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Investigating Reserve Margin of Electricity Generation in Bangladesh

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Abstract

The power sector is essential for the sustainable development of any nation. This study examines various indicators within the power sector, including installed capacity, demand, generation, and shortages of electricity in Bangladesh. A comprehensive analysis of the reserve margin, defined as the unused available capacity of electric power expressed as a percentage of the total capacity in Bangladesh, is conducted. It is observed that the maximum generation and the electricity demand have not increased in line with the rising installed capacity. Over the past decade, the maximum electricity generation has fluctuated between 60% and 70% of the total installed capacity. The reserve margin calculated in this study ranged from 30% to 57.59% during the last ten years. Despite a relatively high reserve margin, electricity shortages relative to demand remain a persistent issue in Bangladesh. The excess power generation capacity is not being utilized effectively, leading to increased costs for consumers and placing an economic burden on the population. It is expected that the stable and reliable electricity generation from the nuclear power and renewable energy in Bangladesh will improve the reserve margin. Policymakers in the power sector should conduct a critical assessment of the electricity generation reserve margin to prevent unnecessary investments in new power plants in Bangladesh.

Keywords: Electricity, Installed capacity, Nuclear power, Power sector, Power plants, Reserve margin.

1 | Introduction

The power sector plays a central role in the economic growth and sustainable development in any country in the world. In Bangladesh, the power sector is regarded as a key driver of economic progress and has experienced significant transformations in recent years. Bangladesh envisions achieving high-income status by the year 2041 [1]. To implement this vision, the sustainable and effective generation of electricity can play

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a vital role in Bangladesh. A sufficient, stable, reliable, and affordable supply of electricity is essential for the economic growth of Bangladesh [2].

Generally, electricity generation in any country is designed to meet the demand for a specific capacity. The total installed electricity generating capacity encompasses the maximum potential output of all operational power plants within the country, along with any electricity that is imported. However, certain portions of this generating capacity may remain unavailable due to scheduled maintenance unexpected outages of power plants, or the need to modulate electricity production in response to demand fluctuations [3]. The capacity for electricity generation, the demand for electricity, and the peak electricity generation are key parameters in evaluating the power sector of any country.

The electricity sector evaluates the balance between supply and demand through a measure called reserve margin. This parameter indicates the percentage of unused capacity for electricity generation during periods of peak demand in relation to the overall capacity for electricity generation [4]. The reserve margin is a vital parameter of electricity generation systems to ensure the reliability and stability of the power sector.

An investigation of a comprehensive overview of the power sector of Bangladesh by analyzing the trend of key parameters is necessary. The analysis of the supply and demand dynamics of electricity can be conducted through the examination of the reserve margin, a critical parameter in the power sector. The comprehensive analysis of the reserve margin of electricity generation in Bangladesh can facilitate the understanding of the power sector. It is also crucial to compare the calculated reserve margin with established benchmarks and to discuss the challenges associated with planning and sustaining an adequate reserve margin for the long-term viability of the power sector in Bangladesh. This study can systematically evaluate the key indicators of the power sector in Bangladesh.

The research framework for this study is outlined. Initially, a comprehensive investigation of the power sector in Bangladesh was performed through a concise literature review and through analyzing of critical indicators, including the installed capacity for electricity generation, electricity demand, maximum generation, and the shortage in electricity generation. Subsequently, the reserve margin for electricity generation in Bangladesh was computed, and its trends were evaluated. Following this, a brief discussion was presented regarding the challenges and implications associated with the key indicators of the power sector and the reserve margin. Finally, the study was concluded summarizing the results and importance of the reliable electricity generation in Bangladesh.

2 | Overview of Key Parameters of Power Sector in Bangladesh

The power sector in Bangladesh has experienced significant expansion driven by a growing demand for electricity. Bangladesh has made considerable progress in increasing its power generation capacity. The installed capacity of electricity generation in Bangladesh has risen to 28,098 MW, with the peak electricity generation reaching to 16,477 MW [5].

