Excellence through Digitalization in Power Generation

Dr Samik Patel[1], Sanjay Nair[2], Akshat Makwana[3], Nandini Sinha[4], Subhadip Sinha[5]
[1,2,3,4,5]*The Tata Power Company Limited, Mundra Thermal Power Station*
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***Abstract*—Power is one of the most vital elements for the growth of industry, agriculture, basic needs of society & national economy. To enhance operational excellence and sustainability, power sector is undergoing a transformative shift driven by Digitalization & Automation. The prime objective of this paper is to explore strategic execution of innovative technologies, focusing to enhance vital Key Performance Indicators (KPI) like efficiency, reliability, safety, security etc. Through inclusive analysis and extensive study of digitalization initiatives such as AI/ML based projects to enhance safety & performance, Physical Security, Authorized operation for critical process, Safety Monitoring, Fire System Surveillance, CCTV Surveillance, Predictive Operation & Defensive Action (ProDA), Advance Data Analysis & integration to avoid generation loss. Holistic study has been conducted for scalable digital innovative initiatives. The study is based on investigation from leading power generating units, indicating successful digital transformation shifts and mitigates challenges. Innovative Digital transformation not only improve operational efficiency but also enhance safety, security and other crucial KPIs. The paper further proposes a framework for evaluating change management, workforce future readiness, digital maturity & cyber security compliance. Eventually, the study determines that Digitalization is not simply a technological upgrade but a strategic enabler for excellence. It is an inclusive approach that includes technology, people and process to revolve the full potential of Digital Transformation in Power Sector.**

***Index Terms*—Digitalization, Automation, Innovation, Operational Excellence**

I. INTRODUCTION

In this era of Industry 4.0, concept of SmartFactory, intelligent decision through real-time, enabling flexible production of high quality efficiently [1][2]. Power sector is transforming to advance innovative technologies to achieve operational excellence and improvement in crucial Key Performance Indicators (KPIs). Digital transformation [3] is broadly described as the integration of digital technologies into core business processes to improve performance and create new value. Globally, Power Generators are under pressure to enhance performance & efficiency, cost optimization, reliability improvement for efficient & sustainable electricity and for this objective, one of the most transformative enablers of this shift is DIGITALIZATION – the strategic integration of digital technologies into process, systems and decision-making frameworks. Digitalization embraces a wide array of innovation & cutting-edge technologies like Industrial Internet of Things (IIoT), Artificial Intelligence (AI), Machine Learning (ML), Big Data Analytics, Digital Twins, Cloud Computing and much more. Digitalization transforming traditional operations by enabling real-time monitoring, predictive operation & defensive action (ProDA) [4], intelligent automation, data-driven decision making. As a result, processes are transforming from reactive to proactive management paradigms, significantly improving reliability, safety & efficiency. At Tata Power's Mundra Thermal Power Station (MTPS), various AI/ML based use cases like Intrusion detection from security boundary, Face Recognition for secured operation by authorized operation team, Safety Personal Protective Equipment (PPE) compliance monitoring, Integrated Operation Excellence Center (iOEC) have been implemented. These concept of excellence through digitalization demonstrates the systematic improvement of Operation & Maintenance (O&M), and strategic capabilities through digital transformation. It implies not only the embracing of new tools but also a cultural and organizational shift towards data-centric decision-making, continuous improvement, pioneering & innovation. It also enables workforce transformation by enhancing skills, safety, and collaboration through digital platforms. In spite of huge benefits, digital transformation has few barriers too, like Cybersecurity risk, workforce resistance, system integration etc. are

being addressed strategically. This study explores the comprehensive view of Excellence through Digitalization in Power Generation. Holistically reviewed vital technologies, implementation strategies and impact to provide comprehensive framework for digital transformation in the sector.

