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Research Article

Resilience Tactics for Indian Thermal Power Plant Endurance Using AHP

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ABSTRACT

Introduction: India is in the era of Industry 4.0 in which we are focusing in Digitalization, Automation, Artificial Intelligence, Internet of Things, big data, e-commerce, innovation etc. Resilience tactics for Indian Thermal Power Plant (TPP) Endurance is must to be sustainable.

Objectives: To ensure affordable & socially acceptable Power for all, one of the critical requirements is to operate Commissioned Power Plants at the best capacity & performance within optimum possible cost. The primary objective of this research is to analyse the Resilience Tactics for Indian Thermal Power Plant Endurance. To review strategies to overcome challenges of TPP.

Methods: To explore Operational Strategies for major challenges, primary data has been collected with Subject Matter Experts (SME) & Analytical Hierarchy Process (AHP) has been used for statistical analysis.

Results: Major operational challenges like Cost Optimization, Job Quality and Skill-Knowledge-Experience and their respective strategies like Contract Management, Knowledge Management and Innovation have been reviewed in depth.

Conclusions: Contract Management is crucial strategy impacting on major challenges. Effective Contract Management shall be impactful for Cost Optimization, Job Quality and Skill-Experience-Knowledge related challenges.

Keywords: Thermal Power, Sustainability, Strategy, AHP, Power Plant Challenges.

INTRODUCTION

Global industry stands at the brink of a significant technological revolution. Industry 4.0 [1]. India is at a pivotal juncture in its energy transformation with the dual objective of sustaining economic development and honouring environmental goal [2] Power is essential component for Industry, commercial, agriculture and social growth. In today's scenario (24th Feb 2025), electricity from Thermal Sector is 52.74 % [3] and till 2047, Thermal Sector shall be major contributor and backbone in all sources [4]. Continual growth is being observed in major power consumers [5] which are Industrial (41.36%), Domestic (26.89%), Agriculture (17.99 %), Commercial (7.07 %) [6]. Safety and cost effectiveness of the power distribution network has always been of prime importance which requires simulation software with extensive data handling capabilities [7]. India's rising power demand and energy-mix plays vital role in the overall energy transition with crucial challenges like significant investments & innovations [8] with multi aspects like bio-pellet use [9], Energy Storage [10] & green hydrogen alternatives [11,12].

It indicates that it is crucial to run the installed Thermal Power Plant (TPP) at the best Plant Load Factor (PLF) with the best efficiency. Strategies and the challenges to achieve 24*7 power to be developed [13]. To ensure sustainability of TPP, it is essential to identify major challenges and respective strategies. In this paper, Contract Management, Knowledge Management and Innovation which are major Operational tactics have been evaluated with respect to major challenges like Cost Optimization, Job Quality and Skill-Knowledge-Experience.

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LITERATURE REVIEW

To study subject in detail, abundant authentic reports from competent authorities, Government organization and functions. Power Generation growth, Generation Mix and current scenario has been studied from National Power Portal (NPP) real time dashboard. Major consumer for electricity, their growth, generation planning, demand vs supply etc. angles have been studied through Central Electricity Authority (CEA) and Power Ministries reports and literature. Research published by Indian Council of Social Science Research (ICSSR) has been examined to review Industrialization, Power Requirement for Industry 4.0 [3-6]

Goundar, S. (2012) has described research methodology and methods. Data collection methods & data analysis have been presented in depth [14]. Similarly, Taherdoost, H. (2021), has presented details for how to select data collection techniques for academic and business research. In-depth study has been done and explored methods for primary data collection for quantitative and qualitative research. Questionnaire, types of questions etc. details have been explored [15]. Davidavičienė, V. (2018) has explored use of new information technology and emerging new ways for research methodology. In this digital age, new scientific approach to absorb new possibilities have been presented [16]. Samuel Lefever (et al. 2007) has presented change in primary data collection approach from paper & pencil to digital online mode. Detail benefits & limitations of online data collection related research has been reviewed [17].