By June 2024, the distribution of installed power generation capacity by fuel type is as follows: gas at 44.28%, furnace oil at 22.93%, coal at 18.18%, power imports at 9.45%, diesel at 2.23%, renewables at 2.12%, and hydro at 0.82%. Furthermore, the grid-based installed capacity is comprised of contributions from the public sector at 40.02%, the private sector at 41.70%, joint ventures at 8.82%, and power imported at 9.45% [5]. The power generation mix in Bangladesh comes from a mix of primary sources to balance the energy needs with long-term sustainability goals.

The predicted installed capacity for electricity generation in Bangladesh is projected to reach 56,734 MW, while the expected electricity demand is estimated at 51,000 MW by the year 2041 [1], [2]. Natural gas remains the predominant source in the power generation mix, accounting for a substantial share of the country's energy supply. Additionally, there is an increasing focus on integrating coal, nuclear, and renewable energy sources into the energy framework of Bangladesh, reflecting a planned diversification of fuel sources. Furthermore, Bangladesh is committed to developing a clean and efficient energy system aimed at sustainable

development, with a comprehensive long-term energy strategy being considered that emphasizes safety, energy security, economic efficiency, and environmental sustainability by the year 2050 [6].

Table 1. Year-wise fuel based generation capacity up to 2041 [1], [2].

Indicators	2025	2030	2035	2041
Total generation capacity of electricity	24.459 MW	31.120 MW	40.858 MW	56.734 MW
Power demand	19.900 MW	27.400 MW	37.300 MW	51.000 MW
Fuel Wise Composition Of Electricity Generation				
Gas/LNG	5%	8%	6%	5%
Coal	29%	30%	29%	35%
Oil	6%	4%	6%	1%
Hydro	1%	1%	1%	1%
Nuclear	9%	11%	11%	12%
Power import	10%	16%	17%	16%

In Bangladesh, both the installed electricity capacity and the demand for electricity have consistently risen, driven by rapid industrialization, urbanization, and population expansion. *Table 1* presents historical data on the installed capacity for electricity generation, electricity demand, and peak electricity generation in Bangladesh, covering the fiscal years from 1999-2000 to 2023-2024 [2], [5], [7]. It is mentioned that the fiscal year commences on July 1st and concludes on June 30th of the subsequent year in Bangladesh.

Table 2. Overview of key parameter of power sector in Bangladesh [2], [5], [7].

Fiscal year	Installed Capacity (MW)	Maximum Forecasted Demand (MW)	Maximum Generation (MW)
1999-2000	3.711	2.974	2,.665
2000-2001	4.005	3.206	3.033
2001-2002	4.234	3.457	3.218
2002-2003	4.680	3.728	3.428
2003-2004	4.680	4.023	3.592
2004-2005	4.995	4.308	3.721
2005-2006	5.245	4.693	3.782
2006-2007	5.202	5.112	3.718
2007-2008	5.305	5.569	4.130
2008-2009	5.719	6.066	4.162
2009-2010	5.823	6.454	4.606
2010-2011	7.264	6.765	4.890
2011-2012	8.716	7.518	6.066
2012-2013	9.151	8.349	6.434
2013-2014	10.416	9.268	7.356
2014-2015	11.534	8.920	7.817
2015-2016	12.365	9.600	9.036
2016-2017	13.555	10.400	9.479
2017-2018	15.953	11.200	10.958
2018-2019	18.961	12.100	12.893
2019-2020	20.383	13.300	12.738
2020-2021	22.031	14.500	13.792
2021-2022	22.482	15.800	14.782
2022-2023	24.911	17.100	15.648
2023-2024	28098	17.830	16.477

Table 1 illustrates that the installed capacity for electricity has increased by 7.57 times in the fiscal year 2023-2024, compared to the fiscal year 1999-2000. Conversely, the projected electricity demand and the maximum generation capacity of electricity have increased by 6.00 and 6.18 times, respectively, over the same period. This indicates that the increase in maximum electricity generation and demand has not kept pace with the significant increase in installed capacity.

