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AI-DRIVEN DECISION-MAKING MODELS FOR THERMAL POWER PLANT OPERATIONS IN WEST INDIA

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Abstract: The present paper discusses how artificial intelligence (AI) can be utilized in the decision-making related to the operation of thermal power plants with the reference to West India, and specifically, to states of Maharashtra, Gujarat, and Rajasthan. The study focuses on the role that the technologies of artificial intelligence such as machine learning, neural networks, and reinforcement learning are playing in reshaping the conventional working models of the thermal power sector in the region. By examining recent applications, barriers, and prospects, the paper offers the information on the prospects of AI to improve efficiency, reliability, and sustainability of thermal power generation in West India. Although the use of AI has certain region-related challenges to address regarding the quality of data, integration of new systems, and adaption of new workforce, the prospective strategic use of AI has a serious potential of optimizing such operations as well as enhancing the environment.

Keywords*:* Artificial Intelligence (AI), Operations of Thermal Power Plant, Decision-Making Models, ML (Machine Learning), The Neural Networks (ANN), Reinforcement Learning (RL), West India (Maharashtra, Gujarat, Rajasthan), Reliability and Energy Efficiency, Sustainability, System Integration, Data Quality, Energy Systems AI

1. Introduction

Increase in the energy demand in India and especially the industrialized west states is a great concern to the power generation systems. Thermal power plants still remain the backbone of electricity infrastructure in the Maharashtra, Gujarat, and Rajasthan even with the ambitious renewable energy targets set. The Central Electricity Authority (2025) notes that X, Y and Z states have an installed capacity of more than 156 GW, of which thermal sources can make up a large part of their energy mix.

According to April 2025, Gujarat has the highest total installed capacity of around 60 GW, followed by Maharashtra (50 GW) and Rajasthan (46 GW) (NITI Aayog, 2025). These states are unique due to extra challenges that they have such as the scarcity of water in the state of Rajasthan, fluctuating quality of fuels and the dilemma of both baseload generation and raising penetration of renewables.

Conventional Thermal Power Plant operation in the West India has been based on experience of the operators, conventionalized operations and simple analyzing tools. Such techniques are finding it difficult to find the most efficient balance as the complexity increases and other aspects of operation begin to compete. Plant operators state that they have a hard time maximizing efficiency and minimizing emissions, maintaining reliability, and adjusting to grid swings at the same time.

These challenges can find good solutions with the help of Artificial Intelligence. Initial experiments with plants in Maharashtra and Gujarat have already shown that AI can work with large amounts of operational data, discover delicate patterns, foresee machine breakdowns, and streamline procedures.

In this paper, the concept of AI-driven decision-making in the operation of the thermal power plant in West India is discussed with the view to how such methods solve shortcomings of existing methods and reveal their potential capacity to transform efficiency, reliability, and sustainability of the operations in the region.

2. Overview of Thermal Power Plants in West India

2.1 Basic Principles of Thermal Power Generation

Power plants in West India work under usually preferred thermodynamic procedures figuring on the Rankine procedure, yet there are localizations. This starts with a heat source, which is mostly coal, but other sources such as natural gas and nuclear energy are used too. Some of the largest plants utilizing coal are located in Maharashtra including Chandrapur (2,920 MW), and Koradi (2,600

MW). Gujarat uses the combination of coal and gas whereas Rajasthan has such plants as Kota (1,240 MW) and Chhabra (1,000 MW).

The difference between West Indian plants is that they adapted to the conditions of their region. Facilities in Gujarat and Rajasthan are replacing their cooling units with modifications to run even under water scarcity conditions, mostly with use of air-cooled condensers. Cooling of plants is routinely done with the use of seawater in coastal Maharashtra. There has also been the development of boiler designs to take the increased ash content of domestic coal.

2.2 Key Components and Regional Adaptations

Boilers: These boilers are made to deal with the increased ash content such as domestic coal (30-45%). Gujarat and Maharashtra plants have also installed fluidized bed combustion technology to achieve efficiency by using lower-quality coal.

Cooling Systems: Plants in water-limited areas of Rajasthan and the northern part of Gujarat have resorted to using of air-cooled condenser, and those in the coastal part of Maharashtra are utilizing sea water cooling systems.

Emission Control: The regulation has become stricter and West Indian industries, as a result have centralized funds in pollution control technology. In their report, NITI Aayog (2025) surveyed the thermal power plants in India and found that about 60 percent of the thermal capacity in the state of Maharashtra, 55 percent in Gujarat and 48 percent in Rajasthan had either installed FGD or had started doing so by the month of January 2025.

2.3 Operational Challenges

Water Scarcity: Shinde et al. (2023) argue that climate change is worsening water struggles among thermal plants in India, and especially in the western states.

Variation in Fuel Quality: Domestic coal available in the West Indian plants is generally high in ash (30-45%) and the calorific value is also found to be irregular, which causes a problem in achieving efficiency in combustion.

Figure 1 Key Operational Challenges in Western India's Thermal Power Plants: A flowchart overview of critical issues (generated with AI).

Environmental compliance: Tight regime on emission initially implemented in 2015 commit high retrofits. The western region has an estimated investment of 35,000 crore in the western region in terms of environment compliances.