II. LITERATURE REVIEW

Since last decade, intellectual attention towards digitalization in industries has been increased. Technical Experts and Researchers are exploring how digitalization can enhance performance & efficiency, strategic decision-making, cost effective innovation in power plants. The literature study synthesizes vital findings from journals, industries reports and various case studies to establish the theoretical & practical foundations of digital operational excellence in power sector. Subject related detail literature review has been summarized in Table 1.

Table 1: Literature Review

Author/Year/Ref	Key Discussion - Arguments
Maria Luisa Di Silvestre et al. /2018 / [5]	Examines how Decarbonization, Digitalization, and Decentralization are changing worldwide energy sector, with a focus on China, EU, USA. Each region adopts distinct models from centralized transmission in China to decentralized smart grids in the USA, and a hybrid approach in the EU. Digital platforms and demand response programs enable new business models. Success hinges on regulatory alignment, technological innovation, and stakeholder collaboration.
Bin Xu et al. / 2019 / [6]	China Energy's NICE exploited a digital twin-based Plant Smart Management platform to optimize performance. Applied to a 320-MWe unit, it identified efficiency losses and proposed optimizations. The platform enables smarter, cost-effective operations and supports flexible strategies.
Julia Turovets et al. /2021/ [7]	Study for digitalization in the electric power industry across 10 major electricity-producing countries: China, US, India, Russia, Japan, Canada, Germany, Brazil, South Korea, and France. Digitalization, decarbonization, and decentralization are transformative forces shaping future
Nicolò Rossetto and Valerie Reif / 2021 / [8]	Digitalization is reforming the power sector by enhancing data-driven operations, enabling decarbonization through RE integration, and supporting decentralization via distributed energy resources. Advanced digital technologies improve infrastructure planning, maintenance, and system efficiency. Data plays a central role in forecasting, market transparency, and consumer empowerment.
Rajesh Singh et al. / 2022 / [9]	This research explores how Industry 4.0 technologies like IoT, AI, blockchain, and big data are revolutionizing the energy sector. These technologies enhance efficiency across generation, transmission, distribution, and consumption. Applications include smart grids, microgrids, peer-to-peer energy trading, and predictive maintenance. The study highlights the need for standardization, green IoT, and digital twins to fully realize sustainable, intelligent energy systems.
Hubert Szczepaniuk / 2022 / [10]	How AI / ML, metaheuristics, and fuzzy inference systems can tackle energy sector issues like smart grid management, cybersecurity, fault diagnosis, and renewable integration. These methods enhance forecasting, optimize energy use, and improve system resilience. Despite their potential, challenges remain in data handling, algorithm efficiency, and cybersecurity, especially for IoT-based systems.
Asif Raihan / 2023 / [11]	AI and ML application can resolve energy sector's vital challenges like inefficiency, unauthorized usage, volatile demand especially in developing countries. Applications span predictive maintenance, smart grid management, energy price forecasting, and infrastructure.
Huijuan QI / 2023 / [12]	AI-based intelligent control system to improve energy efficiency in thermal power plants through optimized waste heat recovery. Techniques like time-sharing control and climate compensation dynamically adjust heating based on outdoor conditions and building usage.
Waqar Muhammad Ashraf / 2023 / [13]	AI-based modelling using Artificial Neural Networks (ANN) considerably enhanced the performance of thermal power plant by optimizing key operational variables, leading to fuel savings, higher efficiency, and reduced emissions. The approach demonstrated scalability and effectiveness in supporting net-zero goals through smart, data-driven operation.
Firas Basim Ismail et al. / 26-09-2024 / [14]	The study develops two Intelligent Monitoring Systems (IMS) using Artificial Neural Networks (ANN) and a hybrid ANN–Genetic Algorithm (GA) to predict and prevent boiler trips in coal-fired thermal power plants. IMS-I uses operator-selected variables, while IMS-II automates variable selection and model optimization. Both systems showed high accuracy in early fault detection, with

