

Data Driven Evaluation of Smart Grid Adaptation in Dhaka Electric Supply Company Limited: Challenges and Opportunities

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ABSTRACT

This paper presents a data-driven evaluation of smart grid adaptation in the distribution network of Dhaka Electric Supply Company Limited (DESCO) using actual feeder-level operational data. The study analyzes feeder load characteristics, consumer distribution, reliability performance, and GIS-supported network information to assess smart grid readiness across selected urban distribution feeders in Dhaka. Key performance indicators, including load factor, connected feeder load, and demand patterns, are evaluated to identify operational challenges such as load imbalance and uneven asset utilization. The results reveal significant temporal and spatial variations in electricity demand among the selected feeders, reflecting differences in consumer concentration and network utilization. Based on these findings, a data-driven smart grid adaptation framework is proposed that links the identified operational challenges with appropriate technologies, including advanced metering infrastructure, distribution automation, outage management systems, and demand response. The proposed framework provides a practical and scalable roadmap for improving the operational efficiency, reliability, and resilience of urban distribution networks. The findings offer valuable insights for the phased implementation of smart grid technologies in Bangladesh and other developing countries.

Keywords: Smart Grid, DESCO, Distribution System, GIS, Load Analysis

1. INTRODUCTION

Demand of electricity is increasing speedily over the world due to rapid industrial expansion, rising appliance ownership (AC, electric cookers, washing machines) and urbanization. Peak demand of residential consumers has also been growing sharply. In Bangladesh, the distribution companies are facing persistent challenges, including poor system visibility, high technical and non-technical losses and poor load management. As a major utility serving the northern region of Dhaka, Dhaka Electric Supply Company (DESCO) Limited plays a critical role in ensuring reliable electricity supply in one of the most densely populated cities in the world.

The basic requirements of smart grid are to create a digitalized, robust and sustainable power network by means of developing two-way communication using real-time data. Fundamental necessities include advanced metering infrastructure (AMI), secure communication network, computerized controls for self-healing, integration of renewable sources and robust cybersecurity [1]. Higher level of monitoring and coordination can be achieved by means of modern technologies which

allows us to incorporate the renewable sources with fully monitoring, flexible operation of DGs and lower operational cost.

Currently, Bangladesh power system facing some major problem in implementing smart grid such as poor planning of distribution network, overloading of system components, lack of reactive power support and regulating service, power theft, low metering and monitoring efficiency and lack of sufficient funds [2]. Some fundamental developments including implementing smart meter and employing bidirectional communication system has been recommended for sustainable implementation of smart grid in Bangladesh [3].

A techno-economic assessment has been proposed using Tongi 33/11 kV substation under DESCO for system loss reduction using the Electrical Transient Analyzer Program (ETAP) and system losses reduction is claimed through simulation by 5.86% [4]. However, actual DESCO operational data (total load, feeder measurements, GIS) has not been considered to perform a comprehensive load characterization and drive smart grid deployment priorities. GIS-driven site suitability design framework

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for small scale microgrid is proposed along with AI based short term load forecasting without incorporating direct metering data [5]. Recently, smart grid technologies have been extensively investigated considering smart meter analytics, advanced communication structure and IoT for improving operational efficiency and distribution system monitoring [6-7]. However, most existing studies emphasize specific applications such as load forecasting, topology identification, state estimation, or network reconfiguration rather than providing a comprehensive assessment of smart grid readiness using operational feeder-level data [8], [9].

Furthermore, although GIS has been widely adopted for network visualization and asset management, relatively few studies integrate GIS with actual feeder operational data to evaluate smart grid adaptation from a utility perspective [10]. Consequently, a significant research gap remains in developing data-driven frameworks that combine feeder-level operational data with GIS-based information for practical smart grid readiness assessment. This study addresses this gap by utilizing real feeder data from DESCO to evaluate smart grid adaptation within an integrated, utility-oriented analytical framework.

