

Bagdadee, Amam Hossain; Zhang, Li

Article

Electrical power crisis solution by the developing renewable energy based power generation expansion

Energy Reports

Provided in Cooperation with:

Elsevier

Suggested Citation: Bagdadee, Amam Hossain; Zhang, Li (2020) : Electrical power crisis solution by the developing renewable energy based power generation expansion, Energy Reports, ISSN 2352-4847, Elsevier, Amsterdam, Vol. 6, Iss. 2, pp. 480-490, <https://doi.org/10.1016/j.egyr.2019.11.106>

This Version is available at:

<https://hdl.handle.net/10419/243920>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



<https://creativecommons.org/licenses/by-nc-nd/4.0/>



The 6th International Conference on Power and Energy Systems Engineering (CPESE 2019),
20–23 September 2019, Okinawa, Japan

Electrical power crisis solution by the developing renewable energy based power generation expansion

Amam Hossain Bagdadee, Li Zhang*

College of Energy and Electrical Engineering, Hohai University, Nanjing 210098, China

Received 7 October 2019; accepted 22 November 2019

Abstract

This paper proposes a different hybrid system that considers the intelligible and complex to understand the problem of regulating the expansion of conventional power plants. The current reality is determined on a long-term power generation expansion plan for Bangladesh from 2016 to 2030. The discontent of the framework and weaknesses in the power systems are facing the main problem by the energy crisis. Thus, long-term renewable energy based power generation model and the use of inhabited coal are inspected in the extent of the costs of natural expansion and green impact. The results demonstrate that in 2030 the power generation needed to meet future demand is assessed at 160TWh. The proposed structure includes two steps. In the first step, the assessment of the importance of technology is carried out using a hybrid methodology and benefits from a system of excellent descriptions, starting points, and risk assessments in the second step that will make a multi-objective show to improve our generation's expansion plans. Two objective capacities are considered in this model. That is, adding weight to the overall placement trend and reducing overall costs. The implementation of renewable power is a great decision to describe the lake of power in Bangladesh because it requires minimal effort and less danger. This activity is essential for developing sustainable power generation in Bangladesh. The numerical model is solved using the NSGA-II algorithm, and the effect analysis is carried out on the key parameters. The results show an expanded offer of constant renewable sources in power generation for ensuring sufficient power supply in Bangladesh.

© 2019 Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Peer-review under responsibility of the scientific committee of the 6th International Conference on Power and Energy Systems Engineering (CPESE 2019).

Keywords: Energy crisis; Renewable energy; Power generation expansion; Bangladesh

1. Introduction

Energy generation expansion plans for power plants include the determination of alternative power generation innovations that will be added to the current framework, and when and where it should be developed to meet the energy demand for development during the perspective development period. Electricity, a type of energy to observe, plays a vital role in the current social order [1]. Power plants convert various renewable energy and

* Corresponding author.

E-mail addresses: a.bagdadee@hhu.edu.cn (A.H. Bagdadee), zhanglinuaa@hhu.edu.cn (L. Zhang).

non-renewable energy assets, such as fossil fuels, a global energy, solar energy, and wind energy, into electricity as indicated by the 2018 Global Status report that around 77.9% of all electricity produced is supplied through fossil assets. Recently, the government has promoted the supply of renewable energy in its energy portfolio, due to difficulties such as fossil fuel constraints, ecosystem pollution, the importance of strengthening energy mixtures, and the possibility of getting more incentives from fossil assets [2]. The problem of spreading generation expansion was considered in all admirations, but a large number of experiments focused on finding the lowest cost expansion plan [3]. However, there are several conflicting goals, such as environmental impacts, reliability, imported fuels, and security in the regulation of generation expansion. Nowadays power is acting a great function wherever modern community lives and works in the industry, agribusiness, transportation, etc. The nation's living standard and daily prosperities are directly depended on the electricity accessibility. The electricity consumption is growing steadily as technological innovation [4]. Sufficient and reliable electricity sources are essential things that need to be considered for sustainable and productive economic progress as well as reducing demands. In Bangladesh, 90 million of the 160 million people can access electricity, but high-quality power is still uncertain because of the energy crisis. In this industry need to meet the requirements lost in the future demand. As a result, the power generation industry requires generation expansion planning that can be adjusted to achieve harmony between free-market activities [5]. Generation expansion assesses speculation and operational choices for various technologies as a matter of long-term regulation. In principle, the focus of the generation expansion planning problem is on the economic approach. Bangladesh is considered unproductive against the effects of climate change [6]. There are need proper guidelines from the Bangladesh Government for reducing the impact of the environment, need to regulate the green generation expansion of power plants to meet demand with low cost.