The annual growth rates for various indicators presented in *Table 1* can be determined. The computed annual growth for installed capacity, maximum demand, and maximum electricity generation reached peak values of 24.75% during the fiscal year 2009-2010, 11.13% in the fiscal year 2010-2011, and 24.04% in the fiscal

year2010-2011, respectively. Notably, the annual growth rates for installed capacity and maximum demand recorded negative values in the fiscal years 2004-2005 and 2012-2013, indicating a reduction in both installed capacity and maximum demand compared to the preceding fiscal years. Additionally, the annual growth rate for maximum electricity generation also exhibited negative values in the fiscal years 2004-2005 and 2017-2018, signifying a decline in the annual increase of maximum electricity generation relative to prior fiscal years.

Fig. 1 illustrates the trend of maximum electricity generation expressed as a percentage of the total electricity generation capacity. The fiscal year represents the following year in the graph, i.e. the year 2000 represents the fiscal year1999-2000. Between the fiscal years 1999-2000 and 2009-2010, this percentage fluctuated between 70% and 80%. In the fiscal year 2009-2010, the percentage reached a low of 67.31%, followed by minor fluctuations in subsequent years. From the fiscal years 2015-2016 to 2023-2024, the maximum electricity generation percentage decreased further, ranging from 60% to 70%. This indicates over the past decade that, 30% to 40% of the electricity generation capacity has remained unutilized.

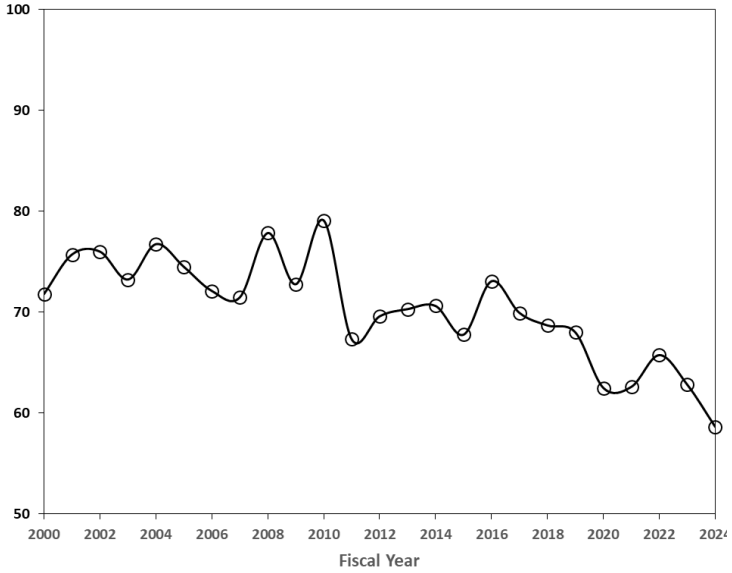

Fig. 1. Maximum electricity generation of total capacity.

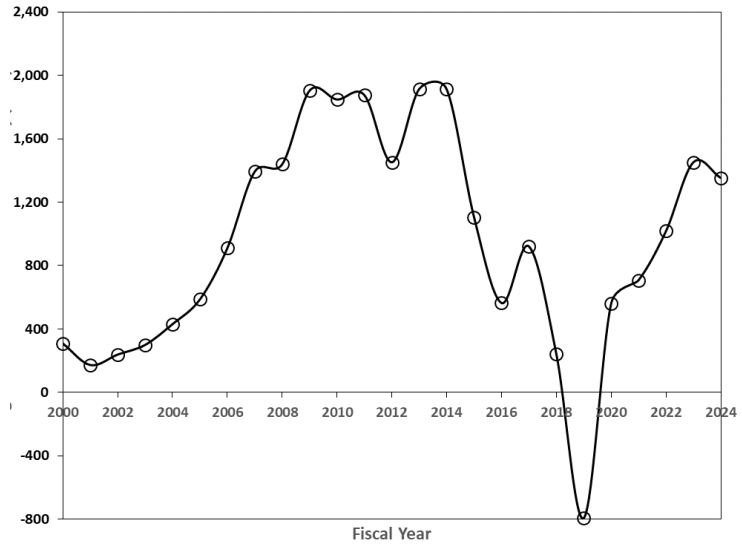

Fig. 2. Shortage of electricity demand.