Grid Flexibility Requirements: As India continues to add capacity in renewable energy (with Maharashtra, Gujarat, and Rajasthan leading the way), thermal plants are more and more being required to operate at high levels of flexibility to take account of solar and wind fluctuations.

Aging Infrastructure: Thermal capacity in western region is estimated to be nearly 30 years old with an over 25-year-old serving equipment beyond years of the design life.

3. Artificial Intelligence in West Indian Energy Sector

3.1 AI Technologies and Their Applications

Some of the main artificial intelligence technologies are being applied in the sphere of energy production in West India.

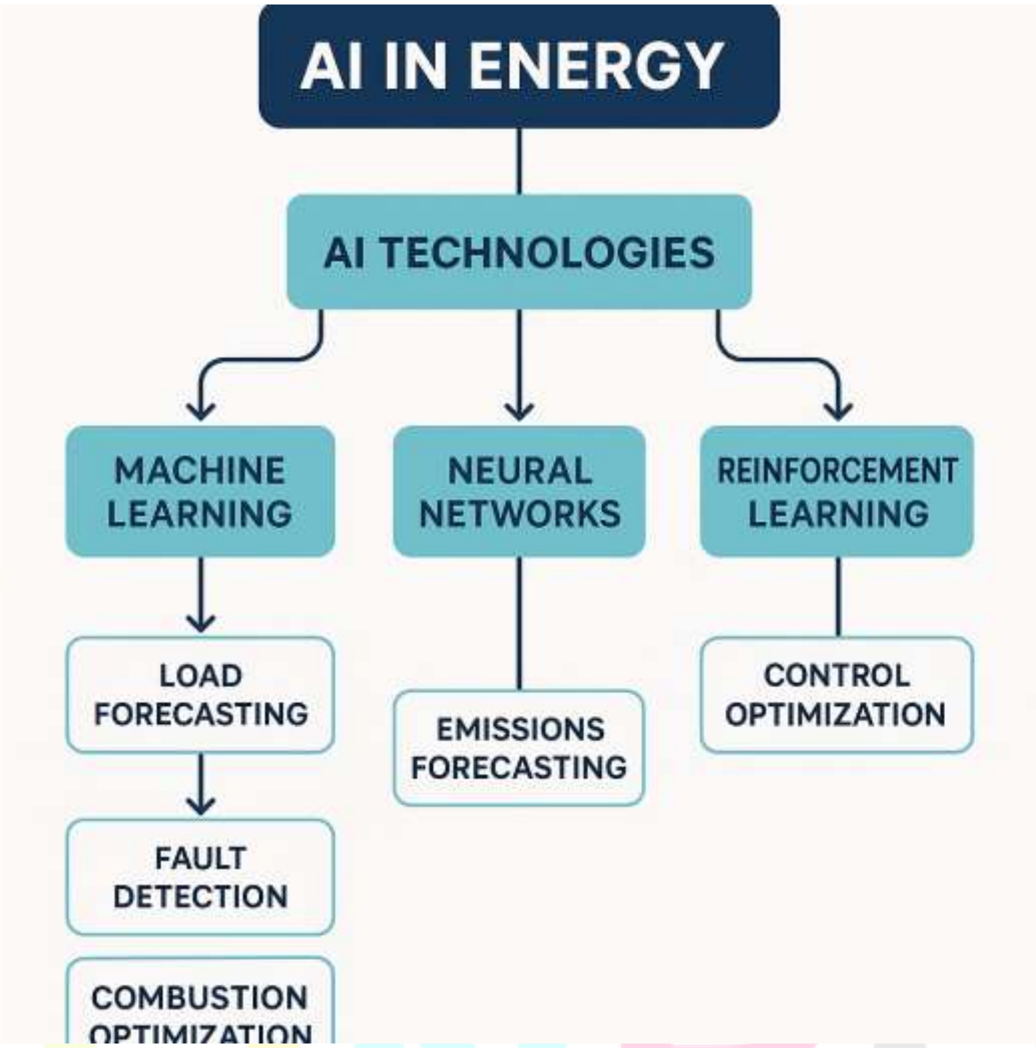

Figure 2 The Flowchart of the Artificial Intelligence in the energy sector and identifies major technologies (generated with AI)

Machine Learning (ML): the most actively used form of AI in the energy sector of the region. Applications include:

• **Predictive Maintenance:** The Chandrapur Super Thermal Power Station has implemented vibration analysis algorithms, which have purportedly made 15-20 percent of the unplanned shutdowns of components that are subject to the technology inspection (Esenogho, 2022).

• **Load Forecasting:** During the year 2023, Gujarat Energy Transmission Corporation implemented an ML-based forecasting system and managed to raise the accurate loading forecasting by a magnitude of around 8%.

• **Combustion Optimization:** The benefit of using ML-based combustion optimization, as shown by a pilot at 500 MW unit in Maharashtra, is a 0.8 percent saving in the heat rate (Kumar, 2024).

Neural Networks: The industries within the industrial belt of Gujarat have started to use the neural networks in modelling complex processes such as the dynamics of boilers. Deep learning models are formulated to forecast and optimize emissions in regard to operational parameters.

Reinforcement Learning: Academic-industrial collaboration in Maharashtra is investigating RL toward achieving at once multiple control parameters to balance efficiency, emissions, and health of equipment's.