2. SMART GRID IMPLEMENTATION

To increase the distribution system performance, smart grid technologies have been studied extensively. To

implement the smart grid irrespective of area, facilities have to be ensured in major three categories such as power utilities, consumers and government and regulators. The power utility authority facilities include (i) increased system reliability and efficiency, (ii) reduced the technical and nontechnical losses of the distribution system, (iii) rapid restoration of the system, (iv) increased grid visibility, (v) renewable integration and (vi) peak load management [11]. The consumer facilities include (i) Smart power outage management, (ii) supply stable system voltage and frequency, (iii) load shifting facility during peak hour and (iv) user friendly and transparent tariff [12]. Studies have recommended the following key requirements that should be implemented for smart grid from the conventional one and all the points are figured in Fig. 2 for better understanding.

- a) Implementation of the advanced metering Infrastructure
- b) Distribution Automation
- c) Integration of renewable energy
- d) Implementation of two-way communication system
- e) Integrating energy storage solutions
- f) Demand side management or Demand response
- g) Supervisory control and data acquisition

Studies have revealed that smart grid employment can considerably decrease the losses, enhance reliability, and improve voltage profile.

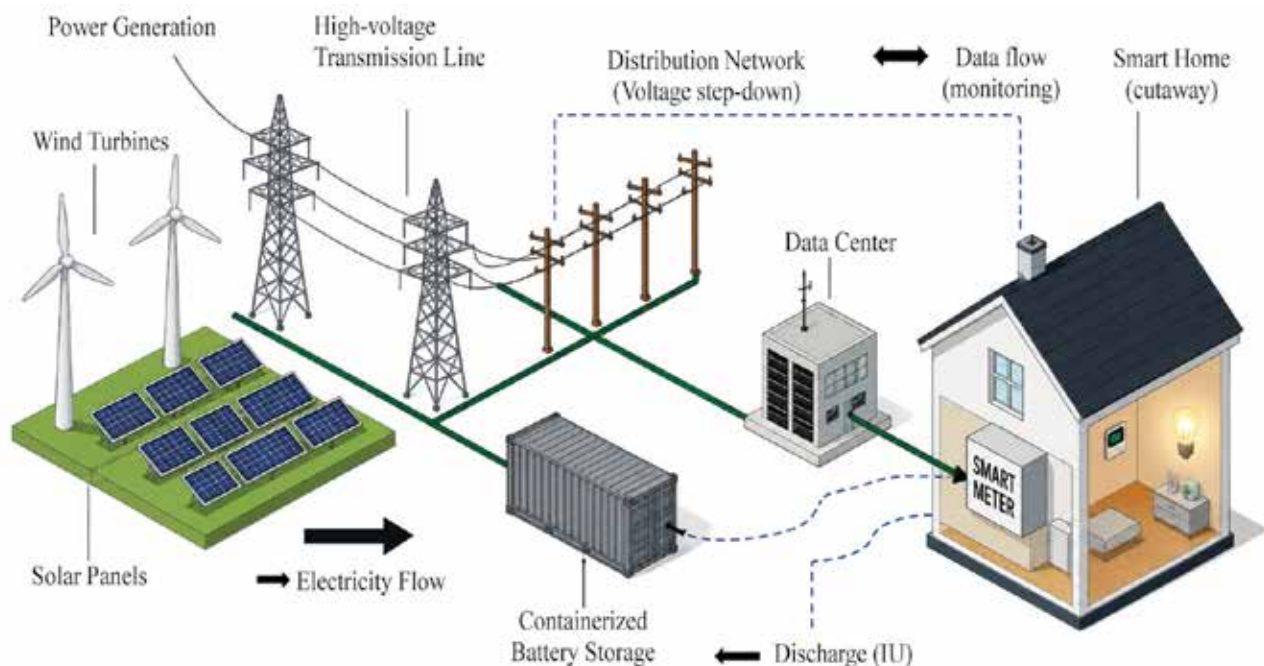


Fig. 1: General framework for implementation of smart grid technology replacing a traditional grid system

3. SMART GRID IN DEVELOPING COUNTRIES

Several developing countries like India, China and Brazil are making their grid smarter [13-15]. Hence, many pilot projects have been taken in hand and started implementation them gradually. Journey of smart grid in India has been started in around 2010 to 2013 by modernizing the aging infrastructure, taking steps for reducing system losses and integrating renewable sources. Strategic indicators comprise of planning about transition by “India smart grid task force” (ISGTF) in 2010, fixing target to transform the power sector into a secure, adaptive, and sustainable network by “smart grid vision and roadmap for India” in 2013, forming the national smart grid mission (NSGM) in 2015 for implementing the smart grid and it started its operation in January, 2016. India start replacing the conventional meter into smart meter along with the improving tariff system and reducing theft in 2016 under the smart meter national program. To implement SACDA and advanced communication technologies, several pilot projects have been commenced under the smart city initiatives [16].