	IMS-II offering better performance and adaptability for complex diagnostics. The approach enhances plant safety, reliability, and operational efficiency.
Yousu Chen et al. / 2024 [15]	AI/ML in power systems, highlighting techniques like supervised learning, reinforcement learning, and graph neural networks. It showcases their role in fault detection, forecasting, asset management, and grid optimization, while also addressing challenges like data quality, explainability, and regulatory concerns
Nitin Swarnkar / 2025 / [16]	AI technologies like ML, ANN, and RL are improving thermal power plant operations in Maharashtra, Gujarat, and Rajasthan by addressing challenges such as water scarcity, aging infrastructure, and fuel variability. AI applications have led to measurable gains in predictive maintenance, combustion efficiency, and resource optimization, though adoption faces hurdles like data quality, system integration, and workforce readiness.

2.1 Research Objectives

The primary Objective is to study how digitalization initiatives beneficial to organization to improve operational performance, reliability, safety & vital KPIs. To achieve this, the study is guided by the following specific objectives:

1. To identify and classify vital digital applications currently being adopted in power plants, including AI, ML data analytics etc.
2. To evaluate the impact of digitalization on critical indicators such as Operational Excellence, Safety and Security Enhancement etc.
3. To review strategic framework for achieving excellence through digitalization, based on empirical findings and best practices from industry case studies, process of horizontal deployment to respective functions.
4. To investigate barriers and challenges faced by power companies in implementing digital solutions, including cybersecurity risks, legacy system integration, skill development and cultural resistance.
5. To provide actionable recommendations for policymakers, technocrats, O&M representative, and technology providers to accelerate digital adoption and maximize its benefits in the power sector.

III. METHODOLOGY

For this study mixed-methods approach has been adopted to investigate how digitalization contributes to achieve vital KPIs. The methodology integrates both qualitative and quantitative techniques to ensure a comprehensive understanding of technological adoption, outcomes, and organizational transformation. A combination of case study, survey research, and secondary data /literature review has been applied.

3.1 Data Collection Methods

a. Case Studies

For this study, The Tata Power Company's Mundra Thermal Power Station (MTPS) was selected based on their level of digital maturity. MTPS is India's first Ultra Mega Power Plant (UMPP) having five units of 830 MW each having total capacity of 4150 MW [17]. Data was collected through:

- On-site observations [18] from implemented digitalization initiatives
- Interviews [19] with plant representatives, users and digital transformation leads
- Review of internal reports and digital implementation roadmaps

b. Surveys-onsite observation and Interviews

A structured site visit for onsite observation & survey was carried out. Qualitative research methodology – interviews & focused group discussion with subject matter experts [20] with 23 professionals across operations (2), maintenance (4), safety (4), security (5), IT (4) functions & leaders (4). The survey focused on:

- Awareness and usage of digital tools
- Challenges before implementation, during implementation & after implementation
- Perceived benefits for respective KPIs
- Impact on KPIs & actual benefits
- To gain deeper insights into strategic and cultural aspects of digitalization

c. Secondary Data Analysis

Industry reports, academic publications from national & international journals, and benchmarking data from Government and other respective organizations such as the Central Electricity Authority (CEA), Ministry of Power etc. were reviewed for this study.

3.2 Validation and Reliability

To ensure reliability and validity:

- Triangulation [21] [22] was used by comparing findings across multiple data sources.
- Pilot testing of the survey instrument was conducted with a small group of professionals.
- Member checking was performed by sharing preliminary findings with interview participants for feedback.

3.3 Ethical Considerations

All participants were informed about the purpose of the study and consented to the use of their responses for research purposes. Confidentiality was maintained by anonymizing company and individual identifiers.