3.2 AI in Energy Management Benefits

Increased Efficiency: Because of AI-based combustion optimization carried out on a thermal plant in Gujarat, a 1.2 percent is improvement caused by an improvement in heat rate, which represents annual savings of around 8 crores of fuel.

Improved reliability: In 2022, western region plants of NTPC that started AI-based monitoring had recorded a 23 percent decrease in forced outage of monitored equipment in 2024 as compared to 2022.

Enhanced Utility of Renewables: The state load dispatch center at Gujarat has worked to use ML and enhance the prediction of solar and wind generation which has helped lower the balancing cost.

Environmental Compliance: The optimization of the combustion in a Maharashtra plant through neural network led to a 15-percent reduction in the amount of NOx emissions with no reduction in efficiency.

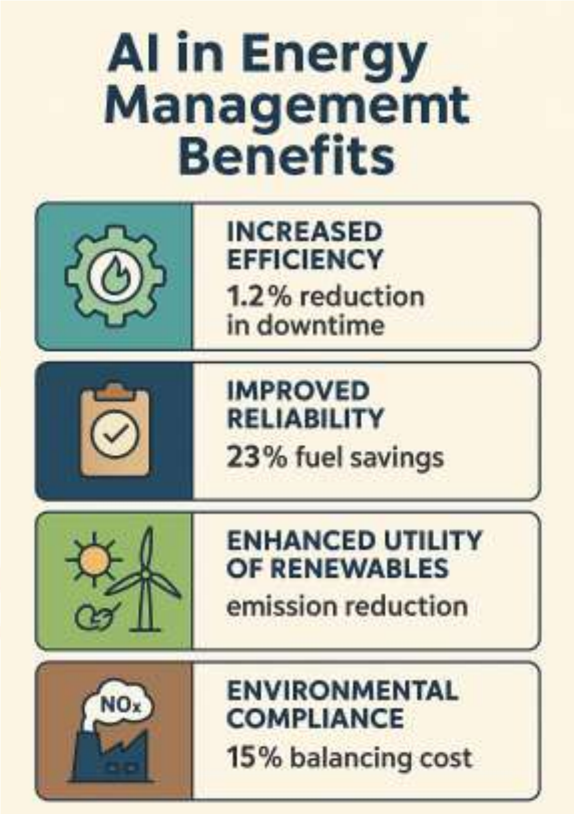

Figure 3 Infographic illustrating the main advantages of AI in energy management (generated with AI)

4. Thermal Power Decision-Making Models

4.1 Conventional Decision-Making Model

The traditional decision-making in West Indian thermal power plants has changed throughout decades and will normally include:

Heuristics and operator experience: At the old plants with more than 20 years of experience at Ukai in Gujarat or Koradi in Maharashtra, operators use such parameters as sound and vibration to make their decisions and operations.

Standard Operating Procedures (SOPs): They are consistent and safe but rather inflexible and do not necessarily optimize under changing circumstances.

Manual Data Monitoring: With 200-300 parameters checked by control room operators in the plants within the whole western region, it is very difficult to detect some fine scale correlations or some upcoming problems.

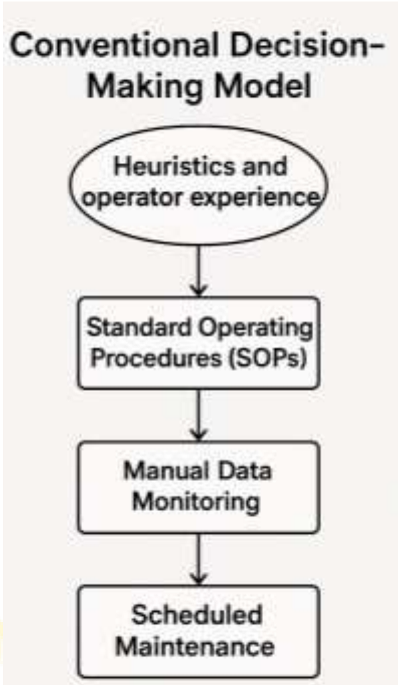

Figure 4 Conventional Decision-Making Process in Thermal Plants displays steps between operator experience and planned repair. (generated with AI)

Scheduled Maintenance: Preventive maintenance is those that are performed on pre-determined schedules such as by the number of run-hours of equipment or time of year no matter what shape they are in.

4.2 Limitation of Traditional Models

Reactive Nature: The decisions are normally taken as the reaction to the identified deviations instead of proactive problem anticipation.

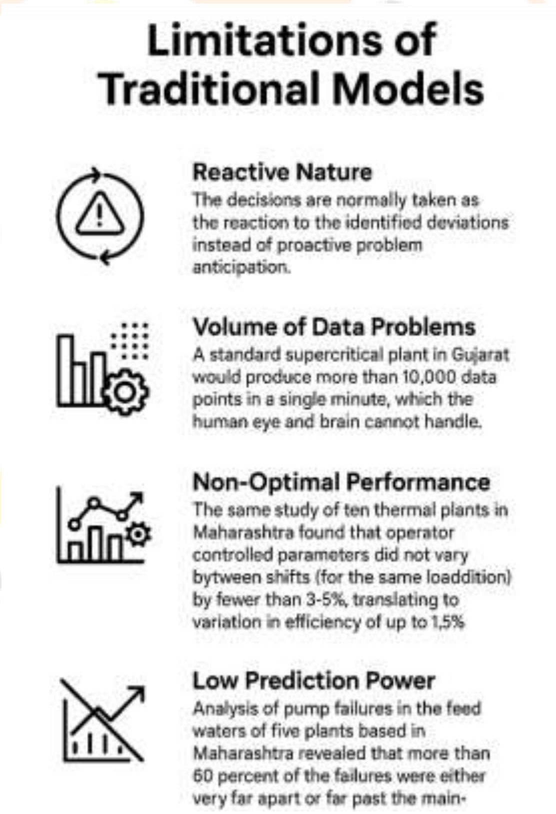

Figure 5 Infographic detailing some of the most important limitations of the conventional models of decision-making in thermal power plants (generated with AI)