Fig. 2 illustrates the trend in the shortage of forecasted electricity demand, calculated as the difference between forecasted demand and maximum generation. The data indicates that in the fiscal year 1999-2000, the shortfall was recorded at 309 MW, which subsequently decreased to 173 MW in the fiscal year 2000-2001. However,

beginning in the fiscal year 2000-2001, the shortfall began to rise significantly, reaching a peak of 1915 MW in the fiscal year 2012-2013. Following this peak, the shortfall dramatically decreased to -793 MW in the fiscal year 2018-2019, signifying a surplus in forecasted electricity demand for that year. After 2018-2019, the shortfall of forecasted demand steadily escalated, culminating in a maximum of 1452 MW in the fiscal year 2022-2023. In summary, a shortfall in forecasted electricity demand has been consistently present, with the exception of the fiscal year 2018-2019, which experienced a surplus. Consequently, power shortages have been prevalent in Bangladesh during both peak and off-peak periods.

3 | Analyzing Reserve Margin of Elecetricity Generation in Bangladesh

In Bangladesh, there is a persistent shortage of electricity, even though there exists a surplus capacity for electricity generation. Consequently, load shedding occurs frequently throughout the country. Analyzing the reserve margin within Bangladesh's power sector is essential to comprehend the disparity between the installed electricity generation capacity and the actual electricity demand.

The reserve margin serves as a crucial parameter for power systems, representing the percentage of unused available electricity generation capacity during peak demand relative to the total generation capacity [4]. The reserve margin within electricity systems plays a crucial role in maintaining the reliability of electricity supply. A higher reserve margin necessitates greater investment to enhance generation capacity, thereby increasing the reliability of the electricity generation system. Conversely, a lower reserve margin demands less investment, resulting in a less reliable electricity generation system.

In this study, the reserve margin for electricity generation was determined using the *Eq. (1)*. Generally, the data of peak demand is used in the calculation of reserve margin of electricity generation. However, in this study, the forecasted demand of electricity was used instead of peak demand of electricity in *Eq. (1)*, due to the unavailability of data of peak demand. The reserve margin was determined by utilizing *Eq. (1)* alongside the data regarding installed capacity and forecasted electricity demand in Bangladesh, as presented in *Table 1*.

$$\text{Reserve margin} = \frac{(\text{Installed electricity generation capacity} - \text{Forecasted demand of electricity})X100\%}{\text{Forecasted demand of electricity}}. \quad (1)$$

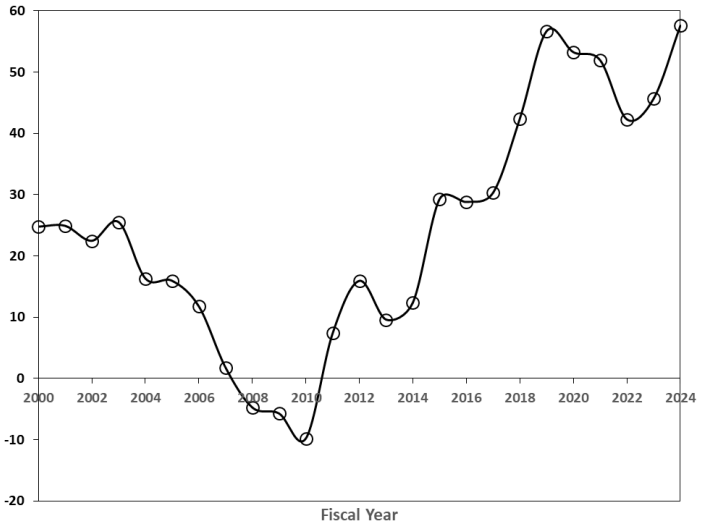

Fig. 3. Reserve margin of electricity generation.