3.4 Description

Tata Power is India's one of the largest integrated power players [23]. Safety is a core value over which no business objective can have a higher priority [24]. Tata group is passionate about achieving the highest standards of quality, always promoting meritocracy [25]. Tata Power is following Tata Business Excellence Model (TBEM) [26] [27] [28] based on the Malcolm Baldrige Business Excellence Model [29]. Based on Tata Power's Vision – Mission, Strategic goal is cascading to respective clusters – Generation, Transmission & Distribution and Renewal. Each Cluster's strategic goal is linked to respective divisions. Mundra Division's strategic Key Performance Indicators (KPIs) and respective targets are being mapped in Division Score Card. During annual strategic meet, all aspects are being evaluated. Based on SWOT analysis and problem bank or crucial issues, appropriate management program – projects are selected. Digitalization project selection is selected based on this strategic process. Each function is following Plan-DO-Check-Act (PDCA) [30] [31]. Cross Functional Team is reviewing problem bank - SWOT to address challenges, performed Root Cause Analysis through appropriate statistical tools and then initiate respective improvement project. To achieve excellence and to improve safety work culture, numerous digital initiatives have been implemented at MTPS. In Table 2, Challenges, Need of Project and Digital innovative projects implemented at MTPS are articulated.

Table 2: MTPS Challenges – Need of Project – Digitalization

Challenges	Need of Projects	Digitalization
Critical IT asset availability 1. To ensure reliability of all Digitalization initiatives, essential requirement is IT infra reliability 2. Huge network infrastructure monitoring manually round the clock is difficult 3. IT Network Monitoring System (NMS) is costly and available at corporate only	To ensure IT system healthiness automatically, round the clock with utmost accuracy is essential to ensure reliability of all Digitalization initiative	AAI (Asset Availability Index) Python based real-time dashboard to monitor IT infra-availability
Security Challenges 1. Mundra premises is in remote barren area 2. International boarder 3. Large boundary & huge area 4. Continuous round the clock 24 x 7 x 365 manual surveillance to all the locations & perimeter are difficult & costly 5. High probability of Intrusion through blind locations or blind time spots	To enable 24x7 perimeter security through an in-house, AI-ML powered human intrusion detection system to address costly manual surveillance with intelligent, real-time alerts without manual error & other techno-commercial limitations	Lakshman Rekha Human Intrusion Detection at boundary perimeter
Authorized operation for crucial area like Hydrogen 1. Hydrogen plant is crucial explosive high-risk area 2. Authorized operation, Secure entry to be ensured 3. Continuous round the clock 24 x 7 x 365 manual surveillance is difficult & costly	To secure hazardous zone by digitalization, AI-ML based Face recognition and real-time alerting to competent authority – Shift Incharge to ensure operation by authorized engineer only	Parirakshit Secured entry & Operation by Authorized person at Hydrogen Generation Plant
Challenge for Safety PPE: Mundra is 5 x 830 MW Ultra Mega Power Plant having around 1300 hector plant premises and different process areas like Boiler, Turbine, CHP, AHP, FOPH, FWPH, RO-DM, ECP etc.	Digitalized tool with video analytics which can monitor & give real-time alert to competent authority for PPE violations round the clock	Trinetra Personal Protective Equipment (PPE) monitoring & real-time alert for violations

Continuous round the clock 24 x 7 x 365 manual surveillance for PPE compliance of all Employee & Associates in all the locations are difficult.		
Operational Excellence 1. Frequent Load variation due to Flexibilization 2. Vital KPI monitoring & improvement 3. APC tracker & start up – shut down cost optimization 4. Daily reports	To improve plant performance & efficiency, reduce operational costs through a centralized, in-house digital platform powered by real-time analytics.	iOEC Integrated Operation Excellence Center Merit Order Tool

1. AAI (Asset Availability Index)

IT asset reliability plays vital role to ensure appropriate functioning of all Digital applications. Python based Digitalization has been implemented for real-time dashboard which indicates status of IT Network Switches, Wi-Fi, Servers, Printers, communication infrastructure – EPABX & IP phones and CCTV. Crucial benefit of this Digitalization is enhancement of availability of IT systems resulting reliability improvement in all other respective innovations.

