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Energy Mix and Base Load Optimisation to Mitigate Environmental Impacts

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Abstract:-*The Government of India's (GOI) policy aims to increase the share of renewable energy to 430 GW by 2030, which will have significant implications for conventional energy generation sources. To remain relevant, conventional sources, particularly coal, must be utilised most efficiently for base load generation. It is important to note that solar or renewables alone cannot be the sole solution. Other sources such as hydro and gas must supplement solar energy to achieve a proper balance in the system while also addressing climate change commitments. Base load power stations have the capacity to provide a continuous power supply throughout the year, meeting the minimum power generation requirement. Coal or thermal power plants in India serve as base load plants. Given this context, this paper aims to determine the optimum baseload power generation capacity and optimise the share of coal in base load generation capacity, considering the changing energy mix. The analysis is based on the normal hourly demand for the state of Maharashtra, India, for 2017. To achieve the proper balance in the system, other sources such as hydro and gas must supplement coal for base load while addressing climate change commitments.*

Keywords: coal as base load, renewable energy, system efficiency, lowest demand.

I. INTRODUCTION

Traditionally, power generation in India relied heavily on coal and hydro as the primary energy sources, with a limited contribution from nuclear energy. As pollution concerns were not a major issue, coal and hydropower plants expanded. However, with growing environmental awareness, there was a shift towards exploring alternative energy sources. The energy mix, including both conventional and non-conventional sources, gained attention, and some countries like Iceland and Paraguay made significant progress in transitioning to non-conventional sources. India, on the other hand, continues to rely on traditional sources heavily. The Government of India (GOI) has targeted achieving 450 GW of non-conventional energy capacity in the electricity industry to reduce dependence on conventional sources by 2030. This initiative is expected to lead to an 11% reduction in emissions from the electricity sector. Three sources are commonly used for base load power plants: coal, gas, and hydro. Coal has the largest share, followed by hydro and gas. However, coal is the most polluting among these sources. Each source has its distinct qualities. Hydropower offers the advantage of instantaneous start/stop capabilities and load management. Still, it faces challenges such as land acquisition, environmental concerns, rehabilitation and resettlement issues, technical challenges, and natural calamities. Gas power plants have a lower impact on climate change and are flexible in meeting fluctuating power demand. They have a low plant load factor (PLF) but are cost-effective compared to gas-fueled combined cycles. As discussed in [8], nuclear power is considered a reliable source for base load applications and has low emissions, putting it on par with renewable energy sources. In assessing the optimal energy mix, cost evaluations and resource assessments have been conducted in various countries, as mentioned by NukiAgyaUtama in [12] for ASEAN countries. It has been recognised that relying solely on a single renewable energy source would be inefficient and not align with the goal of decentralised and dispersed power generation, as noted in [10]. The proposed solution is implementing hybrid renewable energy systems that utilise multiple renewable resources while remaining cost-effective. In order to determine the impact of renewable energy on conventional units and establish an optimal long-term energy mix, the Load Duration Curve approach was employed, as described in [4]. Another study [1] emphasised the importance of considering renewable energy sources' geographical and temporal availability and proposed an integrated system to achieve an ideal energy mix.

II. BACKGROUND

Plants used for base load are designed to operate at a constant rate, providing a continuous power supply 24 hours a day, seven days a week, to meet the minimum load demand. They are not intended to fulfil peak demand, typically handled by other power generation sources. Among the different types of power plants, coal plants are well-suited for base load power generation. Hydroelectric power often supplements them to ensure a reliable and balanced energy supply. However, predicting the base load demand accurately can be challenging due to seasonal variations and changes in the lowest demand throughout the day. These fluctuations make it difficult to forecast the exact base load requirements with certainty. The lowest demand during different times of the year and day can vary, affecting the planning and optimisation of baseload power generation. To effectively manage base load power generation, power utilities and grid operators use historical data, load forecasting models, and advanced analytics techniques to estimate the expected base load demand. These predictions help plan and allocate resources efficiently to ensure a stable and reliable power supply.

III. PROPOSED METHODOLOGY

In order to calculate the base load capacity, a proposed methodology considers various factors that can affect demand variation. These factors include a combination of climatic, weather, and seasonal conditions, the pace of economic growth and any capacity augmentations or breakdowns in generating plants. Planning for potential demand requires a prudent approach, and the methodology suggests considering one of the following options:

Case-1: Determining the bottom-out point of the least average hourly demands observed throughout the year.

