POWER GENXT

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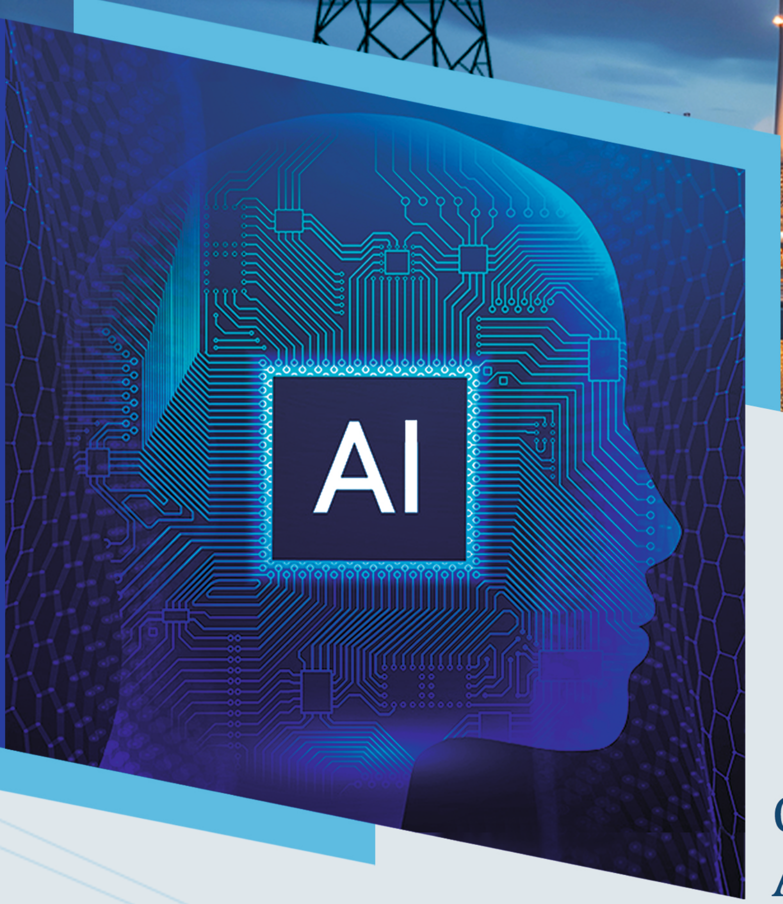

NEED
NATIONAL ENERGY EXCELLENCE DRIVE

CONCEPTS OF ARTIFICIAL INTELLIGENCE AND IT'S APPLICATION IN POWER SYSTEM

ENGINEERS' WELFARE FORUM
THE WEST BENGAL POWER DEVELOPMENT CORPORATION LIMITED

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NEED
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on

CONCEPTS OF ARTIFICIAL INTELLIGENCE AND IT'S APPLICATION IN POWER SYSTEM

at
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ENGINEERS' WELFARE FORUM

THE WEST BENGAL POWER DEVELOPMENT CORPORATION LIMITED

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Dr. P. B. Salim, IAS
Chairman & Managing Director

WBPDCL

Date: 19.02.2025

Message

*I am very glad to know that Engineers' Welfare Forum of The West Bengal Power Development Corporation Ltd. is going to organize the 13th National Seminar on "**Concepts of Artificial Intelligence and it's application in Power System"** at the auditorium of Corporate Office, WBPDCL, Kolkata – 700 106 on 23rd February, 2025 and a Technical journal **POWER GENXT (Vol. – XIII)** will be published to mark the occasion.*

My heartiest wishes and congratulations are due to the members of the Forum.

(Dr. P. B. Salim)

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Recognised by WBPDCL Vide letter No: PDCL/CORP/HR/305/1495 dated:3.3.2012

Date: 19/02/2025

Message From Chairman

The primary objective of power system operation and control is to furnish customers with high-quality electricity at reasonable costs while upholding system stability and reliability. As the demand surges and the electric power system evolves with different types of networks in generation and distribution, the control and monitoring become challenging and operational responsibilities strains the existing energy management systems, typically of numerical analysis software.

Leveraging Artificial Intelligence (AI) tools to support operational personnel in monitoring and decision making minimizes workload and enhances incident response efficiency. This convergence of electric power generation, distribution and operation and AI represents a significant trend in recent years.

AI, commonly characterized as the intelligence exhibited by machines and software, including robots and computer programs, is a scientific discipline that explores, develops, and simulates human behaviour and its underlying principles. The term primarily denotes creating systems possessing human-like cognitive processes and attributes, such as reasoning, learning from experiences, generalization, discrimination, and error correction.

AI techniques have proven instrumental in addressing numerous challenges in power systems, and their effectiveness is further amplified when combined with traditional mathematical approaches. Examples of these techniques include artificial neural networks (ANNs), fuzzy logic (FL), adaptive-network-based fuzzy inference systems (ANFISs), intelligent techniques and expert systems.

This issue of **POWER GENXT**(Vol-13) has come up with write up and reviews on AI applications in power systems, particularly in stability, control, and protection, identifying key challenges and research gaps based on recent publications.

