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Major challenges for Indian thermal power plant endurance

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Abstract

India have strategic ambition to be "VIKSIT BHARAT BY 2047" and we are focusing to be global leaders by Innovative approach. We are observing transformative shift to advance technology, Green & Renewable Energy (RE), Automation & Digitalization, AI-ML and much more progression. To ensure appropriate growth for these initiatives one of the most essential elements is electricity. Due to population rise, lifestyle change, Industrial & economic growth, power demand is continuously increasing. As per current scenario in India, Thermal Power is vital source of electricity. India have exponential growth in RE but due to limitations, backbone is Thermal Power as on today. To ensure sustainability, it is essential to identify Major Challenges of Thermal so that appropriate Strategy can be developed.

For commercially viable & socially suitable Power for all, one of the essential requirements is to operate installed Power Units at the best load & efficiency within lowest possible cost. The objective of this study is to identify Major Challenges of Indian Thermal Power Plant Endurance so that appropriate strategies can be reviewed to ensure power sustainability.

For this research, primary data has been collected through Qualitative tools - interviews with Senior Leadership Team and Focused Discussion with Subject Matter Experts (SME) having rich experience in Power Industries and Quantitative tool Questionaries has been adopted and 216 samples have been studied to explore research.

Major challenges are Generation Cost Optimization, Job Quality, Fuel Issues, Skill & Experience, Flexible operation, Government Rules and Labor issues. Impact and Occurrence perceptions indicates Risk Priority Number for individual challenges.

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Major Challenges have been identified and prioritise with RPN. Further research related to appropriate strategies to overcome Major Challenges to ensure reliable, affordable, socially suitable & environmentally sound energy source shall be explored.

Subject Classification: *L94 – Electric Utilities.*

Keywords: *Challenges, Risk priority, Thermal power generation.*

Introduction

Today, one of the most basic needs is LIGHTING UP LIVES. SE4all – Sustainable Energy for all [1] is UN declaration to ensure Universal access to energy by 2030 (SDG7). The resolution emphasized the importance of enhancing access to energy that are reliable, affordable, economically feasible, socially acceptable, and environment friendly [2]. The growth and development of any economy rely considerably on its energy services. It is a vital ingredient of the quality life of an individual [3]. The Multidimensional Energy Poverty Index (MEPI) score indicates that India is still a moderately energy poor country with regional disparity in energy poverty [4]. In India, as on 26th March 2025, Thermal Power is contributing 52.62 %, Solar is 21.8 %, Hydro 11.08 %, Wind 10.33 %, Bio 2.43 % and Nuclear is 1.74 % [5]. Major consumers of electricity [6]. Industrial (33.04 %), Domestic (27.94 %), Agriculture (19.29 %) and all are continuously growing [7]. In India, Thermal Power contribution growth is predicted from 994.2 TWh (Trillion-watt hours) in 2022 to 3212.71 TWh in 2047 [8]. India needs to add 80 GW by 2031-32 to meet the demand [9]. Emerging economies have established ambitious aims for enhancing renewable energy capacity to decrease energy exportation in line with their economic growth & development [10]. All though Renewable Energy (RE) addition is aggressively observed [11], to overcome technical limitations & challenges, Research & Development is required & in place [12]. Renewable Energy (RE) sources are not reliable at present, for energy security dependency on conventional method is unavoidable [13]. So, to meet Power demand, India must plan energy mix – flexible operation [14] of all contributors i.e. Thermal, Solar, Wind, Nuclear, Hydro, Bio etc. to manage and control power grid operation [15]. To meet power demand, Coal-based power generation is expected to persist until affordable energy solutions are available [16].

Power shortages are predicted to increase in May and June as a result of India's rapid expansion of renewable energy sources without sufficient storage devices, which has increased grid instability. A ten-year-old policy to limit thermal power development exacerbates this problem by lowering vital baseload support on summer evenings. The situation is further worsened by financial mismanagement in electricity distribution, which is caused by state governments' unwillingness to address income leakage and their reliance on central lending utilities to pay discom losses. Over time, their capacity utilization has been steadily declining. The national average PLF decreased from 78.6% in 2007–2008 to 55.4% in 2019–2020. By 2022, the national average PLF is expected to drop to 48%. Numerous recently constructed thermal power facilities that require significant capital expenditure face a dismal future. [17]

Literature Review

The high capital infrastructure and intricate management dynamics of the power sector have made it a prominent subject of investigation among researchers worldwide. In India, power sector reforms, Research & Development in Renewable Energy (RE) and other aspects of power sector is increased rapidly. For the subject – Major Challenges for Indian Thermal Power Plant Endurance, ample of authentic reports published by Government, Research Organization and competent institution have been explored. Examined international journal's research papers. Annual reports of Power Sector and other relevant information from Real Time Dashboards from Government Portals have been reviewed. Indian Power Sector's current scenario & historical development have been studied from National Power Portal (NPP). Future prediction, Generation Mix have been reviewed from the annual reports of Central Electricity Authority (CEA) & respective information from Ministry of Power and relevant departments.