China starts the research about smart grid in 1990s with research into digital power system and established their first digital substation in 2006. In 2009, the state grid corporation of China formally offered the strong smart grid converting the conventional power grid technologies along with ultra-high voltage transmission. China has invested \$285 billion from 2011 to 2020 for smart grid project for developing large scale ultra-high voltage (1000 kV AC and 800kV DC) system development to integrate urban renewable energy sources. Finally, in intelligent improvement and upgradation phase from 2021 to 2025, China focused on automating distribution networks, developing intelligent micro grids, improving operational efficiency and reliability and incorporating gigantic renewable capacity to make the grid cleaner and more proficient [17].

The implementation of smart grid in developing countries faces significant unique challenges including:

- Primarily high capital costs,
- Inadequate existing infrastructure,
- Limited technical expertise,

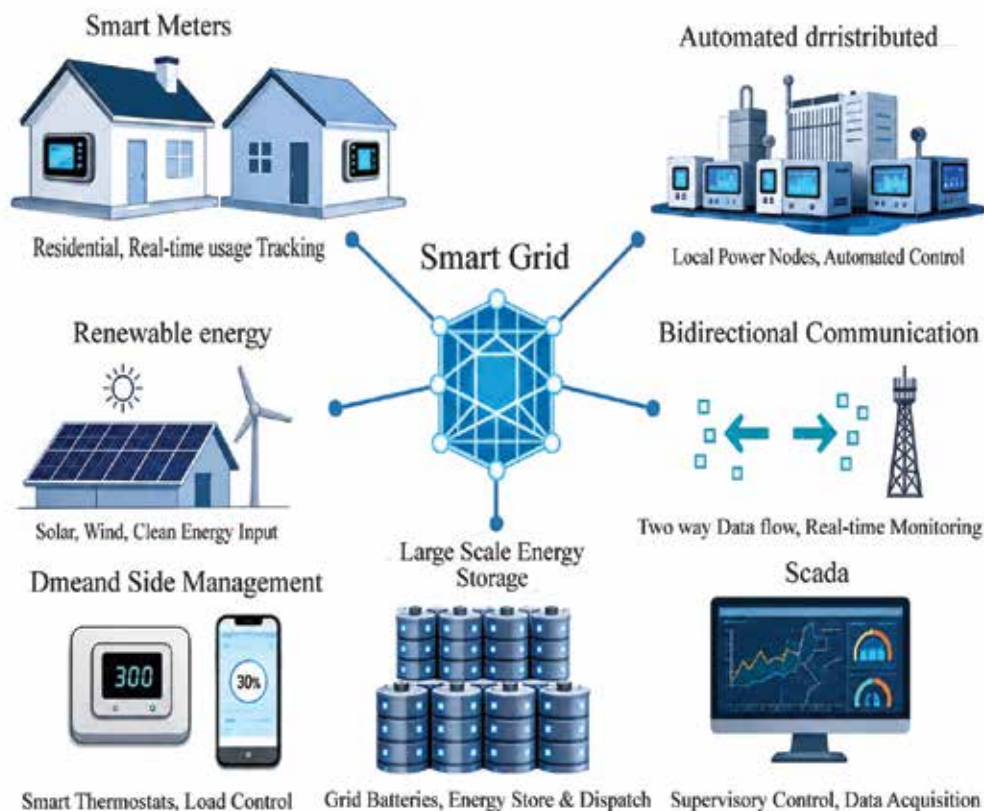


Fig. 2: Primal adaptation features for sustainable implementation of smart grid in Bangladesh

- d) Cybersecurity risk
- e) Regulatory and policy barriers,
- f) Integrating intermittent energy and
- g) socio-economic hurdles.

In spite of these challenges, a number of studies highlighted the potential benefits of smart grid adaption, especially in municipal areas with high load density.

4. METHODOLOGY

The methodology for the research on data-driven evaluation of smart grid adaptation in the distribution network of DESCO focusing on feeder-level load behavior, system inefficiency, and network topology is given in Fig. 3.