Case-2: Determining the bottom-out point of the average hourly demands observed over the months of the year.

Case-3: Determining the highest point among the least average hourly demands observed at the end of each Month throughout the year.

Option-2, based on the minimum of averages tending towards the minimum demand band, is considered a more reasonable choice according to the proposed methodology.

By selecting option-2, the methodology identifies the lowest average demand observed across various months, which helps estimate the base load capacity more effectively. This approach considers the overall trend of minimum demands and provides a reasonable basis for determining the base load requirements.

3.1 Formulation

Given a matrix, Ma, with dimensions x × y, representing the average demands of each hour for the year 2017, where x represents the number of hours, and y represents the number of months, the elements of the matrix are denoted as $Ma(i, j)$ with $i = 1, \ldots, x$ and $j = 1, \ldots, y$. We define the highest, average, and lowest of the average demands for each hour of the year as $Mmax(i)$, $Mav(i)$, and $Mmin(i)$, respectively, with $i = 1, \ldots, x$. The calculations for these values are as follows:

$$Mmax(i) = \max\{Ma(i, 1{:}y)\}, \text{ for } i = 1, \ldots, x \quad (1)$$

$$Mav(i) = (1/y) * \Sigma\ Ma(i, 1{:}y), \text{ for } i = 1, \ldots, x \quad (2)$$

$$Mmin(i) = \min\{Ma(i, 1{:}y)\}, \text{ for } i = 1, \ldots, x \quad (3)$$

We also define the following values:

$$MLmin = \min\{Mmin(1{:}x)\} \quad (4)$$

$$MLav = \min\{Mav(1{:}x)\} \quad (5)$$

$$MHmin = \max\{Mmin(1{:}x)\} \quad (6)$$

$$MHmax = \max\{Mmax(1{:}x)\} \quad (7)$$

In the context of determining the base load demands, we consider three cases:

Case 1: Base load demand is represented by MLmin
Case 2: Base load demand is represented by MLav
Case 3: Base load demand is represented by MHmin

The required base load capacities for each case are calculated by considering an 85% availability factor:

$$\text{Minst-BL1} = \text{MLmin} / 0.85 \quad (8)$$

$$\text{Minst-BL2} = \text{MLav} / 0.85 \quad (9)$$

$$\text{Minst-BL3} = \text{MHmin} / 0.85 \quad (10)$$

To calculate the capacity of a peaking power station, we consider the difference between the maximum and minimum demands:

$$\text{Mpeak-1} = (\text{MHmax - MLmin}) / 0.85 \quad (11)$$

$$\text{Mpeak-2} = (\text{MHmax - MLav}) / 0.85 \quad (12)$$

$$\text{Mpeak-3} = (\text{MHmax - MHmin}) / 0.85 \quad (13)$$

Considering an additional 5% demand as spinning reserve (Mres), the installed capacity of spinning reserve (Minst-res) is:

$$\text{Mres} = 0.05 * \text{MHmax}$$
$$\text{Minst-res} = \text{Mres} / 0.85 \quad (14)$$

Therefore, the total installed capacity (Mtotal) required to meet the total demand is:

$$\text{Mtotal} = (\text{MHmax} + \text{Mres}) / 0.85 \quad (15)$$

These calculations estimate the base load capacity, peaking power station capacity, spinning reserve capacity, and the total installed capacity required to meet the overall demand.

IV. RESULTS AND DISCUSSION

In the Results and Discussion section, the following steps were followed to obtain various results:

Step 1: Calculation of Average Hourly Demand: Hourly monthly data from the state of Maharashtra was analysed to calculate the average hourly demand. This involved determining the average demand for each hour across the months.

Step 2: Determining Optimum Base Load Demand: The optimum base load demand was determined using the calculated average hourly demand. An algorithm or methodology was applied to identify the most suitable base load demand value based on data analysis and specific criteria.

The results obtained from these steps provide insights into the average hourly demand patterns and the optimal base load demand for the given scenario in Maharashtra. These results can be further analysed and discussed to understand their implications for regional power generation planning, resource allocation, and system optimisation.