Researchers have focused on challenges and vital issues related to power sector. Globally, power sector related research is being explored. Pollitt, M. has studied about electricity reform in Chile (2004) [18] and Electricity reform in Argentina (2008) [19] directing lessons for developing countries. Lam and Shiu [20] have reviewed Efficiency and productivity of China's thermal power generation. Liu, Lin, and Lewis [21] have studied about Evaluation of thermal power plant operational performance in Taiwan. See and Coelli [22] has reviewed an analysis of factors that influence the technical efficiency of Malaysian thermal power plants. Indian Power Sector related studies have been reviewed which is summarized in Table – 1.

Table 1

Literature Review

Author (s) / Year / Ref	Key Discussion - Arguments
Hole and Pande [23]	Factors that affected worker's productivity has been explored, Resources & Facilities, occupational health & safety in TPP in Maharashtra has been reviewed
Ghosh, Nandan, and Gupta [24]	Participation of union members in decision-making regarding welfare activities, training and other involvement & respective impact
Jain, Thakur, and Shandilya [25]	Studied 30 state owned power plants for cost benchmarking and discussed that cost of generation can be reduced by keeping same output. Performance improvement.
Behera, Dash, and Farooquie [26]	Discussed about Inefficiency, Improvement in Specific Coal Consumption, Auxiliary Power Consumption, reduction in Cost of Generation & other relevant remedies
Shrivastava, Sharma, Chauhan [27]	Higher cost due to equipment aging, high Auxiliary Power, Lack of department coordination, Remedies: Maintenance Planning, New Technology
Yadav, Jha, and Chauhan [28]	Multi Criteria Decision Making (MCDM) used to analysis performance of Coal fired power plants and respective impacting factors have been discussed
Omer, Ghosh, and Kaushik [29]	Issues: Fuel, Equipment, Environment, T&D losses, Ageing, Demand rise, Disputes etc. Opportunities: Modernization, National Grid, Technologies, Audit etc
Guttikunda, and Jawahar [30]	Atmospheric emissions and pollution related issues have been discussed
Chawla and Singh [31]	Skill related issues, Top Management's role, Talent shortage, Technology vs skill gap, Quality, Cost & Scale of Skilling
Yadav et al. [32]	Reduction in coal consumption, proposed to adopt new technology - Super Critical, Renovation & Modernization, Auxiliary Power reduction
Dubey [33]	Challenges: Performance, Fuel issue, Equipment, Resources, Environment, Manpower etc. Remedies: Cost management, Risk & Contract Management, Robust procurement & Supply diversification etc

Contd...

Verma [34]	Challenges: Fuel, Coal block, Equipment, Finance & Resource, Environment, Law & Order -Local issues, Manpower issues Remedies: Project - Risk Management, Contract Management, Supply Infrastructure, Vendor monitoring, resource planning
Mittal et al. [35]	TPP construction related challenges have been reviewed like Natural Calamities & Accidents, Vendor issues, Resources, Administration, Government
Chand et al. [36]	The impact of the flexibility parameters on the economic dispatch. The addition of RE requires flexibility from the conventional generation in the grid.
Singh and Kaur [37]	Contemporary Issues and Challenges of Power Sector in Haryana like Tarif, Transmission & Distribution loss, Resource constraints
Shrimali [38]	Flexible coal may be the cheapest flexible option, role of coal plants in provision of flexible grid services
Vig, Ravindra, and Mor [39]	Environmental impacts of Indian coal thermal power plants & associated human health risk to the nearby communities
Anupama et al. [40]	Challenges faced by the workforce in adopting its wide range of technologies. It emphasizes the need for organizations to foster continuous learning cultures and implement supportive policies to enable successful digital transformation
Karikalchozhan and Sharma [41]	coal-based thermal plants and gas plants emerges as a key necessity for achieving the desired levels of flexibility. Pumped Hydro and Lithium-ion batteries, have potential to mitigate the requirement for flexible operation
Priyadharshini and Sundaram [42]	Environmental, volatility in fuel prices, supply chain disruptions and tactics like technological innovation, and stakeholder engagement
Patel and Sundarabaskar [43]	Discussed major strategies like Contract Management, Knowledge & Innovation impact on vital KPIs
Pouralizadeh [44]	Resource optimization, Framework for sustainable supply chain management to maintain efficiency while reducing environmental impact.