My heartiest good wishes and congratulations to the Seminar Organising Committee for organising this 13th National Seminar on today's burning topic AI.

(PRASANTA SINHA)
Chairman,
Engineers Welfare Forum, WBPDCL

AI and its Applications in Power Systems

Er Rajiv Salwan
Additional General Manager (IT),
NTPC Limited

Er Rajiv Salwan *has amassed nearly three decades of extensive experience in the comprehensive field of Information Technology, working with both private and public sectors.*

Renowned for his exceptional programming and database skills, Mr. Salwan has played a pivotal role in developing a multitude of critical applications for power plants. Moreover, Mr. Salwan has showcased remarkable proficiency in AI technologies. Utilizing these skills, he has spearheaded the development of an innovative Generative AI-based bot, marking a significant milestone as the first ever bot implemented within NTPC.

In addition to his technical prowess, Mr. Salwan's strategic vision and commitment to technological advancement continue to drive progress and innovation in the IT landscape of NTPC Limited.

ABSTRACT

Artificial Intelligence (AI) is broadly characterized as the study of computations that allow for perception, reason and action. Today, the amount of data that is generated, by both humans and machines, far outpaces humans' ability to absorb, interpret, and make complex decisions based on that data. Artificial intelligence forms the basis for all computer learning and is the future of all complex decision making. AI has left no sector where it is not used. Power sector is one area where AI can be used exhaustively. AI is transforming predictive maintenance by enabling early fault detection, optimizing schedules, and reducing costs. Traditional methods often lead to unplanned downtimes and inefficiencies. AI-driven predictive maintenance uses machine learning, IoT sensors, and big data analytics to analyse equipment performance and predict failures. This paper examines AI techniques like deep learning, neural networks, and methods i.e. model-based, data-driven-based, and statistical-based, highlighting their benefits in asset reliability and operational efficiency. The challenges discussed include data quality, model interpretability, and costs. The study concludes with future AI trends in industrial maintenance strategies.

INTRODUCTION

Energy is crucial for India's economic growth, the fifth largest economy worldwide. According to the Economic Survey 2024-25, India's GDP growth for the financial year 2025-26 (FY26) is expected to be between 6.3% and 6.8%. India's power sector is driven by a robust supply-demand dynamic. As per the Central Electricity Authority, as of December 2024, India's installed power capacity stood at 462.01 GW. Peak electricity demand is expected to reach 277 GW by 2027 and 366 GW by 2032.

To meet the forecasted demand, health and performance of the power plant will play major role. Equipment of power plant should be capable to manage load factor effectively to align with the fluctuating power demand scenario.

Major critical equipment in a power plant are Boiler, Turbine, Heaters, WHRB (West Heat Recovery

Boiler), CEP, Condenser, Generator, Transformers, Air pre heater, Pulverisers, ID/ FD/PA fans, Boiler feed pumps – both turbine driven and motor driven, CW pumps, etc. responsible for maintaining PLF and efficiency of a plant. During the past, it was found any equipment failure leads to significate implication on reliability, efficiency and economical viability of power plant and generating companies incurred huge losses.

There is a need for new technologies to be implemented in power plants, with a focus on Artificial Intelligence (AI) to monitor critical parameters in real-time and data mining of historic operating data to detect equipment anomalies, providing methodological scientific frameworks and a comprehensive system-based approach for predictive maintenance of equipment.

FORMULATION

Maintaining health of equipment in power plant have significance not only in terms of achieving high level of performance parameters but also for ensuring reliable power to consumers and availability during peak hours. However, Over the years, performance of power plants are deteriorating due to aging factor and poor health of equipment.

There are indices on that basis performance of power plant measures i.e. Plant Load Factor, Planned Maintenance, Forced Outage, Operating Availability, Partial Loss, Reserve shut down etc.

The goal of AI is to enable the use of predictive maintenance, which increases the efficiency and productivity of existing equipment, reduces operation costs, and maintains a high level of operation. Plants achieve these benefits by diagnosing and detecting the condition and performance of the plant through factors such as vibration, noise, temperature and pressure to predict equipment failure.

Pattern recognition is the ability to identify and interpret patterns in data. This essential skill allows humans to make daily judgments, recognize objects, and solve problems by analyzing data for patterns. It can be accomplished either by using algorithms designed to detect specific patterns, or through machine learning, where algorithms train on past data to recognize new patterns.

Leveraging of artificial intelligence techniques like deep learning, machine learning, and neural networks to identify intricate patterns in large data sets. This emerging technology has already led to major advancements in image recognition, speech recognition, natural language processing, and predictive data analytics. The applications of AI span diverse industries and have yet to be fully tapped.

AI based predictive models will be built using historical data for the equipment available in plant information servers. The models will support different modes of operation (startup, shutdown, steady state, etc.) for rotating, reciprocating, and static equipment. The models will have the capability to define criteria to generate alerts based on general attributes like absolute value, rate of change, etc. of system tags. The models will provide predictions of expected equipment and sensor behaviour on a sensor-by-sensor basis for each process, based on current conditions and known history of loads, ambient conditions, and operational conditions. For each alert, the user will be able to investigate the model predicted values, raw process values, and the deviation leading to the alert, on a tag-by-tag basis.