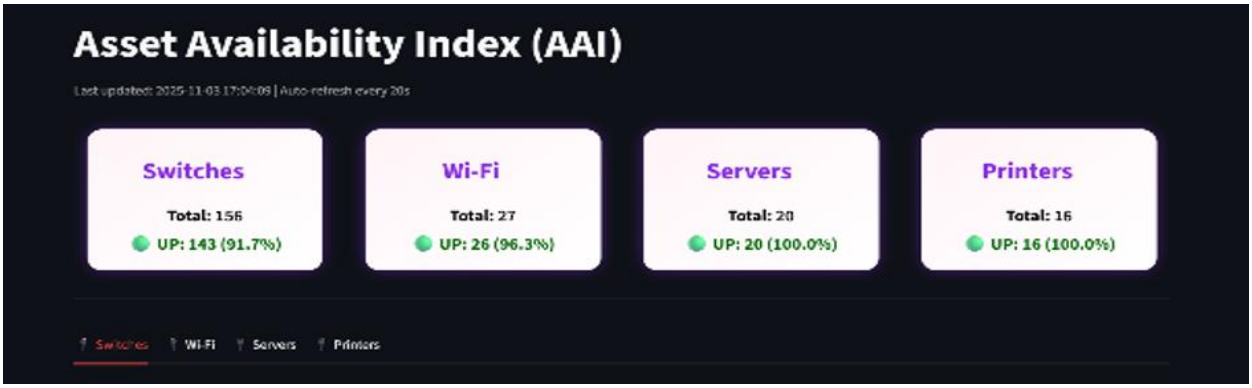

Figure – 1: Asset Availability Index (AAI)

2. Lakshman Rekha

To mitigate security challenges discussed in Table 1, AI-ML based digital tool has been implemented with existing CCTV infrastructure to detect human intrusion from security boundary. Tool gives real-time audio alert in Security Control Room (SCR) in case of detection of human at security perimeter with provision of auto email notification to security officers to initiate prompt corrective actions.

Figure – 2: Lakshman Rekha Overview

To implement this Digitalization project, YOLOv8 (You Only Look Once) – a state-of-art object detection model trained to identify human presence is being used. PyQt5 GUI framework for real-time video display and interaction has been adopted. Multiple IP cameras installed along perimeter stream live footage to Security Control Room with recording and video analytics. This tool ensures smooth frame capture, processing and display without lag.

Figure – 3: Human Detection

3. परिरक्षित (Parirakshit) Authorized Entry at Hydrogen Plant

Hydrogen gas is colourless & odourless, highly flammable when mixed with air or oxygen, explosive in air at concentrations between 4.1% to 74.2 % by volume, flammable in dry oxygen from 4 % to 96 % by volume, capable of ignition with minimal energy input – even an invisible spark can trigger an explosion. Given these properties, the hydrogen generation plant is a high-risk zone requiring robust safety and security. To address challenges described in Table 1, परिरक्षित has been implemented which ensures secured entry & operation by authorized person. Crucial benefit is round the clock automated surveillance without any manual error and violance will be notified through real-time email to Shift Incharge.

For this, Utilizes MTCNN (Multi-task Cascaded Convolutional Networks) for accurate face localization. Employs FaceNet to convert detected faces into numerical embeddings. Uses a trained Support Vector Machine (SVM) classifier to identify authorized personnel. Recognized faces are logged with timestamps; unknown faces are stored for review. Region of Interest have been included for focused detection area to optimize processing and reduce false positives. To ensure reliable face recognition, low-confidence predictions have been filtered – confidence thresholding is used. To ensure efficient use of system, threaded processing – background thread handles recognition independently of video capture. Enables access to log and to view details, intranet web-based access to Operation & Security have been provided.