Volume of Data Problems: A standard supercritical plant in Gujarat would produce more than 10000 data points in a single minute, which the human eye and brain cannot handle.

Non-Optimal Performance: The same study of ten thermal plants in Maharashtra found that operator-controlled parameters did not vary between shifts (for the same load condition) tor fewer than 3-5%, translating to variation in efficiency of up to 1.5% (Kumar, 2024).

Low Prediction Power: Analysis of pump failures in the feed waters of five plants based in Maharashtra revealed that more than 60 percent of the failures were either very far apart or far past the maintenance activities scheduled.

5. AI-Decision making models

5.1 Methods Machine Learning

Predictive Maintenance: In the Vindhyachal plant of NTPC, located in some areas of Maharashtra, ML-based vibration analysis has managed to decrease unplanned offline of the monitored components of the turbines by 18% after two years (Makanju, 2024).

Performance Optimization: In a 500 MW plant in Maharashtra, regression and ensemble learning was used to find the best setpoints of more than 30 parameters that could be controlled, with improvement of 0.8-1.2 percent compared to operator-controlled baselines on the heat rate.

Anomaly Detection: In one gas-based plant in Gujarat, an unsupervised learning algorithm was being used to monitor more than 5,000 parameters in all plants 24 hours per day and managed to detect early signs of the deterioration of a gas turbine combustor that would have not been caught by the conventional monitoring.

5.2 Operations Decisions and Neural Networks

Complex Process Modeling: An example in point is a 660 MW MA, supercritical unit in Maharashtra, which uses a neural network model of its boiler that is trained to model the sophisticated non-linear relationships that exist between over 50 inputs to the boiler, and critical outputs.

Advanced Control Systems: The use of a neural network controller (in the control of superheat temperature) at a plant in Gujarat led to a decrease in for the temperature deviation by about 40% relative to conventional controllers.

Emission Prediction and Control: A neural network was implemented in a coal plant in Rajasthan and used to predict the formation of NOx depending upon the combustion parameters and advise modification of the process settings to achieve both low emissions and efficiency.

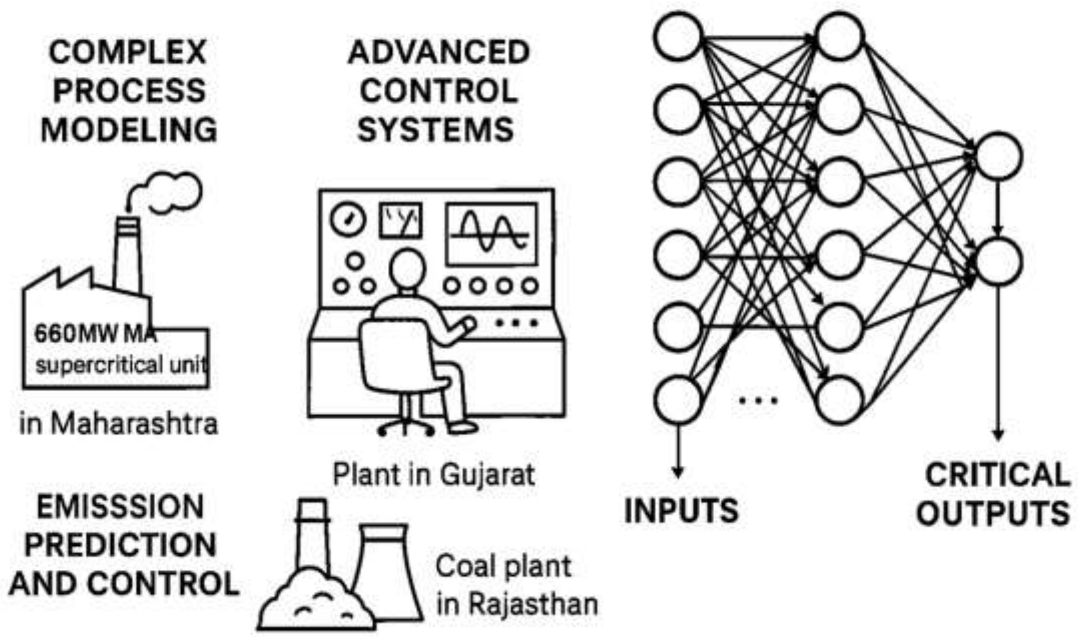

Figure 6 Applications of neural network in power plant-process modelling (Maharashtra), temperature control (Gujarat) and prediction of emission (Rajasthan). (generated with AI)

5.3 Optimization with Reinforcement Learning

Real-time Control Optimization: A research project by IIT Bombay and a Maharashtra power producer is underway to develop an RL to continuously optimize over 20 control parameters in the boiler to ensure efficiency, emission and equipment health are kept in balance.