Fig. 3: Research Design

Data Description and Study Area

The study was conducted within the service area of Dhaka Electric Supply Company Limited (DESCO), which supplies electricity to the northern part of Dhaka City and adjoining areas of the Gazipur district. The analysis focuses on the Uttara Sector 13 distribution feeder, selected as a representative case study for evaluating smart grid adaptation at the feeder level.

The analysis is based on actual operational data collected from DESCO over the period of February, 26 to March, 26. The dataset comprises hourly feeder load demand, distribution transformer ratings, substation specifications, feeder capacities, consumer information, and GIS-based distribution network topology. In addition, selected system-level operational data, including national load demand profiles, were obtained from the National Load Dispatch Centre (NLDC) to provide a broader context for assessing smart grid implementation challenges and opportunities.

Prior to analysis, the collected data were preprocessed to ensure consistency and reliability. This process included verification of data completeness, removal of duplicate records, correction of inconsistencies, and integration of operational feeder data with the corresponding GIS network layers. The processed dataset was subsequently used for feeder-level performance evaluation, spatial network analysis, and the assessment of smart grid readiness within the DESCO distribution network.

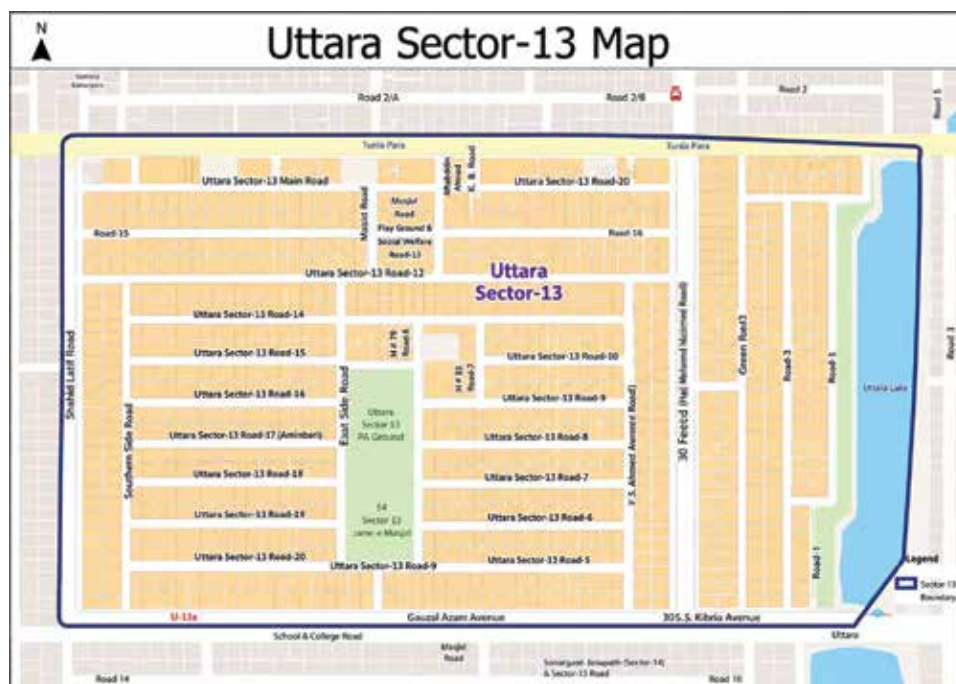


Fig. 4: GIS map of selected study area (Uttara Sector 13)

The Uttara sector 13 is characterized by a mix of residential, commercial, and industrial loads, serving total 8090 consumers. The power distributed network is divided into some feeders to act as primary link that transmit electrical power from a main substation to consumers or through distribution transformer. In the study conducted area six feeders such as Gareeb-E-Newaj, Gausal Azam, Uttara West, GA North, Sector-13, Shah Makdhum are considered. Both single phase and three phase consumers are distributed in each feeder to properly transmitting and distributing the electrical power. Number of consumers along with their load in different feeder is presented in Table 1 for better understanding.

In power system distribution network, there are different types of consumers and the sensitivity of supply to the corresponding consumer may differ with respect to time. Such as electrical supply should be continuing without any interruption in medical centers but disturbance is acceptable in any time in residential building. So, number of different types of building should be considered for implementing the smart grid in any distribution network. Gausal Azam feeder was included in Table 1 to present the overall feeder inventory within the DESCO service area however, it was not selected for the detailed feeder-level analysis because other data are not found from authority.