METHODOLOGY

Power plants supply critical energy to society, so ensuring their safe, efficient operation is vital. To minimize shutdowns and costs, modern plants use artificial intelligence (AI) techniques, which fall into three categories: model-based, data-driven, and statistical methods. Despite model limitations, data-driven and statistical AI has expanded to monitor key equipment.

In thermal and renewable power plants, for example, advanced pattern recognition allows for swift, accurate identification and diagnosis of equipment faults. This results in reduced repair times and minimal disruption to power generation. The core methods of APR can be grouped into three main categories: model-based methods, data-driven methods, and statistical methods. These techniques empower APR systems to analyse data, detect patterns, and gain insights that can drive innovation across sectors.

To create modeled estimates and perform other essential functions, AI analysis quantifies the “similarity” between any two data records being compared. These computed similarity values are scalars ranging from zero to one, with one indicating the plant conditions in both records are identical (e.g. temperature, pressure, and flow values). A value of zero shows the conditions are completely different.

Before analyzing a system, snapshots of plant data are collected and stored in a file as “reference data records.” These records cover various system operating conditions to establish a knowledge base defining the system’s characteristics.

After collecting and storing the reference data records, a new “input data record” snapshot of system data is obtained for assessment. The input record is compared to the reference records using an AI similarity operation. Several reference records with the highest similarity and bounded input point values are selected as “nearest neighbor” records. A “recognition matrix” of similarity values between the input and nearest neighbor records is computed. This matrix and the input record are used to calculate “output data record” values for each monitored point, summarizing the system’s status.

The output record is an extremely accurate representation of how the system should be behaving based both on past performance and on current operation. The calculated output values have high fault tolerance because any defective plant input parameters do not significantly bias or affect the computation accuracy. AI utilizes the massive amounts of plant data available today to make real-time decisions that positively impact reliability and performance. By providing early notifications, AI allows more time to plan maintenance and avoid potential equipment failures, enabling personnel to work more effectively and improve performance. While model-based, data-driven, and statistical methods can be used for pattern recognition, data-driven and statistical approaches are often preferred for complex power plant processes. These methods employ machine learning algorithms on real-time data to detect and diagnose faults.

Model-based method utilizes a mathematical model to forecast the expected behavior of the system and then compares it with real-time observations to identify and diagnose faults. However, its effectiveness may be hindered by the need for a precise model, which can be challenging to acquire.

Data-driven methods are utilized to identify correlations between system measurements in order to detect and diagnose faults. These correlations are established by training an empirical model using normal, fault-free data. Subsequently, the estimation residuals of new measurements are evaluated to effectively identify any faults that may be present.

Statistical-based methods, on the other hand, involve the comparison of extracted signal features with the expected normal baseline values in order to make decisions for the AI System. These data-driven and statistical-based approaches have gained significant global adoption across various industries. According to research, the utilization of data-driven techniques, such as deep learning, machine learning, supervised and unsupervised learning, as well as a hybrid approach, has been proven to be effective (Source - https://doi.org/10.1016/j.simpat.2011.01.005).

RESULTS

Application implemented by NTPC

Jyoti Bot

Jyoti Chat-bot simplifies user experience giving quick answers to complex query and assisting in day-to-day work. Leveraging the power of advanced machine learning models and Large Language Models (LLM) Jyoti-Bot offers a more human-like, responsive, and intelligent conversation experience, significantly enhancing user engagement and service efficiency. The Jyoti Chat-bot is a versatile, in-house developed, voice-enabled solution designed to provide comprehensive information across an organization.

The Jyoti Chat-bot integrates various subjects related to power plant. It is acting as a learning tool for new entrants for sap related functions. It offers access to HR related policies by use of LLM thru generative AI and hence makes Jyoti a powerful tool for streamlining access to critical organizational data and serves as a self-learning tool.

Boiler Health & BTL Prediction Application

Boiler Health & BTL Monitoring System is an in-house developed application rolled out to some units of NTPC, which is being used by the OS, Plant Operation and maintenance departments. This system is aimed at monitoring Boiler water wall health and prediction of possible Boiler Tube Leakage due to chemistry/fatigue. The system uses **statistical models** to calculate the damage induced by water chemistry and high fatigue operation (temp and pressure ramps). Salient features of the system are:

1. This system can be accessed anytime, anywhere and from any device authorized within NTPC. The system has been published in NTPC Intranet.
2. System learns the Boiler water wall health from past operation and maintenance on the Boiler.
3. System focuses on water wall damage induced by water chemistry and high fatigue operation and utilized statistical models to learn and accordingly predict next possible Boiler Tube Leakage.
4. System gives Online Boiler Health status – Monitoring in Dashboard.
5. System provides Most contributing parameters affecting Boiler Health since past 7 Days since start.
6. System provides trends of all Boiler Tube Leakage responsible Chemistry/fatigue Parameters for analysis & corrective actions.