Figure – 4: Authorised Person Check

Figure – 5: Email alert for unauthorised entry

4. TRINETRA

At MTPS, around 2000 business associates operate daily across various plant zones. Adherence to safety PPE norms such as wearing helmets, safety jackets, and shoes is mandatory in workplace. Traditionally, compliance was monitored manually by safety officers through random visual inspections, which posed challenges in consistency, coverage, and timely corrective action as discussed in Table 1. To address these challenges, “TRINETRA” application has been implemented which is monitoring PPE compliance and triggers real-time email notification in case of PPE violence. For “TRINTRA”, YOLOv8 Object Detection model has been trained to identify helmets and safety jackets.

Figure – 6: Safety PPE Check

Figure – 7: Safety PPE Alert

5. iOEC

Digital Application - iOEC

The integrated Operation Excellence Center (iOEC) is a Python-based digital web platform developed in-house to enhance operational efficiency and reliability. It integrates directly with the PI Web API to fetch real-time plant data, enabling smart tools and analytics for decision-making and to achieve organizational goal. In addition to efficiency modules, iOEC have modules to monitor daily routine activities like Digital Shift Logbook, Digital Shift Reports (Shift-wise operational events, performance & abnormalities, key actions in structured digital format), Critical Equipment Trial Record, Digital Auto Daily Generation Report (DGR), Turbine Valve Combination Test Report, Smart Metal Temperature Reports etc.

Holistically project is designed, developed and implemented inhouse by MTPS engineers. Initially they have faced challenges like false detections due to day-night lights, shadow etc., fine tuning issues, change resistance, workforce skill, business associate's acceptance etc. All resistance has been addressed by appropriate actions.

Digitalization list is not limited to this only. Journey is continued to more innovative initiatives for Outage Management, Safety & Security KPI improvement, Efficiency & Process digitalization etc.

IV. RESULTS & DISCUSSION

Case study indicates that MTPS have implemented digital technologies primarily to achieve Operational Excellence, improve KPI performance, safety & security.

The most commonly adopted applications were:

- AAI (Asset Availability Index) – Real-time dashboard for IT infra monitoring
- Lakshman Rekha – Human Intrusion from security boundary
- Parirakshit – Face Recognition for operation through authorised engineer
- Trinetra – Safety PPE compliance to enhance safety work culture
- Coal Belt AI-ML use case to enhance performance, reliability & safety
- iOEC – to achieve Operational Excellence
- Real-time alerts for CCTV issues, Fire Water (Satark) etc critical services

Study directed significant enhancements in key performance indicators (KPIs) post-digitalization project implementation. These results confirm that digitalization contributes directly to operational excellence by enhancing reliability, optimizing costs, and improving efficiency, safety & security.

Organizational Readiness and Challenges

Study emphasized numerous enablers of successful digital transformation:

- Leadership Commitment
- Cross-functional Collaboration
- Training and Change Management

However, challenges persist. Following barriers have been observed:

- Cybersecurity Concerns
- Resistance to Change
- Resource to initiate-implement & maintain digitalization initiatives

These outcomes align with global trends, highlighting the need for strategic planning and cultural alignment.

Strategic Implications

The analysis reveals that digitalization is not a one-time initiative but a continuous journey. Excellence is achieved not only through technology deployment but also through Data-driven decision-making, agile initiatives & sustainable innovation ecosystems.

Power generation companies must adopt a holistic approach that integrates digital tools with organizational strategy, workforce development, and regulatory compliance.

V. CONCLUSION

The research highlights the transformative potential of digitalization in achieving operational excellence not only for power plants but also for other industries for similar use cases. Power plants are evolving from reactive, manual operations to proactive-predictive and intelligent, systems with integration of advanced digitalization & tools like AI, ML, data analytics etc.

Empirical findings from case studies and survey data reveal visible improvements in key performance indicators such as increased system availability & reliability, reduced equipment breakdown, enhanced productivity, and O&M cost optimization.