This paper shows a hybrid system to determine Bangladesh's long-term power expansion plans from 2016 to 2030. These issues are considered from the perspective of a sustainable development approach. This study essential and obligatory factors in addition to the usual generation expansion crisis, and proposes a system of two steps to estimate the results of Bangladesh. The fundamental of this analysis is the primary stage plans to research critical and viable factors through a hybrid network analysis process for hazard investigation to investigate important and successful factors. At that time, the power plant was obtained by a multi-purpose validation model. This model is explained by non-predominant genetic calculations (NSGA-II).

2. Literature review

Bangladesh has more than 160 million people, one of the most populous countries in the world. Agribusiness has been a fundamental source of income for the country's people. However, Bangladesh's gross domestic product (Gross Domestic Product) is 7.75% in 2018 [7]. Central Bank of Bangladesh estimates that economic progress will be more than 8.50% in 2019. Rapid urbanization, filled with relentless financial repairs, has created a massive demand for electricity. It is essential to anticipate the necessary components of poverty, increased monetary, rational structural movements, and security in all countries with poverty. The Bangladesh government must ensure that the electric power is functioning and are usually appropriately moved for public demand. The provisions of the electricity companies are facing the immortality effects of the energy crisis [8]. A stable power supply is essential to promote financial development.

2.1. Crises of the power sector

Following a few paragraphs explain the interruptions and load shedding showing the intensity of power crisis:

According to Table 1, six types of faults caused a blackout in transmission. In national grids are Partial Power failure due to trouble in a generation, partial power outage because of issues in the network by the S/S device, halfway power outage. The breakdown in the transmission line and partial power outage because of lightning in the transmission line/Electrical storm, incomplete power outage because of electricity in the Transmission Line/Rainstorm and Aggregate system discontent [9]. Among them, Partial Power failure due to trouble in a generation is the most dominant one.

People of Bangladesh are suffering much due to normal load shedding, and it becomes a common term in the Power sector of Bangladesh. According to dictionary.com, load-shedding is the cutting off the electric current on specific lines when the demand grows more significant than the supply. In FY 2016–17 load shedding imposed on

Table 1. Interruption of national grid.

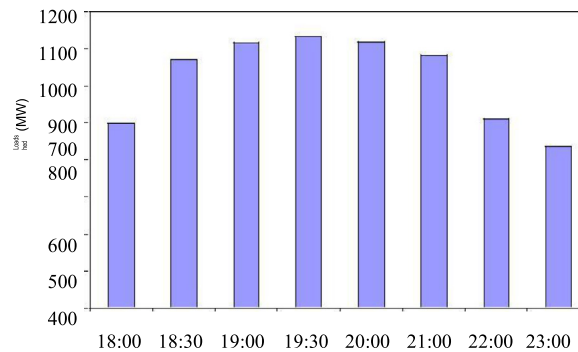
| Sl. no | Type of fault | Total number of fault | Total duration (hours/minutes) |
|--------|---|-----------------------|--------------------------------|
| 1 | Power failure due trouble in generation | 95 | 06/44 |
| 2 | Power failure due to trouble in grid S/S Equipment | 15 | 50/43 |
| 3 | Power failure due to fault in transmission line | 14 | 16/55 |
| 4 | due to the lightning on transmission line/Thunder Storm | 02 | 00/33 |
| 5 | Partial Grid failure | 05 | 01/28 |
| 6 | Total Grid failure | 00 | 00 |

351 days which was in the previous fiscal year 358 days which signifies how frequently load shedding occurs [10]. Table 2 shows that in November 2017 total demand was 12352 MW and complete load shedding by BPDB was 4212 MW. The highest load shed of 873 has done in Dhaka [11].

Table 2. Peak demand & load shed.

| Area | Demand (MW) | Load shed (MW) | Area | Demand (MW) | Load shed (MW) |
|-------------------|-------------|----------------|---------------------------|-------------|----------------|
| Dhaka | 3825 | 873 | Mymen Singh Sylhet | 745 | 283 |
| Chittagong | 1670 | 480 | Barishal Rangpur | 499 | 214 |
| Khulna | 1780 | 785 | Rangpur | 815 | 227 |
| Rajshahi | 1510 | 725 | Total = | 12352 | 4212 |
| Comilla | 815 | 435 | | | |

The following Fig. 1 shows the load shedding of the same day at a different time. It is clear from the graph that the majority of the load shedding has done between 18:30 and 21:00. However, the highest load shedding occurred at 19:30.