Drones based Monitoring for Structural health, Ash Dyke, Solar Panels and Boiler Internals

- Detection of hotspots, cell failure, Interconnection failure, melting of solder, degradation of the solar cell etc.
- Detect/predict when the cleaning required based on fouling.
- Correlating the visual information to actual data in dashboard.
- Identification of distress in Ash dyke, if any (Type of distress and it's location).
- Balance capacity available in Ash dyke (Including water ponding area)
- Level of ash in Ash dyke.
- Digital Elevation Models (DEM): Digital Terrain Models (DTM), Digital Surface Models (DSM) – 3D models

CONCLUSION

Artificial Intelligence (AI) technology has evolved significantly over the past few years. Power generation utilities have actively implemented AI systems in power plants to enhance efficiency and reliability. NTPC will see considerable performance improvements from implementing Boiler Health Monitoring and Boiler Tube Leakage (BTL) detection systems. These AI technologies enable better prediction of boiler tube leaks.

To improve the Performance of Boiler Health Monitoring and BTL Systems following are recommended wrt PI server Data

- Changing the weightage parameter in the BTL Model.
- Availability of PI Server & PI Data.
- Monitoring Health checkup of PI Tags and removal of redundant PI tags from the system by site committee in placed.

Other areas of power plant for AI play significant role i.e. Drone Video Analytic in Solar Power Plant, Monitoring of Soiling Losses, Ash Dyke Monitoring using Drone Video Analytics, Detection of fault in Photovoltaic Panels, Demand Load Forecasting, Management of Smart Grid, safety etc.

In the growing power sector, power generating utilities faces numerous challenges, including efficient energy management, fault detection, asset monitoring and management, and reliability of power plant in the changing scenario. Advanced pattern recognition techniques offer promising solutions to these challenges by enabling the extraction of valuable insights from complex data generated by power plants.

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Application of AI in Grid Stability

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Er Uday Shankar Baral *completed B. Tech. (Electrical) from Techno India, Kolkata in 2008 and successfully executed GIS Project digitizing the transmission network of DVC. He has valuable 14+ years of experience in Electrical Power Transmission sector, adept in formulating and finalizing contracts and execution of capital renovation and augmentation projects in outdoor substations within scheduled deadlines. He is skilled in Problem Solving, adaptability, time management, handling pressure, critical thinking and possess good leadership quality in project execution and implementation.*
His area of present work involves Design, contracting, inspection and ensuring retrofitting of Capital Substation equipment in DVC, currently executing R&M projects, new 220kV Tr. Lines construction Projects and other capital projects of DVC. He is winner of Talent Championship award of Top Ten in DVC in 2016. He has also worked as Field Operations and Panel Engineer in Reliance Industries Limited

I. Abstract

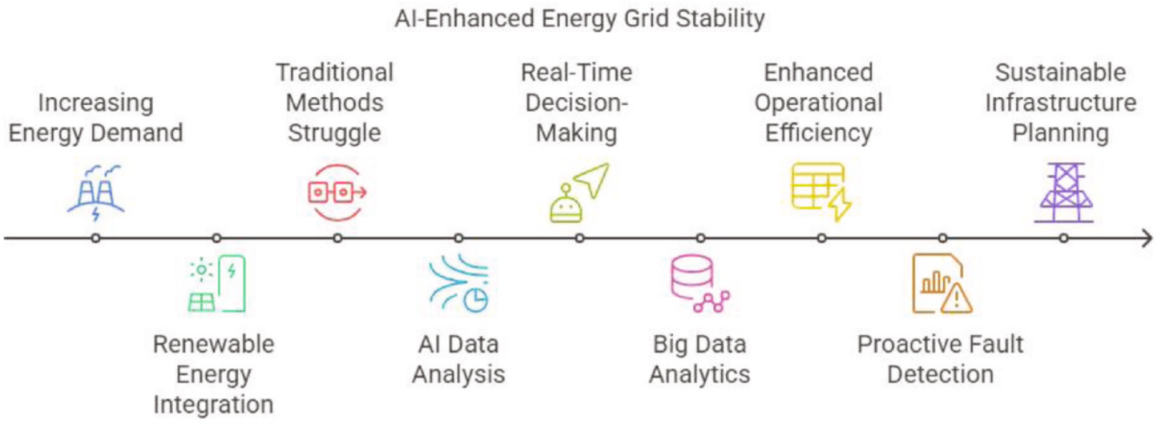
The transmission and distribution (T&D) networks are critical for ensuring reliable electricity delivery; therefore, the health of transmission lines and associated equipment plays a crucial role in maintaining grid stability. With the continuous access of power electronics, increased penetration of EV infrastructure, HVDC transmission lines, and new energy generation in the smart grid, the dynamic characteristics of the power grid are becoming increasingly complex, and Artificial Intelligence technology provides a new solution for the analysis, insight, and regulation of the smart grid.[1] This essay will explore the various applications of AI in maintaining grid stability, highlighting its significance in not only improving operational performance but also supporting the transition towards a more sustainable energy future.

II. Introduction

The increasing complexity of power grid systems necessitates innovative solutions to ensure stability and reliability in the face of fluctuating demand and the rise of renewable energy sources. Artificial intelligence (AI) has emerged as a transformative tool in addressing these challenges, facilitating advanced predictive analytics, real-time monitoring, and automated decision-making processes. As the integration of diverse energy resources becomes more commonplace, the potential for disruptions grows, making the need for robust stability mechanisms imperative. AI technologies, such as machine learning algorithms and neural networks, can analyse vast amounts of data from sensors and smart devices, enabling grid operators to predict outages, optimize energy distribution, and enhance overall efficiency.