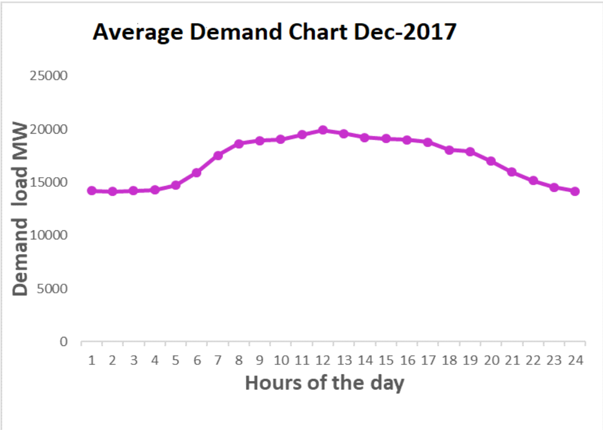

Figure 1: Average Demand Chart for the Month of the Year 2018

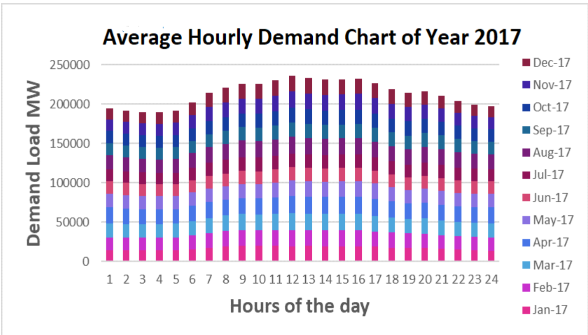

Figure 2: Average Demand Chart of Maharashtra State for the Year 2017

Based on the algorithm, the following values were calculated:

Table 1: Average Demand Table for the Year 2017

	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17
0-1 hrs	14239	16470	17996	20241	17137	15787	15203	18085	15332	15417	14842	14195
1-2 hrs	14115	16198	17558	19787	16952	15307	14763	17708	14967	15298	15148	14151
2-3 hrs	14065	16006	17266	19377	16995	15008	14494	17345	14710	15233	15507	14210
3-4 hrs	14155	15998	17228	19043	16894	14792	14426	17314	14559	15159	15664	14287
4-5 hrs	14514	16372	17437	18133	16909	14838	14718	17599	14797	15510	16100	14733
5-6 hrs	15564	17331	18080	19760	17277	15392	15538	18595	15638	16262	17107	15947
6-7 hrs	17112	18576	19410	20256	17498	15896	16667	19825	16471	16876	18180	17553
7-8 hrs	18848	19871	20002	20275	16791	16124	17194	20538	16853	17237	18859	18644
8-9 hrs	19676	20451	20285	20494	17909	16349	17567	21036	17091	17382	18876	18938
9-10 hrs	19638	19994	19991	20585	18118	16456	17363	20844	17254	17735	18955	19043
10-11 hrs	19705	20194	20499	21179	18548	16829	17352	20924	17587	18388	19867	19490
11-12 hrs	19251	20890	21332	21984	19247	17196	17467	21236	17833	18798	20691	19900
12-13 hrs	19810	19679	21270	21919	19234	17081	17202	21012	17653	18456	20493	19580
13-14 hrs	19483	20320	20780	21689	19156	17000	16962	20737	17484	18227	20184	19205
14-15 hrs	19325	20340	20837	21852	19494	17190	16940	20613	17493	18377	20311	19095
15-16 hrs	19401	20354	20919	22103	19524	17166	16915	20709	17591	18348	20149	18988
16-17 hrs	18817	18912	20337	21804	19134	16777	16590	20162	17226	18046	19813	18796
17-18 hrs	17668	19045	19439	20683	18078	16199	16222	19628	17016	17704	18958	18052
18-19 hrs	17449	18320	18692	19508	17054	15884	16226	19476	17407	18176	18763	17889
19-20 hrs	17201	18260	19109	20245	17597	16360	16826	20118	17848	18197	17763	16990
20-21 hrs	16194	17501	18483	19888	17571	16488	16873	19895	17300	17451	16746	15958
21-22 hrs	15302	16841	18045	19634	17256	16258	16201	19290	16756	16884	16021	15169
22-23 hrs	14613	16599	17901	19863	16989	16250	15839	18806	16293	16388	15398	14547
23-24 hrs	13849	16638	18082	20249	17426	15978	15462	18519	15878	15852	14913	14173