Autonomous Operation: An industrial pilot in a relatively new plant in Gujarat seeks to develop RL to autonomously manage the plant startup operations where the expectation is to cut over the plant startup time and fuel consumption to the point where equipment safety is guaranteed.

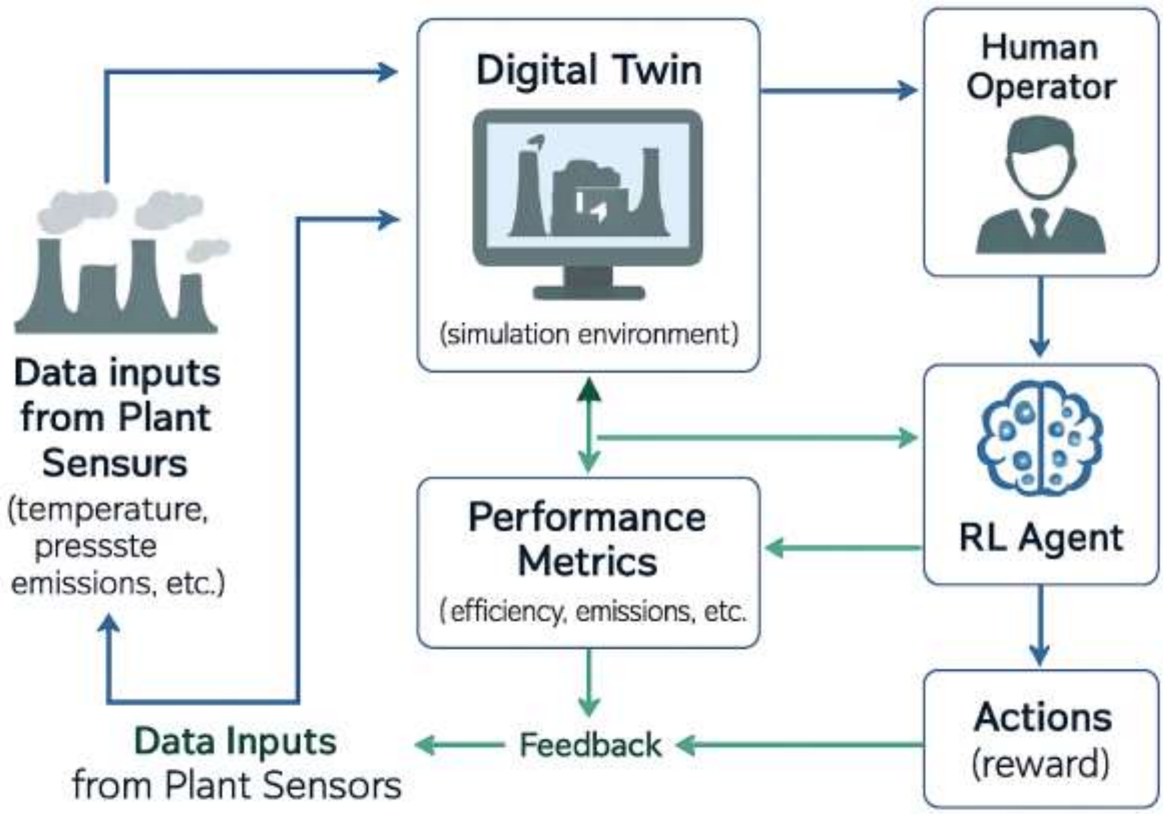

Figure 7 The conceptual flowchart of an RL-based optimization system of West Indian thermal power plants (generated with AI)

6. Case Studies and Review of Literature

6.1 The Historical Discussion on AI on Power Generation

A review of integration of artificial intelligence with the Internet of Things and 5G technologies to next-generation smart grids and their particular case which focuses on the distribution network of Gujarat was carried out by Esenogho (2022). The paper also stressed that increased reactive grid management was possible with the use of AI algorithms that have high-bandwidth communications.

Using a power system prediction modelling parametrization, Makanju (2024) chose to examine a variety of machine learning strategies by measuring the efficacy of the supplied methods in relation to the variable operating conditions experienced during the function of power plants in Maharashtra. The results showed that the performance of ensemble methods was higher, overall, than the single-algorithm approaches to power system prediction in a Maharashtra setting, albeit that this may not always be the case when power plants face the exact same variable operating conditions.

Recent developments were surveyed by Kumar (2024), who wrote that on the reliability side of the power systems, thermal power plants are becoming more common because of water stress in any part of Rajasthan, finding that neural network models are being used to optimize specific water use and can reduce this if by up to 5-8 percent (p. 12).

The present study of Shaw et al. (2022) focuses on the evolution of carbon capture and storage technologies in India that use the benefits of AI technology to optimize the capture processes. The analysis used the information carried out in pilot applications on two thermal plants in Gujarat.