Fig. 3 illustrates the trend of the reserve margin over the past 25 fiscal years. As indicated in *Fig. 1*, the reserve margin was recorded at 24.78% for the fiscal year 1999-2000, which subsequently rose to 25.54% in the fiscal year 2002-2003. However, a consistent decline in the reserve margin was noted from the fiscal year 2002-2003 until the fiscal year 2009-2010, culminating in a drop to -9.78% during the latter year. This negative

figure signifies that the projected demand exceeded the available electricity capacity. A significant recovery occurred in the fiscal year 2011-2012, with the reserve margin increasing to 15.93%, followed by a minor reduction in the subsequent year. Beginning in the fiscal year 2012-2013, the reserve margin exhibited a positive upward trend. From the fiscal year 2016-2017 onward, the reserve margin consistently surpassed 30%, peaking at 56.70% in the fiscal year 2018-2019, indicating that the installed capacity was 56.70% greater than the anticipated electricity demand in Bangladesh. Following this peak, the reserve margin experienced a decline. However, the reserve margin reached to 57.59% in the fiscal year 2023-2024.

The analysis conducted in this study revealed that the reserve margin over the past decade ranged from 30% to 57.59%. It is important to note that the reserve margin for electricity generation varies by country. Generally, a reserve margin below 15% is regarded as tight, while a margin exceeding 20% is typically viewed as oversupplied. Margins falling between 15% and 20% are considered to be in a balanced state [8]. The reserve margin generally falls within the range of 10% to 20% [9]. The International Energy Agency (IEA) generally recommended a reserve margin ranging from 20% to 35% [10]. From an economic perspective, an adequate reserve margin indicates that the power system possesses a sufficient level of generation capacity, allowing the system planner to design the generation system effectively [9].

The surplus capacity can have considerable economic consequences for Bangladesh. Power plants incur significant fixed costs, which include investments in infrastructure, maintenance, and operational costs, regardless of whether they are in use. The excess capacity may result to some power plants operating at suboptimal levels or being idle, which can lead to inefficiencies and raise the cost of producing electricity and adversely affect the overall financial stability of the power sector.

4 | Discussion

Bangladesh has experienced surplus electricity generation capacity due to the substantial investments in new power plants and infrastructure in recent years. Power producers sometimes get paid for their availability even when they are not producing electricity, which could raise the cost of the electricity supply. Thermal power generators in Bangladesh receive capacity payments under the provisions of power purchase agreements, regardless of their actual utilization [11]. Since the installed capacity determines the fixed costs of electricity generating, these expenses are incurred even if the reserve capacity is not used for power production. Therefore, an excess of power capacity will result in higher electricity costs, which will put economic pressure on electricity users [6]. Over one-third of Bangladesh's power generation capacity remains underutilized, incurring costs while remaining inactive. Also, the ongoing development of superfluous new fossil fuel power plants is likely to burden the economy of Bangladesh [12]. Despite having a significant surplus of power reserves, the power sector in Bangladesh will persist in facing challenges related to capacity payments, subsidy obligations, and fuel import expenditures [13].

Nuclear power plays a significant role in electricity generation, particularly when it comes to managing steady electricity. Nuclear power is cost competitive with other types of electricity generation, except where there is direct access to low-cost fossil fuels [14]. Generally, nuclear power plants are designed to operate at a steady and dependable level and act as baseload generation in the grid due to the combination of high capital costs and complex operational constraints [15]. Nuclear power is the most reliable energy source and it has the highest capacity factor of any other power source. The capacity factor of a nuclear power plant is 92.5% [16]. With a high capacity factor, nuclear plants typically operate at or near their maximum output for a considerable duration, thereby providing a stable and reliable electricity source which is crucial for sustaining a strong reserve margin. However, nuclear power may not be ideal for addressing peak demand, as their consistent output is instrumental in maintaining a stable reserve margin. Therefore, nuclear power can be an important source in upholding a stable and dependable electricity reserve margin, owing to its baseload generation capabilities and high operational availability.