Table 2: Trend of Base Load Capacities in MW-2017

Connected Sizes	Case-1	Case-2	Case-3
Base Load Demand	16293	18580	20130
Max. Load Demand	9711	7423	5773
H6Rotary Reserve Demand	1300	1300	1300
Total Demand	27533	27533	27533

The Step 3:

MLmin = 13,849 MW
MLavg = 15,793 MW
MHmin = 17,196 MW
MHmax = 22,103 MW

Step 4: The installed capacity of baseload plants:

Minst-BL1 = 16,293 MW
Minst-BL2 = 18,580 MW
Minst-BL3 = 20,230 MW

Step 5: The installed capacity of peak load power plants:

Mpeak-1 = 9,711 MW
Mpeak-2 = 7,423 MW
Mpeak-3 = 5,773 MW

Step 6 and Step 7: The installed capacity of the spinning reserve:

Minst-res = 1,300 MW

The results indicate that an optimum capacity of 18,580 MW can be considered for the base load power station, which is neither too low nor too high. This capacity can be met through coal, hydro, and gas sources. Each source has advantages and disadvantages, including factors such as cost of capital, social and environmental considerations, commercial viability, and availability of resources. The right energy mix can be achieved by combining these three sources to meet the minimum demand and achieve an optimal capacity. These findings provide valuable information for decision-making regarding power generation strategies, resource planning, and achieving a balanced and efficient energy mix in Maharashtra.

V. CONCLUSION

In conclusion, using the CAGR (Compound Annual Growth Rate) method enables the calculation of future trends in the power generation sector. Estimating the minimum capacity required for baseload power plants can result in cost savings, improved generation efficiency, and reduced environmental impacts. Optimisation and efficiency can be enhanced by employing a combination of coal, hydro, and gas as generation sources. Coal, with its high plant load factor, can serve as the primary source, while hydro and gas can be utilised to meet fluctuations in base load demand, ensuring system stability. To further enhance resource efficiency and emission reductions, it is essential to determine the true costs associated with each energy source and combine them effectively. A sustainable and optimised power generation system can be achieved by adopting a holistic approach and considering both economic and environmental factors.

REFERENCE

[1]. Aboumahboub, T., Schaber, K., Tzscheutschler, P., & Hamacher, T. (2010). Optimisation of the utilisation of renewable energy sources in the electricity sector. Proceedings of the 5th IASME/WSEAS International Conference on Energy and Environment.

[2]. Gruenwald, O., & Oprea, D. (2012). An optimisation model of energy mix taking into account the environmental impact. 11th International Conference, Energy - Ecology - Economy.

[3]. Maharashtra State Load Despatch Centre. (2018). Maharashtra State Load Despatch Centre. Retrieved from https://mahasldc.in/home.php/dailyreports/

[4]. Lyzwa, W., & Wierzbowski, M. (2016). Load duration curve in the long-term energy mix optimisation. 13th International Conference on the European Energy Market (EEM).

[5]. National Electricity Plan, Volume 1, Generation. (2018). Retrieved from https://powermin.nic.in

[6]. Government of India. (2017). Flexibility in the generation and scheduling of thermal power stations to reduce emissions. Ministry of Power.

[7]. Government of India. (2018). Flexibility in the generation and scheduling of thermal power stations to reduce emissions. Technical Report.

[8]. Pavel, G. L., Budu, A. R., & Moraru, D. E. (2017). Optimisation of energy mix - nuclear power and renewable energy for low emissions energy source a benefit for future generations. Energy Procedia, 112, 412-417.

[9]. Russo, C., Thomas, M., Sumner, R. H. C., Schiffer, H.-W., & Bing, L. (2014). Socio-economic impacts of advanced technology coal-fuelled power stations. Coal Industry Advisory Board.

[10]. Shaha, R., Kothari, D. P., & Chandrakar, V. S. (2016). Optimisation of renewable energy sources for hybrid power generation. 2016 Biennial International Conference on Power and Energy Systems: Towards Sustainable Energy (PESTSE).

[11]. Upadhyay, M. K. (2017). Analysing the impact of clean coal technology on the overall energy scenario. NITI Aayog, Government of India, Joint Report between NITI Aayog and Institute of Energy Economics Japan IEEJ.

[12]. Utama, N. A. (2012). Power generation optimisation in ASEAN by 2030. Energy and Power Engineering, 4, 226-232.