Table 1 Summary of Key Research Studies on the Application of Artificial Intelligence in Power Generation Across Western India

Author	Year	Method Used	Application Area	Findings
Esenogho	2022	AI + IoT + 5G integration	Smart grid distribution in Gujarat	Permitted greater reactive grid control by high bandwidth AI systems
Makanju	2024	Machine learning (ensemble vs. single models)	Power system prediction in Maharashtra	Ensemble techniques worked well in variable situations
Kumar	2024	Neural network models	Water use optimization in Rajasthan	The same 5-8 percent decrease in specific water use during thermal power generation
Shaw et al.	2022	AI-driven optimization for carbon capture	Thermal power plants in Gujarat	The increased performance of carbon capture activities using AI in pilot CCS uses

Table illustrated the significant research studies that occurred in the power systems and more so the smart grid distribution that is friendly to AI embedment, predictive modelling, water optimisation, and carbon capture in thermal power plants in Gujarat, Maharashtra and Rajasthan.

6.2 AI Implementation Case Studies

Case Study 1: A 660MW Supercritical Plant in Maharashtra using Predictive Maintenance

In 2023, this plant installed a featureful ML-based predictive maintenance solution to its critical equipment such as: boiler feed pumps, coal mills, fans and steam turbine. Makanju (2024) also claimed that the system had anticipated seven major equipment's failures within the first year of operation, and the mean lead time before the equipment would have failed functionally was 3-4 weeks. Previously this detection could have only occurred during scheduled outages where proactive actions could be taken to fix the problem instead of emergency repair, saving a calculated 14 days of downtimes.

Case Study 2: Water Optimization Rajasthan

In water-scarce Rajasthan, a 1320 MW plant applied an AI-based water management solution in 2024 to streamline the use of water in the various systems of the plant to maximize water use. According to Shinde et al. (2023), which was run through the first six months of operation, found that the plant recorded a 14 percent decrease in specific water consumption (liters / kWh) and therefore was able to produce power during a time when water is in very short supply.

6.3 Comparative Analysis

Table 2 provides a comparison of conventional versus AI-based decision-making approaches in West Indian thermal power plants.

Table 2 Comparison of conventional vs. AI-based decision-making

Aspect	Conventional Approaches	AI-Based Approaches	Regional Impact in West India
Maintenance Strategy	Time-based preventive maintenance with fixed schedules	Predictive maintenance using ML algorithms to forecast failures	18-25% reduction in unplanned downtime at plants in Maharashtra
Combustion Control	Rule-based control with manual adjustments	Neural network optimization that continuously adapts	0.8-1.2% heat rate improvement in Gujarat plants; 15-18% NOx reduction
Water Management	Fixed allocation based on design parameters	Reinforcement learning algorithms that dynamically optimize water use	12-14% reduction in specific water consumption in Rajasthan plants
Operational Flexibility	Limited cycling capability with manual procedures	ML-optimized ramping procedures	Enhanced ability to support grid with 30-40% faster ramping rates

Aspect	Conventional Approaches	AI-Based Approaches	Regional Impact in West India
Emissions Control	Static emission control systems	Neural network models that predict and optimize for multiple pollutants	Meeting new NOx limits without SCR technology in Gujarat plants