Nevertheless, the journey toward digital excellence is multifaceted. It requires strategic alignment,

leadership commitment & workforce readiness and robust cybersecurity frameworks. Organizational culture and legacy infrastructure remain significant barriers that must be addressed through targeted change management and capacity-building initiatives. In conclusion, digitalization is a critical enabler of excellence in power generation. When implemented holistically, it empowers utilities to improve vital KPIs and remain competitive in a rapidly changing energy landscape. The insights from this study provide a roadmap for stakeholders to harness digital technologies effectively and sustainably.

RECOMMENDATIONS

Based on the findings and analysis presented in this study, the following recommendations are proposed to accelerate digital transformation and achieve operational excellence:

1. Develop a Strategic Digitalization Roadmap: Industry should create a phased and well-defined roadmap that aligns digital initiatives with strategic vision & goals. This includes prioritizing high-impact areas such as predictive Operation & Maintenance, performance optimization, and crucial KPI improvement.
2. Invest in Scalable and Interoperable Technologies: Adopt digital platforms and tools that are scalable and compatible with existing infrastructure. Interoperability between legacy systems and new digital solutions is critical to ensure seamless integration, data flow & change management.
3. Strengthen Cybersecurity Frameworks: As digitalization increases exposure to cyber threats, industry must implement robust cybersecurity frameworks, conduct regular audits & compliance management, and train staff in cyber hygiene to protect critical assets and information security requirements.
4. Foster a Culture of Innovation and Change: Encourage cross-functional collaboration, continuous learning, and openness to change. Leadership should actively promote digital literacy and innovation across all levels.
5. Upskill the Workforce: Industry should develop training programs to equip employees with the skills needed to operate and maintain digital applications. This includes technical training, data analytics, and respective competencies.
6. Monitor and Evaluate Performance Continuously: Industry shall define vital KPIs & respective target. Real-time digital dashboards to monitor performance shall be developed for regular monitoring & evaluation to identify gaps and appropriate corrective & preventive measures.

REFERENCE

[1] Xu, X., Lu, Y., Vogel-Heuser, B., and Wang, L., "Industry 4.0 and Industry 5.0 inception, conception and perception," *Journal of Manufacturing Systems*, vol. 61, pp. 530–535, 2021.

[2] Xu, M., David, J. M., and Kim, S. H., "The fourth industrial revolution: Opportunities and challenges," *International Journal of Financial Research*, vol. 9, no. 2, pp. 90–95, 2018.

[3] Kraus, S., Jones, P., Kailer, N., Weinmann, A., Chaparro-Banegas, N., and Roig-Tierno, N., "Digital transformation: An overview of the current state of the art of research," *SAGE Open*, vol. 11, no. 3, 2021.

[4] Patel, S. G., "Predictive Operation & Defensive Action (PrODA) for Intelligent Process Automation (IPA)," SSRN, 2025, SSRN 5240971.

[5] Di Silvestre, M. L., Favuzza, S., Sanseverino, E. R., and Zizzo, G., "How decarbonization, digitalization and decentralization are changing key power infrastructures," *Renewable and Sustainable Energy Reviews*, vol. 93, pp. 483–498, 2018.

[6] Xu, B., Wang, J., Wang, X., Liang, Z., Cui, L., Liu, X., and Ku, A. Y., "A case study of digital-twin-modelling analysis on power-plant-performance optimizations," *Clean Energy*, vol. 3, no. 3, pp. 227–234, 2019.

[7] Turovets, J., Proskuryakova, L., Starodubtseva, A., and Bianco, V., "Green digitalization in the electric power industry," *Foresight and STI Governance*, vol. 15, no. 3, pp. 35–51, 2021.

[8] Rossetto, N. and Reif, V., "Digitalization of the electricity infrastructure: A key enabler for the decarbonization and decentralization of the power sector," in *A Modern Guide to the Digitalization of Infrastructure*, pp. 217–265, Edward Elgar Publishing, 2021.

[9] Singh, R., Akram, S. V., Gehlot, A., Buddhi, D., Priyadarshi, N., and Twala, B., "Energy System 4.0: Digitalization of the energy sector with inclination towards sustainability," *Sensors*, vol. 22, no. 17, p. 6619, 2022.