Table 1: Number of consumers with their load in different feeders

Feeder Name	No. of Consumer	Total Load (KW)	Feeder Load Capacity (KW)
GA North	2202	10221	10410
Gareeb-E-Newaj	1993	12580	13233
Gausal Azam	1422	13214	19182
Sector-13	1773	11189	11113
Shah Makdhum	33	290	310
Uttara West	667	3951	4213
Total	8090	51446	58461

5. RESULTS AND DISCUSSION

This section illustrates the results of data driven analysis conducted on the distribution network of DESCO. Load data and GIS based network information is used to determine the load behavior, technical losses and feeder

performance. To detect the operational inadequacies and their insinuations for smart grid adaptation in DESCO, load factor, power losses and feeder loading are studied as the fundamental factors.

Load Profile Analysis

The load characteristics of the feeder Gareeb E Newaj is investigated using 24-hour interval real data to assess system efficiency and utilization performance in Fig. 5. The observed load curve illustrates the significant deviation of demand between peak and off-peak demand levels. Peak load consumed during the evening hours at 18.00, while minimum demand is found during early morning hours. During the evening period, the maximum (peak) load is consumed as 205 kW, while the minimum (off peak) demand is recorded as 60 kW during early morning hours. The 3364.8 kW of total energy consumption is calculated over the study period causing in an average load of about 140.19 kW.

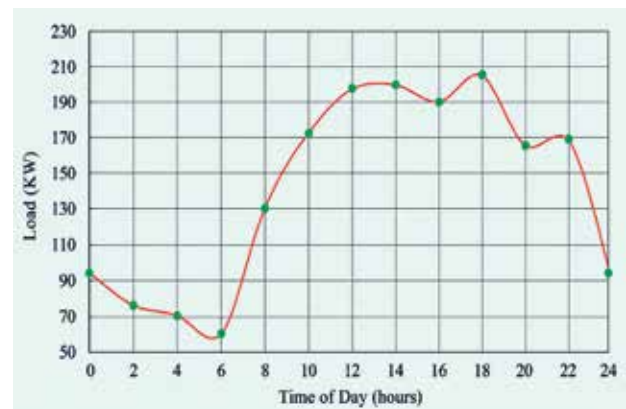


Fig. 5: Daily load curve of Gareeb E Newaj Feeder

Based on the above values, the load factor of the feeder is calculated as 0.684 which indicated the comparatively competent utilization of the feeder capacity. However, a considerable difference between peak and off-peak load recommends the existence of demand variability, which may lead to reduce system efficiency during low load periods and increase the technical losses.

From the smart grid viewpoint, this deviation highlighted the potential reimbursements of employing demand side management (DSM) schemes, such as peak shaving and load shifting. These approaches can lead to flatten the load curve to reduce the stress on distribution network and improving the load factor. Besides, the high peak consumption comparative to the average demand suggests that network components need to be sized to accommodate short duration peaks that may not be

economically appropriate. Hence, the outcomes reveal that while the feeder demonstrates a reasonable high load factor, there leftover opportunity for optimization through involvements of smart grid, mainly in improving load uniformity and decreasing peak demand.

Feeder Performance Analysis

The performance of the designated distribution five feeders is assessed based on key operational signs including peak load, average load, load factor and load changeability. These studies offer insight into feeder utilization, efficiency and appropriateness for smart grid adaptation.

Fig. 6 illustrates the variation in peak and off-peak load demand among the selected feeders. Gareeb E Newaj feeder exhibits the highest peak load of 205 kW, followed by GA North (98.5 kW), Sector 13 (93 kW), Shah Makdhum (52 kW), and Uttara West (46.5 kW). The peak load of Gareeb E Newaj is approximately 2.1 times higher than that of GA North and 4.4 times greater than that of Uttara West, indicating a substantial disparity in feeder loading characteristics.

The minimum off-peak load of 12 kW is recorded for the Shah Makdhum feeder, reflecting the highest variation between peak and off-peak demand among the selected feeders. To quantitatively evaluate feeder utilization, the load factor was calculated as the ratio of average load to peak load for each feeder. The feeder-wise load factor analysis is presented in Table 2.