Past research review shows that Generation Cost, Productivity & Quality, Manpower, Flexible Operation, Fuel issue, Government – Environment issue, tread union – local issue etc. are vital challenges.

Research indicates that still Thermal Power is back bone in power generation mix and for couple of decades it will be major contributor [45]. It is essential to run established thermal power plant at best possible PLF with optimum cost [46] so vital challenges and mitigation plan to be studied.

Research Gap Analysis

Research in the field of Indian Power Sector indicate that Thermal Power is essential and back bone contributor in current scenario, and it will be major contributor for next couple of decades too. So, it is essential to search out the way how Thermal Power can be sustainable. What are the major challenges, how sustainability can be ensured for the affordable & acceptable power for all.

Research Objective

To ensure reliable & cost-effective Power for the growth of Nation & to mitigate power deficit challenge, one of the essential requirements is to run the commissioned Thermal Power Stations at the best Plant Load Factor & with the best design performance level within lowest possible cost.

Primary Objective: The prime objective of this research is to identify the major challenges for Indian Thermal Power Plant Endurance.

Secondary Objective: To check their priority with Risk Priority Number (RPN) and identify the priority percentage of major challenges.

Research Methodology

To review Major Challenges for Indian TPP Endurance, both methods have been used to collect, review & analysis of data, Primary & Secondary data collection methods [47].

Research Data Collection Tools & Procedure:

Qualitative tool – Interview & Focused Group Discussion (FGD) with Subject Matter Experts (SME) who have rich experience in Thermal Power Industries have been conducted to identify Major Challenges of Indian TPP. Quantitative tool – Questionnaire has been used to collect perceptions for Impact and Occurrence to calculate Risk Priority Number (RPN) so that priority of Major Challenges can be calculated.

Data Collection & Sampling Methods

Primary Data: To collect primary data, Qualitative tool – Interview & FGD have been used as this subject is related to human perception & complex social phenomena. Both tools can help to identify critical issues & patterns and ideal for experience study.

To identify major challenges of Indian TPP, 28 (twenty-eight) interviews of leaders having more than 15 years of power sector experience and qualified in respective functional areas have been conducted like Department / Functional Head (16- Sixteen) of Operation, Control & Instrumentation, Electrical, Mechanical, Chemical, Coal Handling, Ash Handling, Business Excellence, Maintenance Planning & Efficiency, Procurement & Store, Fire & Safety, HR & IR etc. General Manager & Joint General Managers (5 – Five), Deputy General Manager (4 – Four) and two from Solar Business leaders who have experience in Thermal Sector.

Additionally, eight (8) Focused Group Discussion (FGD) with Subject Matter Expert (SME) having more than 10 years of power sector experience and qualified in respective functional areas have been conducted. Total 69 members have participated in eight FGD, average group of 6 to 11 SME from different functions, roles & responsibilities like Junior Engineer, Assistant Engineer, Lead Engineer, Assistant Manager, Deputy Manager, Manager etc. from all major functional area like Operation, Maintenance & Services have participated.

For Quantitative samples from Survey link online Questionnaire have been used and collected data from responders having average 15.5 years of relevant power industries experience. Collected primary data has been formatted and after processing, analysis & review has been done. MIS has been prepared.

Primary Data Sampling Statistics

To study Major Challenges for Indian TPP endurance, Questionnaires [48] have been designed by interview with Senior Leaders and Subject Matter Experts (SME). For comprehensive optimal data, survey samples from 66 Power Stations installed at Northern, Southern, Western & Eastern Grid have been collected. Total 216 survey samples through online form designed in SurveyMonkey application have been analyzed. Data has been collected in November 2024 which cover 22 different functions & departments and inclusive 29 roles & designations. These samples are distributed systematically. Average age of responders is 38 years having average relevant experience of 15 years which indicates professional maturity of responders.

Secondary data has been used from ample of Government published reports & website / portal's Realtime dashboard, past research & statistical analysis and other relevant data.

Challenges for Thermal Power Plant in India

Qualitative tools (Interview & FGD) have been used to identify major challenges and Quantitative tool (Surve-Questionnaire) has been used to verify and prioritize the identified Major Challenges for TPP. After discussion with Senior Leaders & SMEs, major seven risk have been identified for which criteria are (i) direct impact on TPP Endurance, (ii) Techno-Commercial viability, (iii) Operational Challenges to run & sustain the TPP. These seven risk have been listed in questionaries and opinion from responders have been collected. For each seven risk, Occurrence and Impact in the scale of 1 (lowest) to 5 (Highest) has been asked. To verify Risk Priority Number (RPN) [49], Arithmetic Mean (AM) of Impact and Occurrence have been identified. In Statistics, AM is defined as the ratio of sum of all the values or observations to the total number of values or observations. It is used to review central tendency [50].

$$\overline{x} = \frac{\Sigma_{u=1}^{n} x_i}{n}$$

- $\bar{x}$ = Arithmetic Mean / average
- $\sum$ Xi= Sum of observations
- N = Total of observation count

Impact analysis includes (a) the impact of failure, (b) the scope of the impact of failure on special cases, and (c) the difficulties in failure control and prevention.