**Fig. 1.** Load shed at a different hour.

As a result of these persisting problems cause low access to electricity and poor reliability. Many of the rural areas and inhabitants are still out of reach of power. So they cannot contribute to the country's GDP as much as they could. Another side effect is that people who have access to power are not getting it correctly. Extensive load

shedding is done by the electricity company which makes the life of general people horrible. All types of industries failed to achieve their objective production which in turn lowered down their contribution to GDP.

2.2. Renewable energy potential

Bangladesh invests in the supply of abundant renewable energy sources. Among renewable resources, solar, wind, biomass and hydropower can be used successfully in Bangladesh.

2.2.1. Solar energy

Bangladesh is located somewhere in the range of 20.300 to 26.380 in the north and 88.040 to 92.440 in the east. This is the best area to use solar energy. Annual radiation amount is ranging from 1840 to 1575 kWh/m² and 50%–100% higher than in Europe [12]. The expertise of solar power related to the framework is around 50,174 MW. In Bangladesh, the amount of solar radiation fluctuates from season to season. In this way, we might not get the same solar energy regularly. The most extreme radiation doses can be accessed from the spring of April to at least December and January. Fig. 2 shows the design of natural solar radiation for each month.

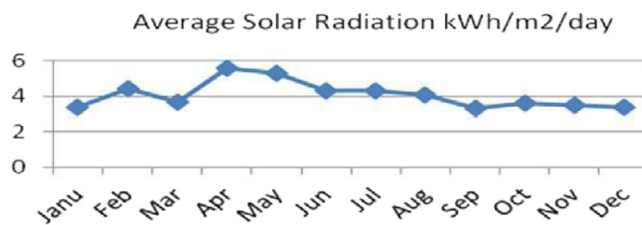


Fig. 2. Monthly average solar radiation profile in Bangladesh [13].

2.2.2. Wind energy

The lack of robust wind speed information has hampered the assessment of wind energy property. There is in wind speed report announcing that it is reliable and used in Bangladesh wind energy assessments. Several coastal zone areas were investigated to assess wind energy potential. The most significant normal wind speed is around 5.3 ms⁻¹ in April length growth, and this is the lowest in Bangladesh, which is around 2.6 ms⁻¹ in December. The technical capacity of wind energy is rated at 4614 MW [14].

2.2.3. Biomass

In Bangladesh can control fertilizers used for biomass-controlled electricity generation, plant accumulation, dropping poultry, water hyacinth, and rice husk and so on. The annual rate of biomass that can be recovered in Bangladesh is around 1.26 million tons per year. There are around 50% of rice husk is used for energy applications, such as steam generators for local cooking and fertilizing rice. Thus, 50% of rice husk can be used for electricity generation. Only 57% of poultry manure is practical for small generations of controls. The technical potential of biomass energy is estimated at 566 MW [15].

2.2.4. Hydro-power

The landscape of the country is flat that required to limit exploitation of hydropower further due to the potential for substantial social and ecological impacts. The available limit for hydropower is 745 megawatts, of which around 200 megawatts are only slightly smaller than the typical estimated hydropower plant. The absolute installation limit for hydroelectric power plants in 2010 was 230 MW [16]. The expansion of 100 MW from the Karnafuli Hydroelectric Power plant will be included in 2016.

3. Methodology

Different attributes and specific situations in the energy sector of all countries can cause a big difference in the expansion arrangement process. In this paper, concentrate on improving rational and sustainable power resources, and considering the problem of extension of indigenous generations by considering various important economic, ecological, social, political and security supply criteria. The Extended Energy Generation event used in this study is a situation-based energy status indicator made by the Stockholm Condition Foundation. The basic idea of expansion energy generation is a user-driven context based inspection. This situation includes various ways energy is given, changed, and created in a particular place or economy, under the scope of selective assumptions about society, economic progress, technology, and so on. The impact of environmental pollution factors is caused by each stage of fossil fuel processes such as the power plant, including electricity generation and costs of greenhouse gas emissions, distribution, and end-client training procedure. This stage proposes a multi-objective integer programming model to erase expansion plans and to determine the limits of the chosen innovation.