III. Overview of grid stability and the role of AI in modern energy systems

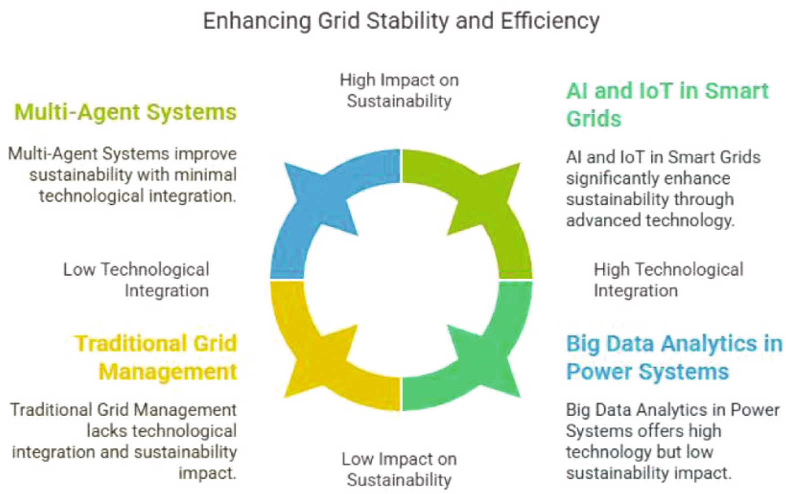
The stability of modern energy grids is critical for ensuring reliable electricity supply in an era marked by increasing demand and renewable energy integration. Traditional grid management methods often struggle to cope with the complexities introduced by variable energy sources and dynamic consumption patterns. Here, artificial intelligence (AI) plays a transformative role by enhancing grid stability through advanced data analysis and real-time decision-making.



As shown in the diagram, AI algorithms utilize vast datasets to optimize grid operations and improve forecasting accuracy, thereby facilitating more resilient infrastructure planning.[2] Moreover, big data analytics, a subfield of AI, addresses the limitations of classical methods by efficiently processing extensive data generated from IoT devices and sensors within the grid. This capability not only enhances operational efficiency but also enables proactive fault detection and real-time adjustments, ultimately supporting the integration of decentralized energy resources and promoting sustainability.[3]

IV. AI Techniques for Grid Monitoring

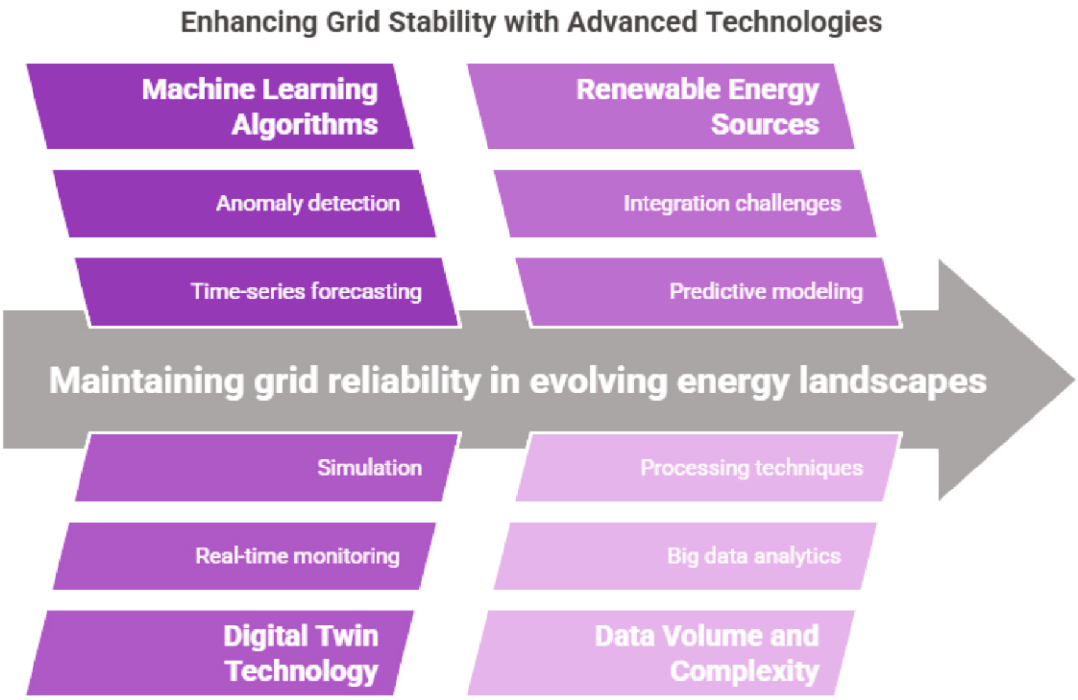
The integration of artificial intelligence techniques in grid monitoring represents a significant advancement in ensuring grid stability and efficiency. By employing multi-agent systems technology, grid components operate autonomously, allowing for real-time interaction and adaptability to changing conditions. This loose coupling of agents enhances the resilience of the smart grid, facilitating better management and responsiveness to fluctuations in energy demand and supply.[4]



Furthermore, the application of big data analytics within power systems enables the extraction of meaningful insights from vast datasets, addressing the complexities associated with traditional methods that often struggle to cope with the volume and variety of data present in modern grids. As noted, "Smart grids use IoT sensors to manage and monitor energy consumption and reduce waste". Similarly, smart energy management, waste reduction, and enhanced public transportation are all vital components of creating greener, more efficient urban environments." (Samudrapom Dam). Such techniques are imperative for developing more sustainable urban energy environments while simultaneously bolstering the stability of the electrical grid.