Occurrence refers to the probability of the occurrence [51].

Both are calculated in the range of 1-5 where 1 is lowest and 5 is highest. So max RPN will be 25 (5 x 5 = 25). RPN (%) will be calculated based on max value 25 for each challenge.

Data Interpretation and Findings

Collected data for each challenge, tabulated for Impact & Occurrence assessment. In table-2, for each challenge, Impact, Occurrence, Risk

Table 2

Challenges, Risk priority number

SN	Challenges	I*	O^	RPN= I*O	RPN %	C** %
1	Generation Cost Optimization	4.55	4.12	18.73	74.92	20.82
2	Job Quality	4.29	3.77	16.18	64.70	38.8
3	Skilled / Knowledge / Experience	4.04	3.28	13.25	53.00	53.54
4	Flexible Operation	3.73	3.24	12.08	48.31	66.97
5	Fuel availability, transport, storage, cost & quality	4.09	2.79	11.41	45.62	79.65
6	Government Rules & Regulation (Incl Environment)	4.43	2.25	9.96	39.83	90.72
7	Union / Labour issues	3.88	2.15	8.34	33.37	100

I* = Impact, O^ = Occurrence, C** = Cumulative Percentage

(*Source:* Researcher's primary data)

Priority Number (RPN), RPN % and Cumulative RPN have been described for detail study.

For each Challenge, Impact & Occurrence have been calculated by Arithmetic Mean (AM) as shown in above table. In Fig 1, Major Challenges has been shown in Clustered bar analysis. Most critical Challenge is Cost Optimization with RPN 74.92% and lowest is Union / labour related due to low occurrence value. Individual data of Impact and Occurrence indicates few high impact challenge have low frequency of occurrence so

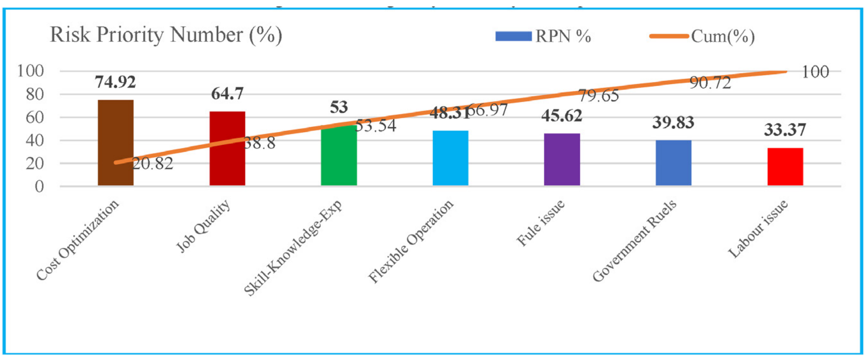

Figure 1

Challenges by Severity Perception

overall RPN is low, for example – Government rules have Impact value is 4.43 but occurrence is 2.25 so resulting RPN is 9.96 which is comparatively lower. Government rules are not changing frequently so occurrence is low and RPN is low. Similarly, labour issues have high impact, but occurrence is low, so RPN is low. Whereas other challenges have high impact and high occurrence so resulting RPN is high.

Conclusion

With consideration of current Indian Power scenario, Consumption pattern, Major Power Consumer's growth plan, alternate power generation growth and research for new alternatives, worldwide political, socio-economic scenario and other respective factors, Thermal Power for India shall play vital role to provide basic electricity demand and essential role – backbone for power requirements. Study has been carried out to identify major challenges and different perceptions of management categories, experience and functional group perception for Indian Thermal Power Plants. Research Signifies that as per overall perception major challenges are (a) Generation Cost Optimization, (b) Job Quality, (c) Skill – Knowledge – Experience, (d) Flexible Operation, (e) Fuel issues like availability, transport, storage, cost & quality, (f) Government & Environment Rules & Regulation, (g) Union, labour and political issues.

Limitation of Study

This study has been conducted as holistic view of all perceptions. However, sequence may slightly vary based on different perceptions of groups like based on functional priority, role-based perception may be different likewise experience and management cluster's perception may slightly different. Other factors like plant size, locations etc. may impact on perceptions.

Opportunity for Future Research

Further study to shall be explored to identify appropriate strategies to overcome these Major Challenges to ensure sustainability of Indian Thermal Power Plants to lighting up lives.

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