3.1. Objective function

The proposed model combines two objective capabilities: intensification the trend of the proposed generation expansion plan and reducing current estimates of total costs. This model takes into relation various orders, such as power quality, meeting demand, stability, and upper and lower limit of selection factors. The representation of sets, parameters, and elements selected in numerical models such as:

A. The proposed methodology, relationships between Eqs. (1) and (2), taking into description the gradient loads obtained from various techniques (M_j) from the main stage, are characterized to maximize the gradient of the expansion plan. As well, this objective potential is the whole of the proposed plan to determine the best combination of power generation techniques that exploit the general needs of each option determined by generation extension performances model Eq. (2).

$$\max Y_1 = \sum_{s=1}^S \sum_{j=1}^j M_j N_j^t \quad (1)$$

$$N_j^t = Z_j^t Q_j + N_j^{t-1} \quad (2)$$

B. The objective purpose of this model in Eq. (3) is to balance the power supply and demand activities and minimize the economic costs of all frameworks in the horizon setting including speculative costs, operation, and maintenance of costs, fuel costs, environmental costs. The existing calculation process is as follows Eqs. (3)–(7).

$$T_{\text{cost}} = (T_{\text{inv}} + T_{\text{mc}} + T_{\text{fc}} + T_{\text{evc}}) \quad (3)$$

Absolute investment Costs: The constant progress of power generation expansion innovations, the parameter η Eq. (4) is presented with conditions, which is the rate of progress of speculation.

$$T_{\text{inv}} = \sum_{2016}^{2030} \sum_{i=1}^8 \text{Inv}_{2015} \times (1 + \eta_i)^{(t-2015)} \times \frac{K/1+K}{(1 - (1 - K))^t} \times (1 + K)^{-(t-2015)} \quad (4)$$

Maintenance & operation costs to consider the complexity and various parts of maintenance costs, the parameter μ , that is, the level of progress of maintenance costs is shown in condition (5).

$$T_{\text{mc}} = \sum_{2016}^{2030} \sum_{i=1}^8 (O \& M)_{2015} \times (1 + \mu_i)^{(t-2015)} \times P_g \times (1 + K)^{-(t-2015)} \quad (5)$$

To calculate absolute fuel cost, the parameter ω is also presented in condition (6). The rate of progress in fuel costs

$$T_{\text{mc}} = \sum_{2016}^{2030} \sum_{i=1}^8 \text{Fuel}_{2015} \times (1 + \omega_i)^{(t-2015)} \times P_g \times (1 + K)^{-(t-2015)} \quad (6)$$

Absolute environmental costs include two segments. The first part is the environmental costs of conventional plants (coal plants and combustible gas plants) and renewable energy-based power plants, and the last part is the environmental costs of nuclear power plants.

$$T_{env} = \sum_{2016}^{2030} \sum_{i=1}^8 (CO_{2(Emission)})_{2015} \times (1 + \sigma_i)^{(t-2015)} \times Pg \times (1 + K)^{-(t-2015)} \tag{7}$$

3.2. Model constraints

Power and Energy balance power demand and Power Supply. In this paper, the power unit is TW-hour power includes a variety of constraints such as constant quality requirements. The most extreme and smallest recommend of renewable energy assets, and the upper and lower limits of all innovations are considered in the accompanying relationship. Following are the model requirements. In most cases, the retention limit can be resolved as a deterministic or probabilistic grant that electricity supply planning needs to meet the increasing power demand in the region; this study presents four explicit sub-instructions as shown in conditions (8)–(11). The parameter α of Eq. (10) is expressing the proportionality factor between the power obtained and the absolute power demand, which is evaluated from the power information. The parameter β of Eq. (11) is the power proportionality coefficient purchased an absolute peak load demand. In line with this, total limits can be accessed from all periods to protect the framework without affecting the quality and to ensure that the recognition limits are sufficiently accessible to meet the symbol of regular demands. Between the upper and lower bounds are visible as estimates

$$\sum_{i=1}^8 E_g + E_c \geq E_D \tag{8}$$

$$E_g \leq 6000 \times T_c \times P_f \tag{9}$$

$$\alpha \times E_D \geq E_C \tag{10}$$

$$\beta \times P_{ED} \leq E_P \tag{11}$$

Energy security is commonly explained as “access to sufficient and consistent energy to meet demand”. Relying on technology that is isolated is significant supervision. As a result, restrictions on access do not exceed the upper limit patent for various technologies in all periods. This is confirmed by considering the distinct idea of renewable energy generation technology, the parameter “ γ ” symbolize of activity factors protected from the energy framework used in a condition (12). The K parameter of conditional expression (13) is the load end coefficient, which is used to meet the load peak demand.