V. Machine learning algorithms for real-time data analysis and anomaly detection

The integration of machine learning algorithms into real-time data analysis and anomaly detection is pivotal for enhancing grid stability in contemporary power systems. As the shift toward renewable energy sources introduces variability and complexity, traditional methods falter under the weight of large data volumes, leading to inefficiencies and inaccuracies in power management. Machine learning, particularly through big data analytics, offers sophisticated techniques to process and analyze these extensive datasets more effectively. By employing time-series forecasting and anomaly detection methods, these algorithms can identify operational inconsistencies and predict potential failures, ensuring a responsive and adaptive grid environment.



The emergence of Digital Twin technology (Digital Twin technology creates a duplicate model, which is the virtual replica of the physical object and resembles the original object providing us with continuous monitoring, analysis, and optimization using data from sensors, IoT devices, and other sources, therefore creating an accurate, dynamic representation of the physical entity) further amplifies these capabilities, facilitating real-time monitoring and simulation that generates actionable insights for operators.[5],[6] Thus, harnessing these innovative approaches is essential for maintaining grid reliability and optimizing overall performance in evolving energy landscapes.

VI. Predictive Maintenance and AI

The adoption of predictive maintenance powered by artificial intelligence (AI) is crucial for enhancing the reliability of power grids, particularly as they integrate renewable energy sources. By leveraging data collected from IoT devices, AI can predict equipment failures before they occur, leading to significant reductions in downtime and maintenance costs. This proactive approach is essential for managing the fluctuations associated with renewable energy, such as those witnessed in solar photovoltaic systems, which require consistent operational stability despite variable energy input.[7]. Furthermore, the ability of AI to analyze vast amounts of data allows for improved fault detection and more efficient grid operations, thereby ensuring a robust infrastructure. As noted, Machine learning presents a promising alternative by enabling efficient, non-destructive assessments, illustrating how these technologies foster innovation in maintaining grid stability while sustaining operational efficiency ("Machine learning presents a promising alternative by enabling efficient, non-destructive assessments. By providing reliable insights into how filler content and testing conditions influence SEC performance, this model supports the development of advanced tribological coatings for engineering applications." (Soham Nandi).

VII. Utilizing AI for forecasting equipment failures and optimizing maintenance schedules

The integration of artificial intelligence (AI) in forecasting equipment failures and optimizing maintenance schedules represents a significant advancement in enhancing grid stability. By leveraging machine learning algorithms, operators can analyze vast amounts of operational data to predict potential failures before they occur, thus minimizing downtime and maintaining service reliability. For instance, through real-time monitoring and predictive analytics, AI systems can identify patterns that precede equipment failure, thereby facilitating timely interventions. As noted in research, digital technologies substantially improve infrastructure design and forecasting accuracy, which is critical for effective grid management.[8] Additionally, with the evolving landscape of solar energy production, AI can optimize the synchronization of maintenance operations with energy market conditions, ensuring that equipment is serviced when it least impacts power generation and aligns with demand fluctuations.[9] Consequently, this proactive approach not only enhances operational efficiency but also supports the overall resilience of power distribution systems.

VIII. Conclusion

The integration of artificial intelligence (AI) into power grid management is revolutionizing how energy systems maintain stability, particularly in the face of increasing demand and variable renewable energy resources. By employing sophisticated algorithms and machine learning techniques, AI enhances the ability to predict energy loads, manage distributed generation, and optimize the integration of renewable sources, ultimately bolstering grid resilience. These systems can analyze vast amounts of real-time data to identify patterns, forecast fluctuations, and trigger adaptive responses that mitigate risks of blackouts or instability. As AI technologies continue to evolve, their potential to automate routine tasks and provide strategic insights will likely advance further, fostering a future grid that is not only more efficient but also capable of self-healing. The implications of these advancements extend beyond mere stability; they hold the promise of a more sustainable and adaptable energy landscape, essential for addressing the challenges of climate change and energy security.

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Applications of Artificial Intelligence in Electricity Distribution Utility's Systems

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Joined CESC Limited in July, 1983 and retired as Dy GM (Planning), in 2022; Presently working as Consultant to the Company.

Worked in the area of electricity distribution planning, regulatory affairs, capex budget - planning, monitoring and control, project execution / management.

Involved in consultancy jobs for reform activities of distribution utilities in key Indian States and abroad in association with global professional services companies.