[10] Szczepaniuk, H. and Szczepaniuk, E. K., "Applications of artificial intelligence algorithms in the energy sector," *Energies*, vol. 16, no. 1, p. 347, 2023.

[11] Raihan, A., "A comprehensive review of artificial intelligence and machine learning applications in energy sector," *Journal of Technology Innovations and Energy*, vol. 2, no. 4, pp. 1–26, 2023.

[12] Qi, H., Wen, H., and Xu, A., "Artificial intelligence control system of heat recovery in thermal power plant," *Thermal Science*, vol. 27, no. 2, Part A, pp. 1241–1247, 2023.

[13] Ashraf, W. M. and Dua, V., "Artificial intelligence driven smart operation of large industrial complexes supporting the net-zero goal: Coal power plants," *Digital Chemical Engineering*, vol. 8, p. 100119, 2023.

[14] Ismail, F. B., Al-Kayiem, H. H., and Kazem, H. A., "AI adoption for steam boiler trip prevention in thermal power plants," *International Journal of Energy Production and Management*, vol. 9, no. 3, pp. 131–142, 2024.

[15] Chen, Y., Fan, X., Huang, R., Huang, Q., Li, A., and Guddanti, K. P., "Artificial intelligence/machine learning technology in power system applications," Pacific Northwest National Laboratory, Richland, WA, USA, Rep. PNNL-35735, 2024.

[16] Swarnkar, N. and Jain, H., "AI-driven decision-making models for thermal power plant operations in West India," *International Journal of Novel Research and Development*, vol. 10, no. 6, pp. d300–d311, 2025.

[17] Tata Power, "Tata Power Mundra Plant."

[18] Mazhar, S. A., Anjum, R., Anwar, A. I., and Khan, A. A., "Methods of data collection: A fundamental tool of research," *Journal of Integrated Community Health*, vol. 10, no. 1, pp. 6–10, 2021.

[19] Alshenqeeti, H., "Interviewing as a data collection method: A critical review," *English Linguistics Research*, vol. 3, no. 1, pp. 39–45, 2014.

[20] Kabir, S. M. S., "Methods of data collection," in *Basic Guidelines for Research: An Introductory Approach for All Disciplines*, vol. 1, no. 9, pp. 201–275, 2016.

[21] Heale, R. and Forbes, D., "Understanding triangulation in research," *Evidence-Based Nursing*, vol. 16, no. 4, p. 98, 2013.

[22] Bans-Akutey, A. and Tiimub, B. M., "Triangulation in research," *Academia Letters*, vol. 2, no. 3392, pp. 1–7, 2021.

[23] Tata Power, "About Tata Power | Reliable & Sustainable Energy Solutions."

[24] Tata Power, "Our Vision, Mission, and Core Values."

[25] Tata Group, "Values and Purpose."

[26] Tata Business Excellence Group, "Tata Business Excellence Model (TBEM)."

[27] Aithal, P. S., "Achieving business excellence through ethical business model: A success story of Tata Group, India," *Poornaprajna International Journal of Management, Education & Social Science (PIJMESS)*, vol. 1, no. 1, pp. 375–408, 2024.

[28] Unnikrishnan, P. M., Tikoria, J., and Agariya, A. K., "A review of select business excellence models," *Evidence Based Management*, 2017.

[29] National Institute of Standards and Technology, "Baldrige Excellence Framework."

[30] Peças, P., Encarnação, J., Gambôa, M., Sampayo, M., and Jorge, D., "PDCA 4.0: A new conceptual approach for continuous improvement in the Industry 4.0 paradigm," *Applied Sciences*, vol. 11, no. 16, p. 7671, 2021.

[31] Jagusiak-Kocik, M., "PDCA cycle as a part of continuous improvement in the production company—A case study," *Production Engineering Archives*, vol. 14, 2017.