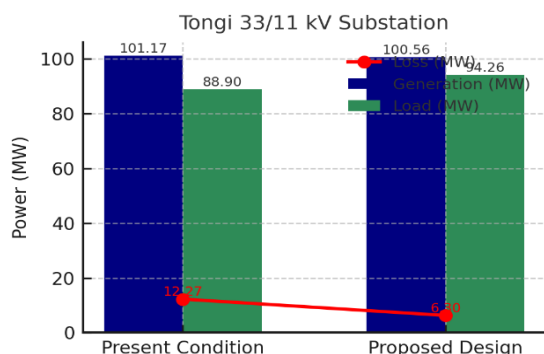


Fig. 4: Comparison of power generation, load, and losses in existing vs. proposed design.

Voltage profiles were also significantly improved, as shown in Fig. 5. All bus voltages were stabilized within the permissible $\pm 5\%$ range of nominal (11 kV).

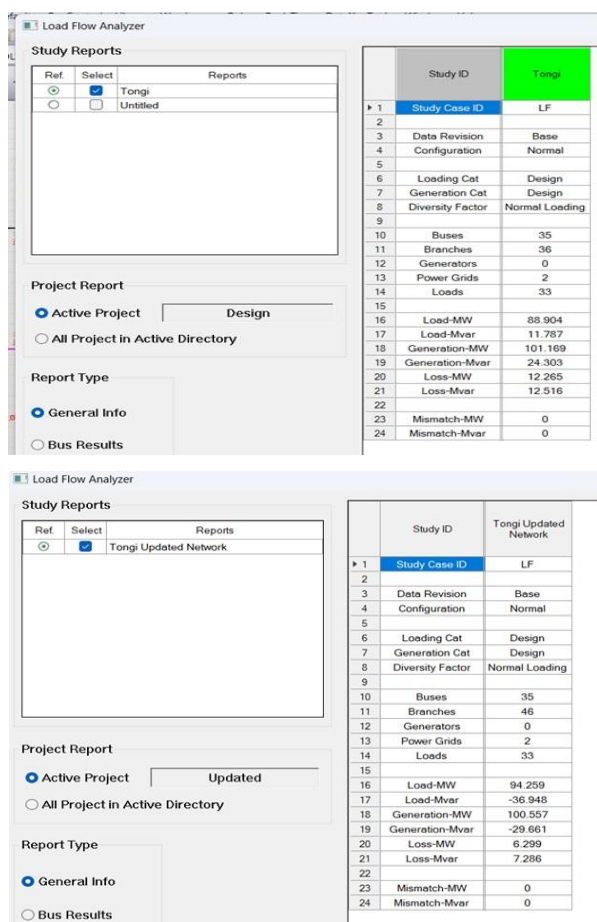


Fig. 5: Voltage profile before and after applying loss reduction techniques.

Finally, Table. 1, compares the loss percentages in the existing and improved cases.

Table. 1: Power loss comparison before and after implementation.

Parameter	Existing System	Proposed Design	Improvement
Generation (MW)	101.169	100.557	-0.612
Load (MW)	88.904	94.259	5.355
Loss (MW)	12.265	6.299	-5.966
Loss (%)	12.12%	6.26%	-48.40%

4. Economic Analysis

4.1 Significance of Evaluation

While technical loss reduction measures improve system efficiency, their adoption ultimately depends on financial viability. Therefore, a cost-benefit analysis was performed for the Tongi 33/11 kV substation under Dhaka Electric Supply Company (DESCO), considering installation, operation, and long-term savings over a 15-year project lifetime.

4.2 Power and Energy Savings

The proposed strategies—parallel feeder reconfiguration, capacitor bank installation, and DG integration- reduced system losses from 12.265 MW (12.12%) to 6.299 MW (6.26%), yielding a net saving of 5.966 MW. Over one year of operation (340 days at 24 hours/day), this translates to substantial energy conservation. Using an average residential tariff of 8.85 BDT/kWh, the annual energy savings are estimated at 646 crore BDT.

4.3 Implementation Costs

The capital cost of the proposed upgrades, including feeders, capacitor banks, DG units, and switchgear, was estimated at 216 crore BDT. Maintenance costs were considered at 2% annually, with depreciation calculated at 15.8% using the capital recovery factor. Salvage value after 15 years was projected at 163 crore BDT. Cumulative maintenance over the project life was approximately 648 crore BDT.

4.4 Financial Outcome

The effective net cost of the project was estimated at 281 crore BDT, while the cumulative net

income from energy savings amounted to 662 crore BDT. This results in a net profit of approximately 381 crore BDT over the project lifetime as shown in Fig. 6.

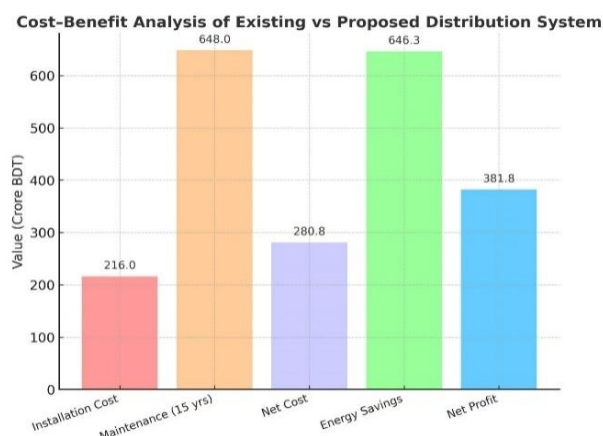


Fig. 6: Cost benefit analysis of existing vs proposed distribution system.

The findings confirm that the proposed loss-reduction design is both technically effective and financially rewarding. Despite the initial capital and maintenance requirements, the energy savings outweigh costs significantly, ensuring a positive financial return. This demonstrates that similar interventions across other substations can provide Bangladesh's utilities with sustainable pathways for improving distribution efficiency, reducing operating costs, and meeting long term energy security goals.

5. Conclusion and Future Work

This study presented an ETAP-based analysis of loss-reduction strategies for the Tongi 33/11 kV substation under Dhaka Electric Supply Company (DESCO). By implementing parallel feeder reconfiguration, capacitor bank installation, and distributed generation (DG) integration, system losses were reduced from 12.12% to 6.26%, nearly halving total losses. In addition to improving voltage profiles and eliminating feeder overloads, the proposed design was confirmed to be financially feasible, yielding a net profit of approximately 381 crore BDT over 15 years. These results demonstrate that targeted technical interventions in distribution networks can deliver substantial operational and economic benefits, providing a scalable framework for utilities in Bangladesh and similar developing contexts. Future research should extend this work by integrating smart grid technologies such as advanced metering infrastructure (AMI) and real-

time monitoring systems to improve visibility and theft detection. The application of artificial intelligence and machine learning algorithms can enable adaptive optimization for feeder reconfiguration, theft detection, and predictive maintenance. Moreover, the integration of renewable distributed generation with storage solutions would further enhance reliability and support Bangladesh's clean energy transition. Expanding the methodology across multiple substations and utilities will allow validation under diverse operating conditions, while incorporating resilience and power quality analyses will ensure stable operation under high renewable penetration. Finally, examining policy frameworks and incentive mechanisms will provide the regulatory support necessary for large-scale adoption of loss-reduction initiatives.

Conflict of Interest

There is no Conflict of Interest

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