$$\gamma \times \sum_{i=1}^8 E_g \geq \sum_{i=5}^6 E_g \tag{12}$$

$$\sum_{i=1}^8 I_C + E_P \geq (1 + K) \times E_L \tag{13}$$

Positive response decision variable,

$$E_G \geq 0, E_C \geq 0, E_P \geq 0 \tag{14}$$

3.3. Optimizing the generation expansion by NSGA-II

This is used in the NSGA-II algorithm to determine the proposed multi-purpose model and to determine the selection factor. This is a transformational calculation, prepared to find the principle set of placements on the surface of the Pareto model. It was developed as an able calculator to overcome the problem of multi-objective progress. In the NSGA-II algorithm analysis, the cost and location variables of all people in the population at new points such as large genetic calculations, four properties including positioning, instruction sets, extraordinary verify, the mass distance must be determined, and population estimates deployed must be discarded in a non-dominant placement approach. At all points, people who are not ordered by different people are in front of 1 Pareto. Various people

are dominated by people from the front one from the front two. The highest crowd distance has higher strength as with traditional genetic algorithm; hybrid managers and changes are used for NSGA-II calculations. NSGA-II algorithms are elsewhere as with other met heuristic calculations, the sequel from the NSGA-II calculation is relatively sensitive against its parameter estimates. Therefore, the parameters must be comfortable. Here, the best property for calculation parameters is given in Table 3. After adjusting the NSGA parameters; the problem of generation expansion became clear. Recognition of the Pareto Front assessment of context investigation issues is illustrated in Fig. 3.

Table 3. Structures of NSGA-II algorithm.

| NSGA-II | Parameter values |
|----------------------------|------------------|
| populace | 220 |
| integer of iteration | 800 |
| intersect probability | 0.50 |
| Transformation probability | 0.45 |

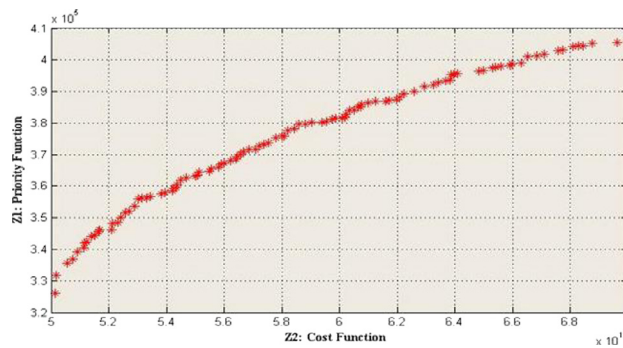


Fig. 3. The approximation of the case study problem.

4. Result and discussions

All placements in the front of Pareto are compared to special situations for improvement, but there is no optimal placement. In this paper use the maximum and minimum utility methods to overcome the selection of the last settings in the settings. In this way, the selected settings are resolved, and the NSGA-II algorithm optimizes other objective capabilities (15) that occur concerning that. In connection (16), Y_j is the utility of the objective capacitance R_i . Y_i is equivalent to one when objective abilities have optimal respect. From connection (17) strengthens the primary utility of the objective element from the selected settings.

$$Max = \delta \tag{15}$$

$$\delta = \min(Y_1, Y_2) \tag{16}$$

$$Y_1 = 1 - \left(\frac{R_1^{max} - R_1}{R_1^{max} - R_1^{min}} \right) \tag{17}$$

$$Y_2 = \left(\frac{R_2^{max} - R_2}{R_2^{max} - R_2^{min}} \right) \tag{18}$$

Specified the previous explanation, different estimates of the solutions selected for objective capabilities are in Table 4. Areas, related costs, and requirements for the solutions are in Fig. 4. The total cost is on the x -axis, and the slope predilection of the plan is on the y -axis. However, that made planning as the optimal Pareto settings.

Table 4. The Properties of the objective operation.

| Objective function | R_i | R_{max} | R_{min} | Y_i |
|----------------------|-----------------------|----------------------|-----------------------|--------|
| Predilection | 463470 | 520262.550 | 262523.943 | 0.7035 |
| Absolute cost | 5.56×10^{12} | 9.9×10^{12} | 3.86×10^{12} | 0.7025 |

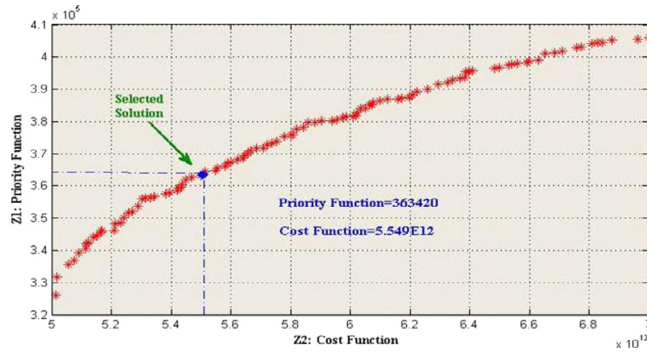


Fig. 4. The Solution of the Pareto front.