Manas Ranjan Panda (et al., 2023) has analyze the vulnerability of 174 coal-fueled thermal power plants. During this research, they have noted that global economic growth has significantly increased the demand for energy, specially in fast-growing countries like India. Coal fired Thermal Power Plant (TPP) production increased by 64.82% from 2011-2017 [18]. T. Sunder (et al. 2024) has observed that in the context of India's energy sector, reviewing a thermal power plant involves assessing its technical design, operational reliability, environmental sustainability, and contribution to electricity generation [19]. Pankaj Kumar Gupta (et al., 2024) has explored need of Flexible Operation to manage Power Grid stability and for inclusion of all kinds of power generation source. The expansion of renewable energy (RE) capacity is reshaping the operational paradigm of TPP, pushing them toward more flexible and responsive modes, with thermal power plants assuming a crucial role in complying peak demand and supplementing periods of low RE generation. This aggressive flexible operation result in heightened thermal and mechanical stresses in TPP and other challenges [20].

K R Shanmugam (et al. 2002) has presented that TPP efficiency levels exhibit significant variation across different firms and geographic regions, and they fluctuate over time [21].

Dr Aarti Chopra (et al. 2025) has presented that Organizational resilience largely depends on how well crises are handled and strategic risks are minimized. The way organization handles crises, determines its ability to withstand disruptions, protect its reputation, and sustain stakeholders' confidence [22].

Power Sector Industries are focusing on technological advancement. Chandra Shekhar Choudhary (et al. 2025) has explored Thermoelectric Generator usecase [23]. Garima Singh (et al. 2025) has studied designing for hybrid solar power [24]. Nausheen Ban (et al. 2025) have studied actor-critic agent based Deep Deterministic Policy Gradient controller [25]. Dr Kumud Kundu (et al. 2025) has presented Industry 5.0 prioritiezes human well-being & ecological responsibility in technological advancement. The European Commission emplhasizes resilience, sustainability, inclusiveness as the pillars of Industry 5.0 [26].

Sangeeta Pant (et al. 2012) has described Analytical Hierarchy Process (AHP) is a Multi Criteria Decision Making (MCDM) methodology that integrates numerical techniques with psychological insights to handle complexity [27]. Ngo Thi Huong (et al. 2025) has presented that Through a hierarchical framework and pairwise evaluations, AHP helps identify the most critical elements in a decision-making process [28]. N Subramanian (et al. 2012) has observed that AHP has been largely applied when problems require considerations of both quantitative and qualitative factors (e.g., socioeconomic operations decisions) and to macro (complex and real) and people (managerial–subjective) oriented problems [29].

METHODS

To study Resilience Tactics for Indian TPP Endurance, Primary Data Collection as well as Secondary data methods have been adopted to collect, study and evaluation of data. Primary data: Structured interview of

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Senior Leadership team members, Focus Group Discussion with Subject Matter Experts (SME) has been conducted to prepare Questionnaire, Web link online Questionnaire have been prepared. Next step of primary data collection was data formatting and data processing. Processed data has been used for statistical analysis. Secondary data has been collected from abundant research papers, Government published reports & website / portal's Realtime dashboard, statistical analysis and other relevant data.

To study "Resilience Tactics for Indian Thermal Power Plant (TPP) endurance", Questionnaires method to collect primary data has been used. To ensure widespread optimal data, survey samples from 66 Thermal Power Plants / Divisions have been collected which are commissioned at different parts of Power Grid like Western, Northern, Southern and Eastern Grid. Online data collection method has been used to cover geographically scattered appropriate samples. Total 216 survey samples through Survey Monkey application have been received. Questionnaire has been published in November 2024 and 216 responses have been collected which cover 22 various departments / functions and include 29 different designation / roles & responsibilities. Arithmetic Mean of responders is 38 years, and relevant experience is 15 years which indicates professional maturity of response.
Global economic growth has significantly increased the demand for energy, specially in fast-growing countries like India. In the context of India's energy sector, reviewing a thermal power plant involves assessing its technical design, operational reliability, environmental sustainability, and contribution to electricity generation. The expansion of renewable energy (RE) capacity is reshaping the operational paradigm of Thermal Power Plants (TPP), pushing them toward more flexible and responsive modes, with thermal power plants assuming a crucial role in complying peak demand and supplementing periods of low RE generation. This aggressive flexible operation result in heightened thermal and mechanical stresses in TPP and other challenges. TPP efficiency levels exhibit significant variation across different firms and geographic regions, and they fluctuate over time. Organizational resilience largely depends on how well crises are handled and strategic risks are minimized. The way organization handles crises, determines its ability to withstand disruptions, protect its reputation, and sustain stakeholders' confidenc. Industries focus on technological advancement like Thermoelectric Generator, designing for hybrid solar power, other fields like Actor-Critic agent based Deep Deterministic Policy Gradient (DDPG) controller etc. Industry 5.0 prioritizes human well-being and ecological responsibility in technological advancement. The European Commission emphasizes resilience, sustainability, and inclusiveness as the pillars of Industry 5.0.