Table 2: Feeder Performance Based on Load Factor

Feeder	Peak Load (kW)	Average load (kW)	Load Factor (%)
Sector 13	93	72.7	78.2
Gareeb E Newaj	205	140.2	68.4
Shah Makdhum	52	32.4	62.3
GA North	98.5	72.5	73.6
Uttara West	46.5	38.5	82.8

Lower load factors of feeder Shah Makdhum (62.3%) and Gareeb E Newaj (68.4%) indicates the higher load fluctuation, which may lead to increased I^2R losses owing to poor voltage profile stability and peak loading conditions. On the contrary, a relatively balanced load profile is observed in feeder Uttara West (82.8%), which provides the benefits of improved overall efficiency and reduced operational stress.

The results emphasize the significance of feeder level performance valuation in present distribution systems. In the perspective of Bangladesh's urban networks like DESCO, such data driven investigation helps to switch towards smart grid implementation, facilitating enhanced reliability, optimized asset utilization and reduced system losses.

6. SMART GRID ADAPTATION FRAMEWORK

The transition from conventional distribution networks to smart grid systems is indispensable for enhancing

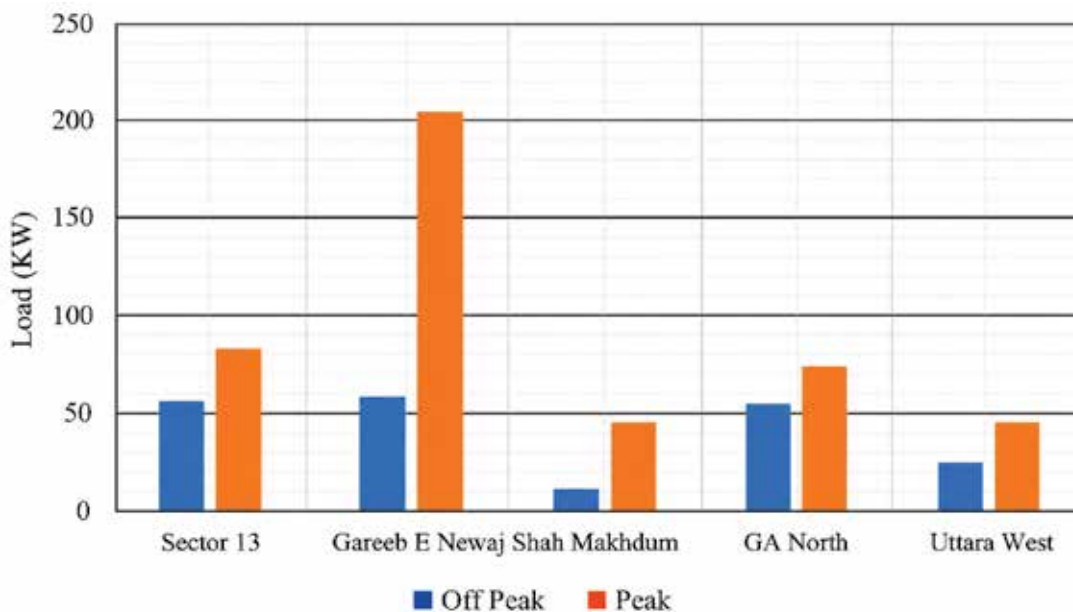


Fig. 6: Peak and off-peak demand of different feeders of study area

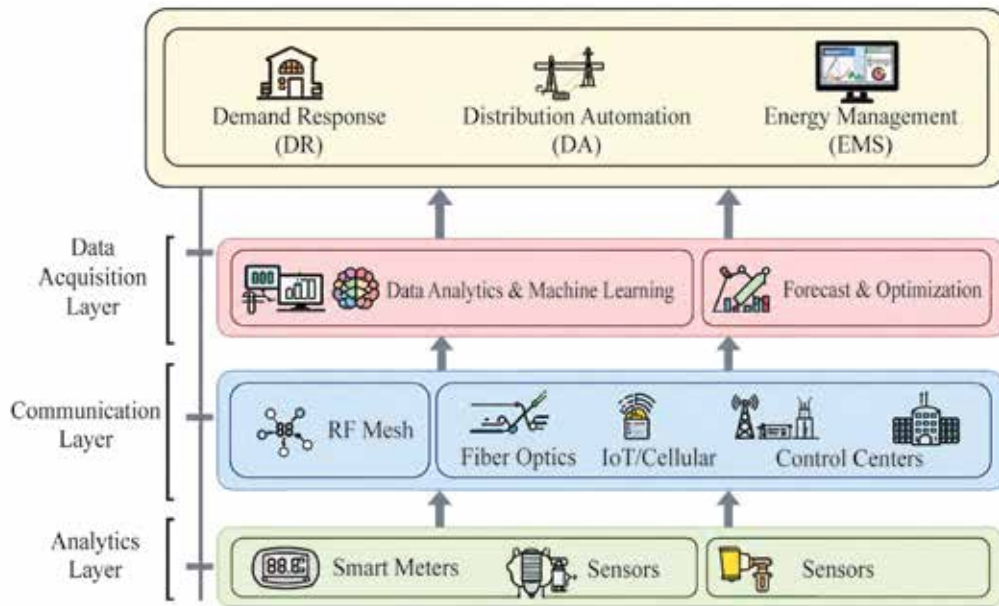


Fig. 7: Smart grid adaptation framework for DESCO

reliability, efficiency, and sustainability in urban distribution system such as those functioned by DESCO. A structured smart grid adaptation framework is offered based on the feeder performance assessment to address system losses, load variability, and peak demand in Fig. 7.

Key Functional Components

The following smart grid components are necessary according to investigated feeder characteristics:

- Advanced Metering Infrastructure (AMI):** Supports DSM and allows monitoring of real time consumption
- Distribution Automation (DA):** Enables automatic fault detection, isolation and supply restoration with improved system reliability.
- Demand Response (DR):** It can shift or reduce load during peak hours and very important for feeders like Gareeb E Newaj, where peak demand is high.
- Distributed Energy Resources (DER):** Integration of battery storage and rooftop solar PV can decrease peak load and improve system flexibility.
- Energy Management System (EMS):** Central Platform for monitoring, controlling and optimization of distribution operations.

Feeder Particular Adaptation Scheme

This framework highlights targeted interventions according to observed feeder performance:

- Gareeb E Newaj:** Needs demand response and peak shaving owing to moderate load factor and high peak demand.
- Shah Makdhum:** Emphasize on improving utilization efficiency and load flattening.