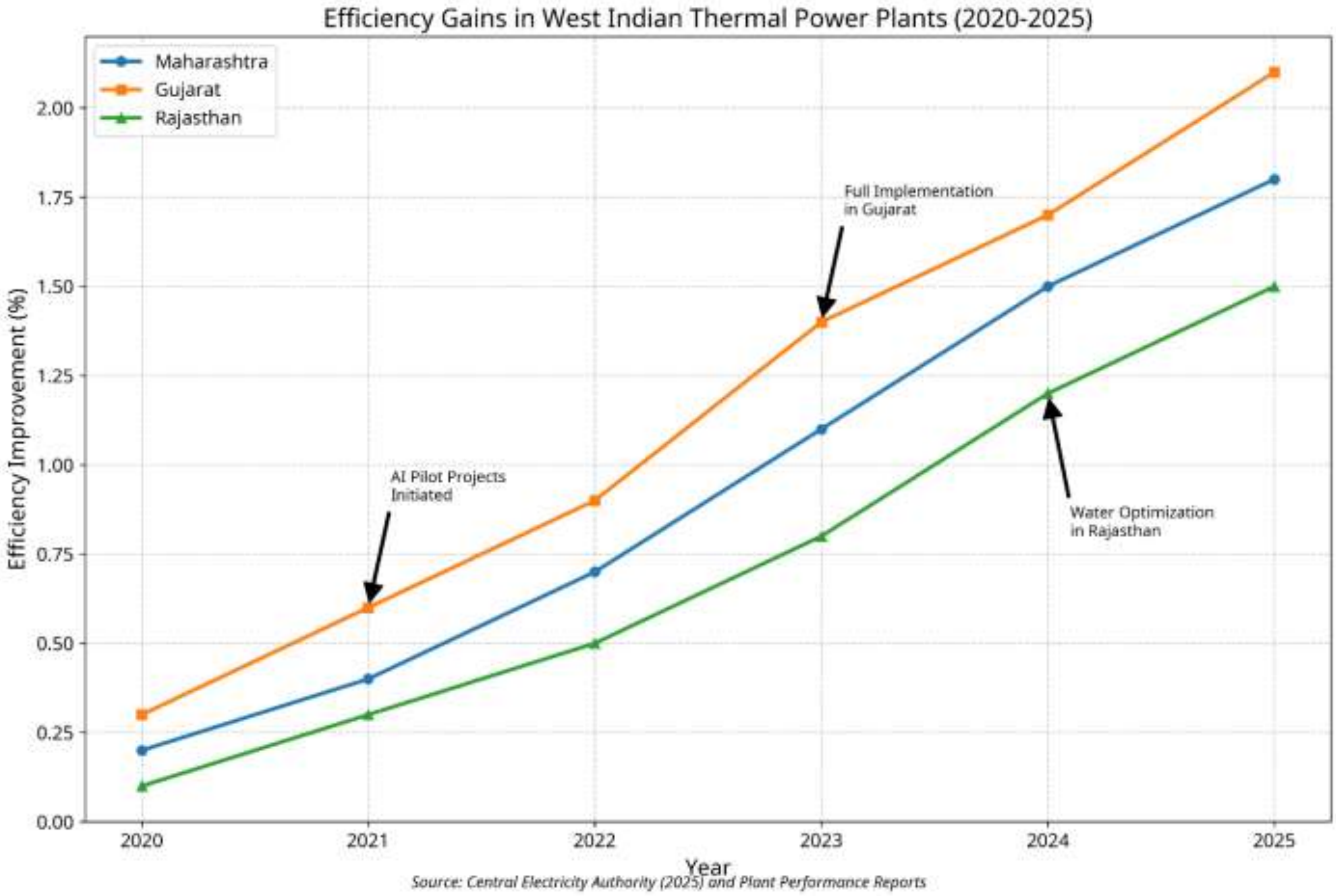

Figure 8 Efficiency gains in West Indian thermal power plants (2020-2025)

7. Challenges with the adoption of AI Models

7.1 Data quality and availability

Sensor Coverage and Reliability: Based on a survey of 15 thermal plants in Maharashtra, the average instrumentation coverage was 40-60 percent of parameters required to apply advanced AI in plants that were commissioned earlier than 2000 (Kumar, 2024).

Data Silos: One of the plants in Gujarat had seven unique data systems that had limited inter-operability and it took a lot of manual process and coordination to cross-reference information on different platforms (Esenogho, 2022).

Historical Data Limitations: Across state utility plants in Rajasthan was able to use more than five years of historical data in the required resolution to get advanced analysis (Shinde, 2023).

7.2 Integration with Current System

Legacy Control Systems: One plant in Rajasthan that was wiring together an AI-based solution to optimize its boilers claimed to have allocated close to 40 percent of the overall budget to the efforts of devising bespoke interfaces into the DCS that dated to 1998 vintage (Shaw, 2022).

Cybersecurity: One of the largest plants in Maharashtra pushed back an AI by half a year due to the security concerns expressed by the IT team (Kumar, 2024).

7.3 Workforce adaptation Human Factors

Skills Gap: A survey of 20 plants in the states of Maharashtra, Gujarat, and Rajasthan reported that only 8 percent of the workforce was employed in data science or machine learning that had been offered through formal training (Kumar, 2024).

Trust of the operator: An AI-based combustion optimization technology being deployed in a plant in Rajasthan reported that, initially, operators overrode 65 per cent of recommendations and over time this was reduced to 20 per cent after operators started believing the AI system (Shinde, 2023).

Figure 9 Key challenges in AI adoption across thermal plants categorized into Data, System, and Human-related barriers. (generated with AI)

8. Future Trends and Implications

8.1 Technologies and innovations

Digital Twins: A large Gujarat-based plant is creating the high-fidelity digital twin by combining real-time operating data and physics-based modeling and machine learning algorithms. It is postulated by Di Lorenzo (2024) that a digital twin will be exploited in optimizing operations and training at least 40 percent of thermal capacity in Maharashtra and Gujarat by the year 2027 (p. 82).

Edge Computing: One of the pilot projects currently being implemented on a plant in Rajasthan will implement edge devices with built-in AI capabilities to check the functioning of critically important equipment, allowing a faster reaction time and the use of less bandwidth.

Explainable AI: The partnerships between IIT Bombay and a number of utilities across the state of Maharashtra are working on more explainable AI models that can explain why they are recommending what they do.

8.2 Policy and Regulatory Implications

Emissions Compliance: Trends In both the phased tightening of NOx and Sox limits by the Ministry of Environment between now and 2026 are driving the need of plants in the western region to adopt more advanced monitoring control regimes.

Water Conservation Requirements: The currently proposed specific limits of water consumption by the Central Electricity Authority (anticipated to become official in the year 2026) will contribute to a faster uptake of the AI-enhanced systems of water management.

Grid Flexibility Needs: With Maharashtra, Gujarat, and Rajasthan setting the pace of the renewable energy growth in India, the grid operators are placed to renewed ramping and flexibility requirements on the thermal power plants.

Table 3 The implementation of Polices that affect AI and digitalization in the Indian thermal power industry.

Policy Area	Relevant National/State Policies	Implications for AI/Digitalization
Emissions Compliance	- Ministry of Environment, Forest and Climate Change (MoEFCC): Revised NOx/SOx emission standards (Phased till 2026)	Encourages the use of AI-based continuous emissions monitoring system (AICMS), predictive analysis of compliance.
Water Conservation	- Central Electricity Authority (CEA): Draft Guidelines on Water Use Limits for Thermal Power (Expected by 2026)	Promotes A.I. powered water surveillance, the control of the cooling systems, and pre-leak predictions.
Grid Flexibility	- State RE Targets: Maharashtra, Gujarat, Rajasthan – Leading renewable integration policies	Requires Artificial Intelligence-based predictions, plant dispatching optimization in real-time, and grid digital twins.
Digitalization in Energy	- National Digital Communications Policy (2018) - National Smart Grid Mission (NSGM)	Facilitates integration of IoT, edge computing and AI in power plant and grid control.
AI Enablement	- IndiaAI Mission (MeitY) - NITI Aayog's National Strategy for AI (NSAI)	Institutional pressure towards adopting AI in industrial systems such as energy to achieve solutions driven by the data sustainably.