The installed capacity for the various types of power generation technology and the scope of the generation expansion planning horizon shows in Figs. 5 and 6. The overall install capacity of the power plant technology mentioned above will reach 160 TWh by 2030, and an annual growth rate of around 30,000 — 6.37%. As far as the growth rate of Fig. 6 is concerned, renewable energy technology (wind power and solar power plants), in any case, will reach the increasing capacities of Fig. 7 by using natural gas and coal power plants is the terminal power plant. In Bangladesh have the capacity of full oil product installations. The nuclear power plant is responsible for 9.38% of all installed installations. Optimal power development to anticipate Bangladesh from 2016 to 2030 comes from long-term demonstrations of renewable energy, including an optimal combination of power plants.

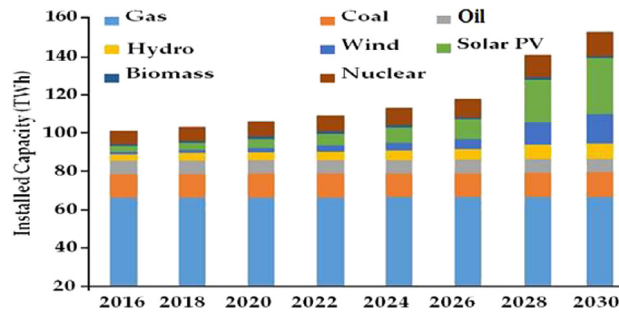


Fig. 5. Install capacity.

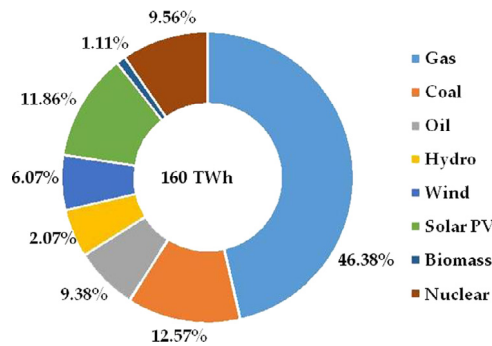


Fig. 6. Percentage of the each install technology.

As shown in Fig. 5, while the supply of renewable energy is increasing, the provision of fossil-based technology will decrease over time. Considering large-scale criteria in traditional generation expansions seems to be a rational explanation behind obtaining these results. The results can create a pattern for the nation to achieve a sustainable and environmentally friendly electricity supply. Also, the use of new and clean technology to be used

in increasingly good practices for increasing business, expanding national capacity, and funding and securing fossil fuel consumption.

Renewable energy based power supply stability and security:

The exploitation of these resources influences the security of the power supply due to separate thoughts about renewable energy resources. As a result, it has imposed upper and lower limits of renewable energy as specific relations requirements between Eqs. (12) and (13). In the situation under consideration, as shown in Fig. 7, the supply of renewable energy increases in the planned range, reaching 22% (upper limit). Excessive dependence on specific innovations reduces the security of the power supply. Therefore, the power plant technology portfolio must be expanded to expand the security and reliability of electricity supply.

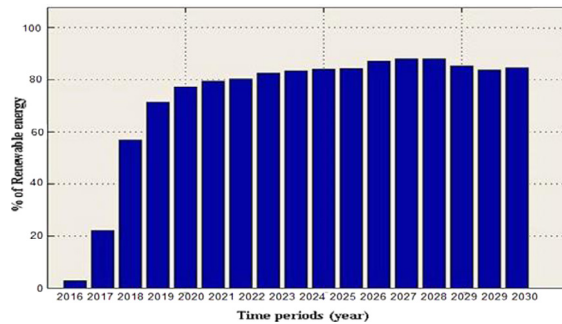


Fig. 7. Percentage of the renewable energy growth in each year.

The smooth progress of the provision of various technologies in deleted configurations, related constraints are given Eq. (14), reducing the limits that can be accessed from any innovation in any period between the marked lower and upper limit. Now, the lower and upper limit values are expected to be 0% and 35%, respectively, from the total install capacity. This model works on various estimates of total installed capacities (40%, 50%, and 60%) of all innovations to investigate the impact of results on the estimated upper limit. Relevant results show real changes in numbers and limits. Increasing technology delivery limits seems to have the potential to lead to imbalanced progress and lead to inoperable planning. The results are a presentation in Fig. 8.