Bangladesh has embarked on the development of nuclear power to diversify its energy mix and to ensure a stable and reliable electricity supply. The initiative aims to bolster the nation’s energy security, decrease

dependence on fossil fuels, and help to fulfil its electricity requirements. Currently, the construction of the Rooppur Nuclear Power Plant is underway, featuring two units, each with a capacity of 1200 MWe. The first unit is expected to begin supplying power to the national grid in 2025, followed by the second unit in 2026 [17]. It is expected that stable, reliable and continuous electricity supply from nuclear power plant will decrease the shortage of electricity in Bangladesh and it will provide a stable reserve margin in future [18].

Renewable energy like solar, wind, hydropower, and biomass can also impact the reserve margin of electricity generation. Renewable energy can increase the total generation capacity, reducing the reliance on fossil fuels, and enhances energy security. Bangladesh has made significant progress in adopting renewable energy, driven by both domestic needs for electricity and to reduce carbon emissions. When renewable energy sources, are integrated into the power grid, they can influence the reserve margin both positively and negatively, depending on how they are managed and how they interact with conventional generation sources. The adoption of cleaner technologies can accelerate the progress towards sustainable development objectives by reducing carbon emissions [18] which can be facilitated using nuclear power and renewable energy in Bangladesh.

The precise forecasting of electricity demand is essential for aligning generation capacity with real needs, thereby preventing overcapacity of electricity generation. Through strategic planning and policy modifications, along with improved demand forecasting, enhanced grid infrastructure, and well-informed investment choices, Bangladesh can achieve a more effective balance between its power generation capacity and actual demand, thus reducing the economic repercussions of surplus capacity.

5 | Conclusion

This study presents the trends of various indicators within the power sector of Bangladesh, including the installed capacity for electricity generation, electricity demand, maximum electricity generation, and electricity shortages. A comprehensive analysis of the reserve margin for electricity generation in Bangladesh is conducted.

The installed capacity for electricity generation, the projected electricity demand, and the peak electricity generation have seen increases of 7.57 times, 6.00 times, and 6.18 times, respectively, in the fiscal year 2023-2024 compared to the fiscal year 1999-2000. Consequently, the peak generation and electricity demand have not risen in accordance with the upward trend of installed capacity. Over the past decade, the maximum electricity generation has fluctuated between 60% and 70% of the total installed capacity. A shortage in the projected electricity demand has been observed in Bangladesh.

The foremost contribution of this study is the investigation of the reserve margin of electricity generation in Bangladesh. The analysis revealed that the reserve margin over the past decade ranged from 30% to 57.59%. This indicates that the installed capacity significantly exceeded the projected electricity demand. However, despite this substantial reserve margin, a consistent electricity shortage relative to demand has been noted. Maintaining a higher reserve margin necessitates increased investment to enhance electricity generation capacity. The surplus generation capacity remains underutilized and incurs costs while remaining inactive, ultimately leading to higher electricity prices and imposing an economic burden on the people of Bangladesh.

Both nuclear power and renewable energy can be a part of long-term energy strategy in Bangladesh. These two energy sources can play a crucial role to meet the growing electricity demand in Bangladesh while diversifying its energy mix, improving energy security, addressing environmental concerns, and managing proper electricity reserve margins. It is expected that the stable and reliable electricity generation by nuclear power and renewable energy will alleviate the electricity shortage in Bangladesh and enhance the stability of the reserve margin.

The future planning of the power sector in Bangladesh must take into account diversity, redundancy, and reliability. Additionally, it is necessary for policymakers to conduct a comprehensive analysis of the electricity generation reserve margin to prevent unjustified investments in new power plants.

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Conflicts of Interest

The author declare no conflict of interest.

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