Experienced in policy making and policy advocacy towards smart grid initiatives (Smart metering, Solar PV integration, Battery Energy Storage System, Microgrid), Demand Side Management, Energy audit, Electric Mobility etc.

Imparting training on Distribution network planning, Regulatory, Renewable Energy integration, EV integration, Smart metering, Demand Side Management etc. to electricity distribution personnel in India and abroad

Published papers and presentation made in various forums – CEA, IEEE and Institutions, Business Chambers etc.

Introduction:

Distribution is the most critical segment of the electricity business chain. Making the distribution segment of the industry efficient and solvent is the key to success of power sector reforms and provision of services of specified standards.

Key challenges in electricity distribution are- reduction in distribution losses, procurement of power at competitive rate, managing load interruptions, providing quality supply, easier/ faster grievance redressal, meeting customer expectations and managing costs.

Electricity distribution is becoming more complex primarily due to the increasing integration of distributed renewable energy sources like solar panels, which are decentralized and can feed power back into the grid, creating a more dynamic and interconnected system compared to the traditional centralized model of power generation; this, along with growing demand for smart grid technologies and consumer-level energy management, adds layers of complexity to the distribution network.

Artificial intelligence (AI) can be applied to address the challenges by detecting electricity theft/unauthorised consumption, accurate demand forecasting, enabling predictive maintenance, optimizing grid operations, detecting faults rapidly, improving power quality monitoring, and providing customer-centric services and managing distributed energy resources through data analysis.

Demand / generation forecasting with AI tools:

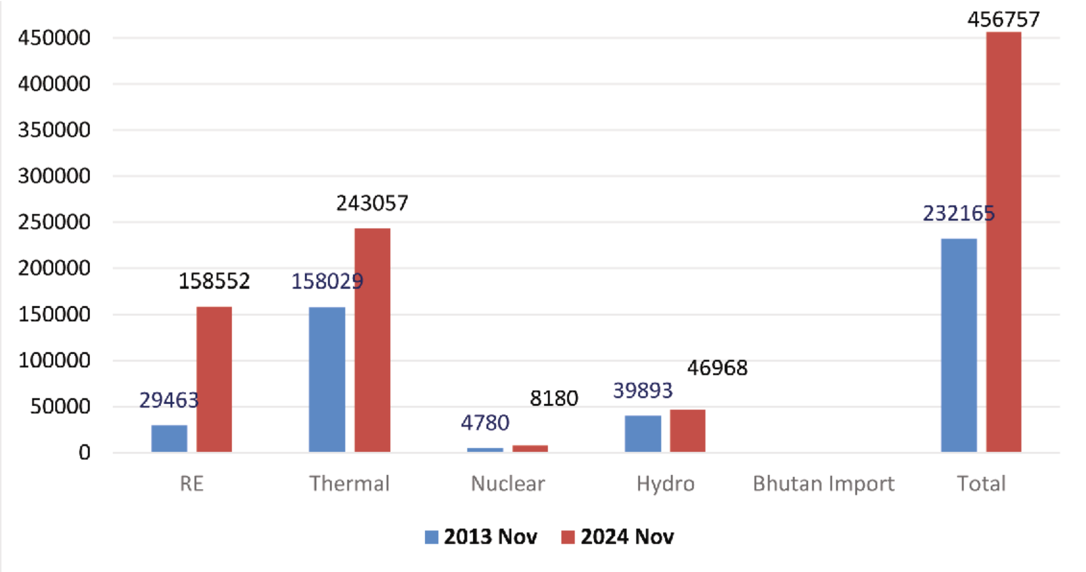
AI for demand forecasting uses its abilities to process and analyse huge volumes of real-time as well as historical data and take into consideration many other variables, like economic indicators, customer behaviour, and weather conditions to generate highly accurate energy demand forecasts.

Since generation from Solar and Wind is contributing a large portion to the overall electricity sector, accurate forecasting of electricity availability from Solar and Wind sources has become very important. AI-powered forecasting typically uses machine learning algorithms trained on large datasets that include: – Historical solar output data: The performance of solar panels over time under varying conditions. - Weather data: Temperature, humidity, and cloud coverage, Wind speed, as applicable.