5. Conclusion

In this paper, propose a hybrid system to consider long-term regular generation expansion issues that enchanting large-scale criteria such as increasing sustainability and supply stability. Comparative models are prepared; taking into account renewable, nuclear power plants and nuclear powers plants, and are effectively relevant to the analysis of the context of Bangladesh's power plan for the horizon from 2016 to 2030. The objective of this model is to reduce all the costs of the whole framework, including investment costs, maintenance costs, fuel costs, ecological costs, and power achievement costs. In the structure is proposed of the two steps framework. Various options are, considering that can be updated including power generation technology. The power generation expansion planning the model at the main stage, the benefits, opportunities, and hazards of technology are considered in the structure. A multipurpose scientific model was created in the second step to determine the type, size and time of the new boundary. The contextual analysis reveals patterns of growth in the share of renewable energy technologies (wind, solar, biomass, nuclear) on the planned horizon. Also, fossil fuel power plants, including steam, gas and combined cycle power plants, are then recognized as responsible for the extraordinary work of the national electricity supply. Also, the Power Plant The gasoline amplification cycle is the most preferred choice among fossil power plants and has the main marginal parts installed from the planning horizon. Electricity demand is identified strongly by some factors and deference electricity demand in different circumstances because it has essential enforcement strategy. As long as the long-term power generation expansion planning is focusing on various variables enables producers of strategies to achieve the most reliable results. It was concluded that need to focus on the sustainable criteria by the continuous improvement and considering the renewable energy based the power generation expansion. Moreover, stable regulation needs to be considered to promote the exploitation of renewable energy.