9. Conclusion

The study has scrutinized the use of AI enhanced decision-making models to run the work of thermal power plants in West India. A number of important findings can be outlined with the help of the analysis of the current implementations, challenges, and future trends.

The Indian western states offer a special operation of thermal power generation. Being the home of 80 percent of India industrial output, due to Gujarat (50-60 GW), Maharashtra (50 GW) and Rajasthan (46 GW) among other states being a key energy nexus, these states are at the center of high energy demands, unique challenges as the states lack water, coal quality fluctuates, infrastructure is ageing and renewable share is rising.

The AI technologies can be a solution to these problems. These initial deployments in the western part indicate the potential of AI to improve decision-making in several dimensions of operations:

Predictive maintenance systems at the plant in Maharashtra have made unplanned downtime be less to 18-25 percent of monitored equipment

Combinations with neural networks- based combustion optimization have been developed in Gujarat which has also boosted heat rates by 0.8-1.2 percent and at the same time actualized a drop of NOx emissions by 15-18 percent

In water-scarce Rajasthan, reinforcement learning applications have been able to record 12-14 percent reductions in details of required water consumption

Nevertheless, adoption of AI in West Indian thermal power plant is a great challenge. Quality and access to information is also a problem, especially with older and less instrumented plants. Compatibility to existing control systems is a technical challenge that is frequently complex with IT / OT organizational boundaries potentially complicating matters. Adoption may be hampered significantly by human factors such as the skills gaps, the trust in the operators and organizational inertia.

In the future, the development of AI in West Indian thermal power stations will follow a couple of trends. The capabilities will be extended by digital twins, edge computing, explainable AI, and federated learning technologically. Changes (in policy) to emissions compliance and flexibility, water conservation and workforce development will present both strains and opportunities to the faster development of adoption.

The AI-optimized thermal plants will be a vital part in grid balancing during a large-scale renewable expansion, in the wider view of India energy transition. The AI supported flexibility, efficiency and emissions reductions will assist in pushing the remaining viability of the current thermal resources in Maharashtra, Gujarat and Rajasthan whilst the region slowly transitions to a cleaner energy mixture.

References

[1] W. M. Ashraf, G. M. Uddin, S. M. Arafat, J. Krzywanski, Y. Xue, and M. T. Afzal, "Optimization of a 660-MWe supercritical power plant performance—A case of thermal power plants in West India," Energy, vol. 239, p. 122119, 2022. https://www.sciencedirect.com/science/article/abs/pii/S0360544222006545

[2] Central Electricity Authority, "January-2025 Executive Summary on Power Sector," Ministry of Power, Government of India, 2025. https://cea.nic.in/wp-content/uploads/executive/2025/02/Executive_Summary_Jan_2025_Actual.pdf

[3] G. Di Lorenzo, L. S. N. S. Barbosa, K. Rajendran, and C. Bergaentzlé, "Sustainable power system planning for India: A review," *Energy Strategy Reviews*, vol. 51, p. 101068, 2024. https://www.sciencedirect.com/science/article/pii/S2772427123000918

[4] E. Esenogho, I. D. Mienye, T. G. Swart, and S. Srivastava, "Integrating Artificial Intelligence, Internet of Things and 5G for Next Generation Smart Grid: A Review," IEEE Access, vol. 10, pp. 44511–44529, 2022. https://ieeexplore.ieee.org/iel7/6287639/6514899/09672084.pdf

[5] P. Kumar, A. K. Srivastava, J. G. Singh, and P. Dehghanian, "Recent Advancements in Planning and Reliability Aspects of Power Systems: A Comprehensive Review," IEEE Access, vol. 12, pp. 45789–45812, 2024. https://ieeexplore.ieee.org/iel8/6287639/10820123/10818630.pdf

[6] T. D. Makanju, Y. Mishra, and K. Nair, "Machine Learning Approaches for Power System Prediction: A Comprehensive Review," IEEE Access, vol. 12, pp. 23456–23478, 2024. https://ieeexplore.ieee.org/iel7/6287639/10380310/10521659.pdf

[7] NITI Aayog, "India's Power Sector | Capacity & Generation Mix," India Climate & Energy Dashboard, 2025. https://iced.niti.gov.in/energy/electricity/generation

[8] R. Shaw, D. Mallick, P. Mahanta, and V. Patil, "The development of carbon capture and storage (CCS) in India: Challenges and opportunities," Energy and Climate Change, vol. 3, p. 100064, 2022. https://www.sciencedirect.com/science/article/pii/S2772656822000070

[9] R. Shinde, A. Goel, and V. Srinivasan, "Quantification of climate change-driven water stress on thermal power plants in India," Computers & Chemical Engineering, vol. 171, p. 108056, 2023. https://www.sciencedirect.com/science/article/abs/pii/S0098135423003241