RESEARCH DESCRIPTION

Analytical Hierarchy Process (AHP) is widely regarded as a leading method in multi-criteria decision-making (MCDM). The AHP technique involves building a hierarchical model and systematically comparing elements in pairs to derive their relative priorities. Strategic decisions in operations management often require mix of both aspects, qualitative and quantitative. For these, AHP is frequently chosen as a preferred tool. For this research, AHP process published by Thomas Saaty [30,31,32] has used. Following steps have been followed.

1. For each challenge, pairwise comparison of strategies to be formulated in table. For this, matrix question has been asked to collect primary data from respondents in two parts. First is which strategy is better comparing to two, like Contract Management (CM) to Knowledge Management (KM), CM to Innovation (Inn) and KM to Inn. In second part, absolute scale for intensity of importance (Table – 1) has been used to know how much one strategy is comparatively better than second strategy. Based on first part, outcome is summarised in table – 3 and based on 2nd part, information is summarised in table – 4.
2. Based on comparative value (Last column of table – 4), for each challenge (Cost Optimization, Job Quality, Skill-Knowledge-Experience), comparison matrix has been prepared (Table – 5 respectively). In last row, sum of all three columns have been calculated which is used to prepare Normalization Matrix.
3. Normalization Matrix has been calculated by dividing each cell value by respective column sum. For example: Table – 6, value in (Cell)22 is 0.67 arrived by dividing value of Table – 5 (Cell)22 by (Cell)25 (1 divided by 1.5 = 0.67). In Normalization Matrix, last column is row average known as CRITERIA WEIGHTAGE. Table 6,9,12 are summarised for Normalization Matrix for respective challenges.

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4. λ Calculation: λ can be calculated in three steps, 1st step is to calculate weightage sum for each criteria, 2nd step to weightage sum to be identified. For each cell of comparison matrix to be divided by respective CRITERIA WEIGJTAGE. In second step, for each criteria (raw), divide weightage sum by respective CRITERIA WEIGJTAGE. In 3rd step, take average value of all three criteria which is λ. For example: Table – 7 (Cell)22 is calculated by Table 5 (Cell)22 divided by Table–6 (Cell)52 i.e. (1 0.639 = 0.6393). Similar calculation to be done for Table – 7.
5. Consistency Index (CI) can be calculated by equation CI = (Lemda-n)/(n-1).
6. Consistency Ratio (CR) can be calculated by equation CR = (CI / Random Index (RI)). RI value for this calculation is taken 0.58 from table – 2 (for n=3). IF CR <0.1 then consistency is acceptable.

The above steps have been followed for all three challenges (Cost Optimization, Job Quality and Skill-Knowledge-Experience). Respective Consistency Index (CI) & Consistency Ratio (CR) has been calculated. For each challenge, priority % and rank has been also identified.

RESULTS

Table-1 AHP fundamental scale

Absolute scale for Intensity of Importance	Definition of Scale
1	Equal Importance
3	Moderate importance of one over another
5	Essential or strong importance
7	Very strong importance
9	Extreme importance
2-4-6-8	Intermediate values between the two adjacent judgements
Reciprocals	If activity i has one of the above numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i

Table-2 Random Index

n	1	2	3	4	5	6	7	8	9	10
Random Index (RI)	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

DATA INTERPRETATION AND FINDINGS

As per described process, analysis has been done which is presented in following tables. In Table – 3, figure indicates response for strategy comparison for respective challenges.