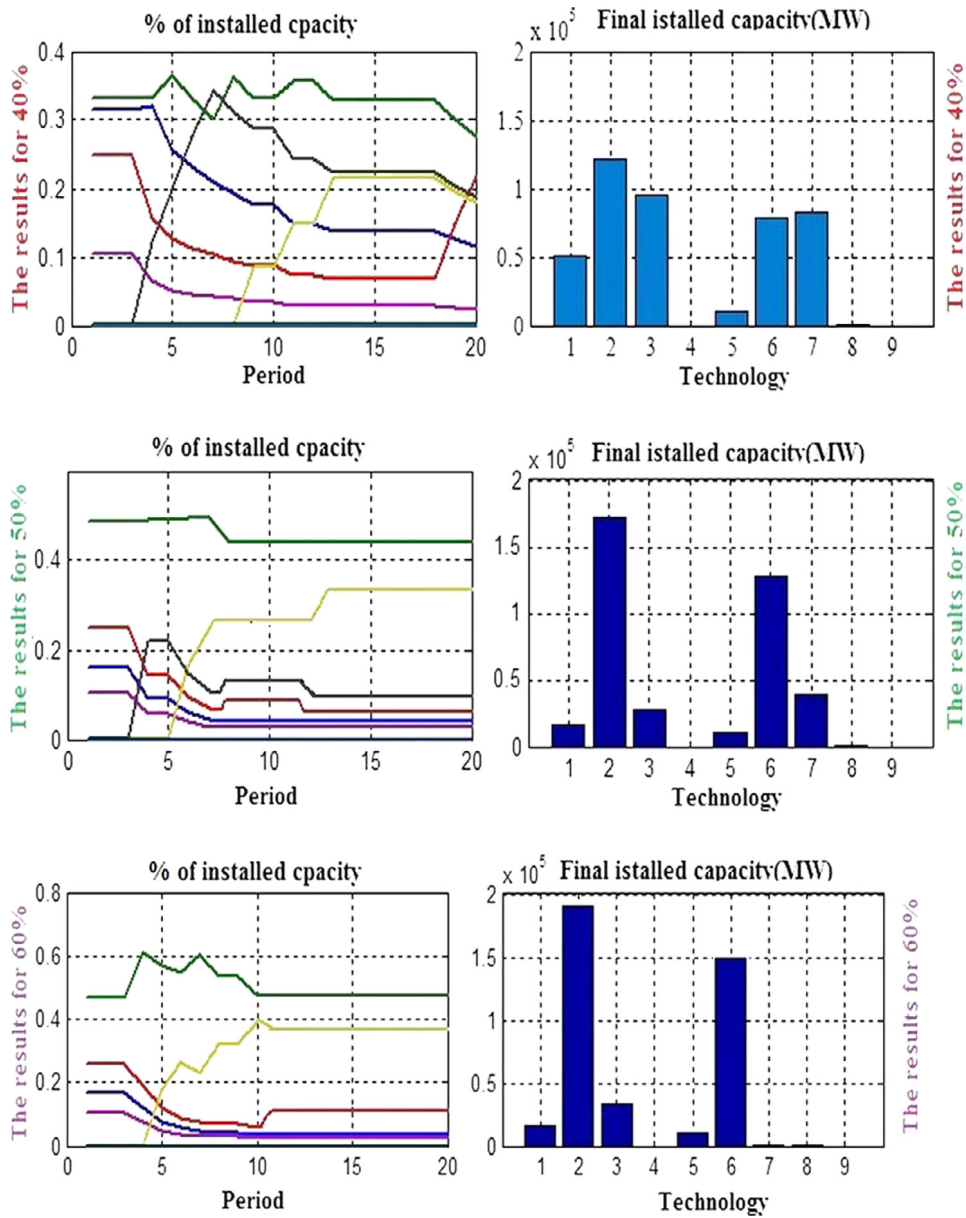


Fig. 8. Impact of The upper limit on technologies with different results (40%, 50%, and 60%).

Acknowledgment

This work was supported by Hohai University under China Scholarship Council (CSC) No. 2017GXZ019296.

References

- [1] Zakir Hossain Khan M, Rasheduzzman M. Performance of the power sector of bangladesh: governance failures and remedial measures transparency international Bangladesh; 2017.
- [2] Chen H, Tang BJ, Liao H, Wei YM. A multi-period power generation planning model incorporating thenon-carbon external costs: A case study of China. *Appl Energy* 2016;183:1333–45.
- [3] Bagdadee AH, Zhang L. *J Electr Eng Technol* 2019. <http://dx.doi.org/10.1007/s42835-019-00220-y>.
- [4] Chen Q, Kang C, Xia Q, Zhong J. Power generation expansion planning model towards low-carboneconomy and its application in China. *Power Syst IEEE Trans* 2010;25:1117–25.

- [5] Jin SW, Li YP, Huang GH, Zhang K. Inexact mixed-integer programming with interval-valued membership function for sustainable power-generation capacity planning. *J Clean Prod* 2016;122:52–66.
- [6] Cheng R, Xu Z, Liu P, Wang Z, Li Z, Jones I. A multi-region optimization planning model for China's power sector. *Appl Energy* 2015;137:413–26.
- [7] C. generation expansion planning model incorporating environment cost and demand side management programs. *Dianwang Jishu/Power Syst Technol* 2015;39:2809–14.
- [8] Feng Y, Ryan SM. Scenario construction and reduction applied to stochastic power generation expansion planning. *Comput Oper Res* 2013;40:9–23.
- [9] McPherson M, Karney B. Long-term scenario alternatives and their implications: LEAP model application of Panama's electricity sector. *Energy Policy* 2014 2018;68:146–57.
- [10] Mondal MAH. Implications of renewable energy technologies in the Bangladesh power sector: Long term planning strategies (Ph.D. dissertation), Germany: Dept. of Ecology and Natural Resources Management, ZEF, University of Bonn; 2018.
- [11] B.J. Tang, Li R, Li XY, Chen H. An optimal production planning model of the coal-fired power industry in China: Considering the process of closing down inefficient plants and developing CCS technologies. *Appl Energy* 2017;206:519–30.
- [12] Wang P, Wang C, Hu Y, Liu Z. Analysis of energy consumption in Hunan Province (China) using a LMDI method based LEAP model. *Energy Procedia* 2017;142:3160–9.
- [13] Xu Zheng, Jianyong Ding, Chao Shang, Qingsheng Lei, Xiaoxin Wang. An assessment method of grid outage cost considering multifactorial influences. *Eng J Wuhan Univ* 2016;49(1):83–7.
- [14] Bagdadee AH. Rural electrification through micro-grid in Bangladesh. *Eng Sci Technol J* 2015;10(5).
- [15] Bagdadee AH. Power quality analysis by the ripple technique. *J Appl Adv Res* 2017;227–34. <http://dx.doi.org/10.21839/jaar.2017.v2i4.74>.
- [16] Weifang Lin, Yong Tang, Huadong Sun, Qiang Guo, Hongguang Zhao, Bing Zeng. Blackout in Brazil power grid on february 4, 2011, and inspirations for stable operation of power grid. *Autom Electr Power Syst* 2011;35(9):1–5.