- Sector 13 and GA North:** Due to balanced load profile, these feeders are suitable for the integration of advanced monitoring systems and phased automation.
- Uttara West:** Designated as ideal feeder for the pilot smart grid implementation because of its high utilization efficiency and stable demand.

Implementation Challenges

In spite of having numerous advantages of smart grid adaptation, a number of challenges must be addressed:

- Still need motivation on centralized generation for meeting demand growth.
- High initial investment cost
- Limited smart communication infrastructures
- Grid and distribution code and standards for smart grid not yet implemented
- Data management and cybersecurity unease
- Governing and strategy constrictions in Bangladesh
- Lack of automatic voltage and frequency mechanism
- Sluggish development of renewable energy
- Poor affordability of consumer to smart utilizations

7. LIMITATIONS AND FUTURE WORK

We acknowledge that the proposed framework was evaluated using operational data from selected feeders within the DESCO distribution network, which may limit its generalizability to other utilities with different network configurations and operating conditions. In addition, the current study primarily focuses on smart grid readiness assessment and does not incorporate real-time operational data, advanced optimization techniques, or economic feasibility analysis. The integration of real-time IoT, machine learning-based predictive analytics, and digital twin technologies can be included for further studies related to readiness of smart grid.

8. CONCLUSION

Bangladesh needs to go ahead with assaulting planning and implementation for aligning with the sustainable development goals (SDG) to move from the conventional grid system towards smart grid. An inclusive data driven assessment of smart grid adaptation in the distribution network of DESCO is presented in this paper using feeder real load data and GIS based network information. This assessment highlights the spatial heterogeneity of the network, where heavily populated city areas experience higher operational stress and demand concentration. The outcomes underscore the limitations of traditional grid operational in handling dynamic city load growth and reinforce the essential for smart monitoring and control technique. In the perspective, a viable pathway is offered by the smart grid for improving system performance. The implementation of advanced metering infrastructure, feeder automation, and demand side management can considerably improve operational visibility, load management, reduced peak load stress, and overall network efficiency.

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