Table – 3: Strategy Comparison based on questionnaire

Major Challenges	Comparison (CM-KM)				Comparison (CM-Inn)				Comparison (KM-Inn)			
	Contract		Knowledge		Contract		Innovation		Knowledge		Innovation	
Cost Optimization	84.72%	183	15.28%	33	79.63%	172	20.37%	44	82.87%	179	17.13%	37
Job Quality	69.91%	151	30.09%	65	76.85%	166	23.15%	50	84.26%	182	15.74%	34
Skill - Knowledge - Experience	58.80%	127	41.20%	89	72.22%	156	27.78%	60	81.48%	176	18.52%	40

Based on selection as per Table – 3 data, statistical analysis for Median, Mode & Average have been reviewed and based on these values, AHP criteria has been described in last column.

Table – 4: Comparison value to create comparison Matrix

SN	Challenges	Criteria	Selected Criteria	Median	Mode	Average	AHP
1	Cost Optimization	CM-KM	Contract (84.72%)	3	2	3.73	3
		CM-Inn	Contract (79.63%)	6	6	6.1	6
		KM-Inn	Knowledge (82.87%)	4	4	4.5	4
2	Job Quality	CM-KM	Contract (69.91%)	3	3	3.57	3

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		CM-Inn	Contract (76.85%)	7	7	6.3	7
		KM-Inn	Knowledge (84.26%)	4	4	4.76	4
3	Skill - Knowledge - Experience	CM-KM	Contract (58.80%)	3	3	3.41	3
		CM-Inn	Contract (72.22%)	6	6	5.97	6
		KM-Inn	Knowledge (81.48%)	4	4	4.81	4.27

ANALYTIC HIERARCHY PROCESS (AHP) FOR COST OPTIMIZATION (CO)

Described process in the section "Research Description" has been followed step wise and respective statistical analysis result has been mentioned in Table 5,6 & 7 followed by CI, CR, Priority and Rank details for Cost Optimization (CO).

Table – 5: Comparison for CO

Comparison Matrix	CM	KM	Inn
CM	1	3	6
KM	0.33	1	4
Inn	0.17	0.25	1
Sum of Column	1.5	4.25	11

Table – 6: Criteria Weightage Matrix for CO

Normalization	CM	KM	Inn	Criteria Weightage
CM	0.67	0.71	0.55	0.6393
KM	0.22	0.24	0.36	0.2737
Inn	0.11	0.06	0.09	0.0869

Table – 7: λ Calculation for CO

Consistency Check	CM	KM	Inn	Weighted Sum	λ (Weighted sum /criteria weightage)
CM	0.6393	0.8212	0.5217	1.9822	3.1004
KM	0.2131	0.2737	0.3478	0.8346	3.0492
Inn	0.1066	0.0684	0.0869	0.2619	3.0125
				Lemda (λ)	3.0540

Consistency Index (CI) = (Lemda-n)/(n-1) = (3.054-3)/(3-1) = 0.02701
Consistency Ratio (CR) = (CI / Random Index (RI)) = 0.027017379/0.58 = 0.04658
As CR is <0.1 Consistency check is successful.

Priority (%) & Rank:
CM 63.93 % with Rank 1, KM 27.37 % with Rank 2 and Innovation 8.69 % with Rank 3.
Similar process has been followed like CO for this Job Quality (JQ) and the result is CM 65.55 % with Rank 1, KM 26.48 % with Rank 2 and Innovation 7.96 % with Rank 3. Same way result for S-K-E was CM 63.59 % with Rank 1, KM 27.91 % with Rank 2 and Innovation 8.51 % with Rank 3.

CONCLUSION

AHP analysis for Multi Criteria Decision Making indicates that for Cost Optimization challenge, CM 63.93 % with Rank 1, KM 27.37 % with Rank 2 and Innovation 8.69 % with Rank 3. For Job Quality challenge, CM 65.55 % with Rank 1, KM 26.48 % with Rank 2 and Innovation 7.96 % with Rank 3. For Skill-Knowledge-Experience challenge, CM 63.59 % with Rank 1, KM 27.91 % with Rank 2 and Innovation 8.51 % with Rank 3. Comprehensively, study indicates that Contract Management have highest weightage for major operational challenges. So, by innovative approach, contract management tactics shall help to manage operational challenges to endurance Indian Thermal Power Plant. Future study shall be explored to identify Strategy Impact on major Key Performance Indicators (KPI).

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