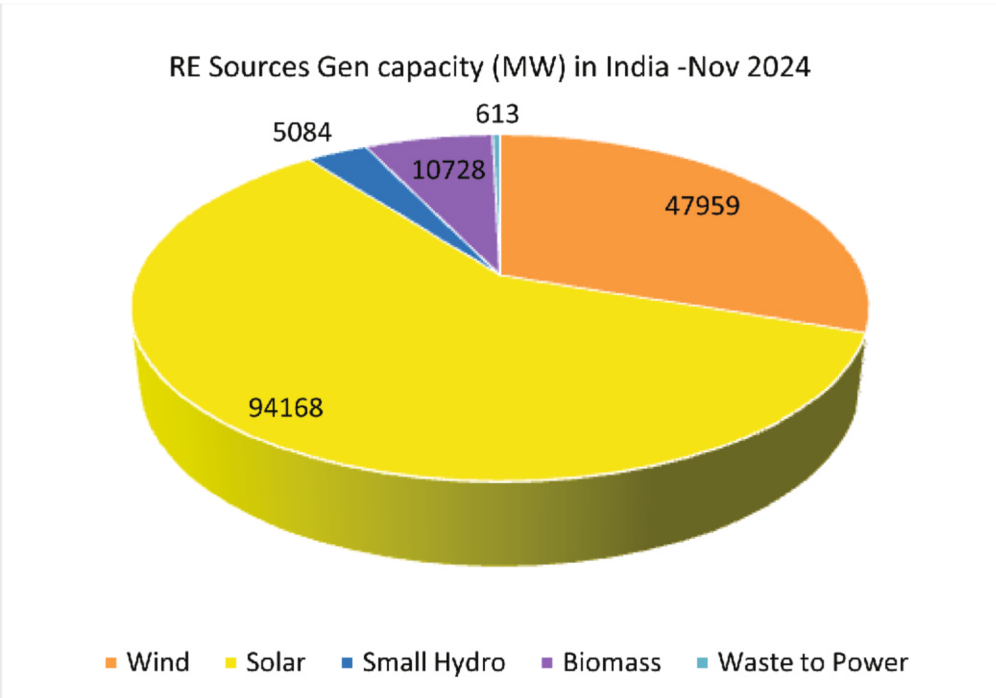
Power sector in the entire world is witnessing major changes. Growth of power sector in India in recent years has been noteworthy. Energy demand coupled with emphasis on renewable energy (RE), the sector has become complex.

As per the Central Electricity Authority (CEA) estimates, by 2029-30, the share of renewable energy generation would increase from 18% to 44%, while that of thermal is expected to reduce from 78% to 52%. The CEA also estimates India's power requirement to grow to reach 817 GW by 2030.

Electricity generation capacity (MW) growth is depicted below in last decade.



Largest contribution in capacity growth is from RE sector. Majority of RE Sources are Solar and Wind.



There is urgent need for timely integration of Solar and Wind capacity to achieve global decarbonisation goals. Policies are framed to promote such sources. Prices of electricity from Solar and Wind is competitive and on lower side comparing to the electricity from non-renewable energy sources.

As, Wind and Solar resources are dependent on weather conditions and aren't constantly available and predictable, they're referred to as intermittent energy resources. Wind and solar power plants, unlike coal and natural gas power plants, cannot be scheduled to deliver specified amounts of power at specified times. Wind and solar power plants generate electricity when the energy resources—the wind and sun—are available. The availability from wind and solar poses challenge for power system operators.

Till penetration of large-scale wind and solar sources into power system, conventional sources are designated to follow the load curve. Load from consumers is generally uncontrollable, generation (Coal, natural gas etc.) are controllable. Wind and solar being uncontrollable sources (must run power plants), load-generation balancing is becoming a critical issue.

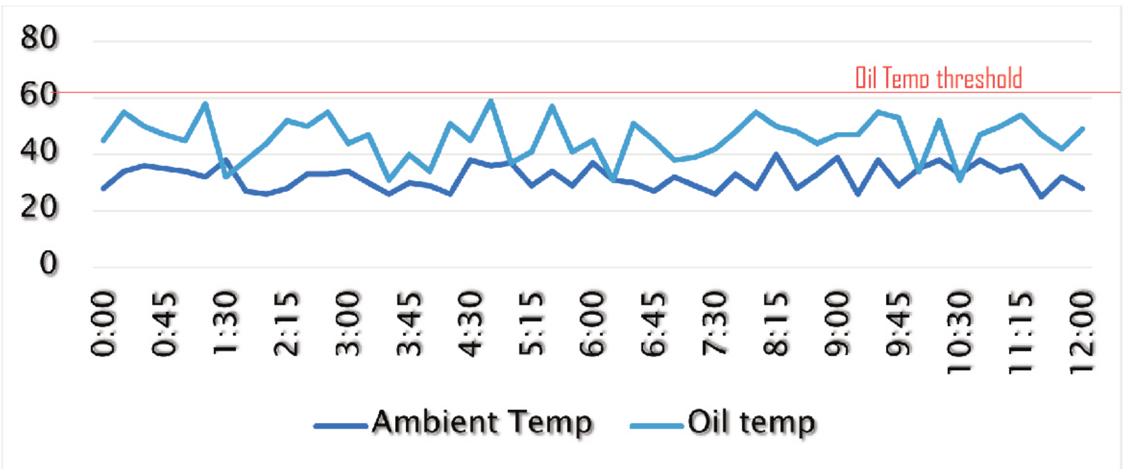
This is why companies are putting significant effort into finding creative ways of applying Machine Learning and Artificial Intelligence in electricity utility, especially working on finding ways to accurately forecast energy consumption, and the performance of renewable sources.

Predictive Maintenance with AI tools:

A common application of artificial intelligence in the industrial sector is predictive maintenance, alongside condition monitoring. AI algorithms analyse historical data from sensors on electrical equipment to predict potential failures. This proactive approach allows utilities to perform maintenance before issues arise, minimizing downtime and maintenance costs. Electricity distribution grids are becoming more decentralized operating near their operational limits. Remote IoT (Internet of Things) sensors are employed to collect data on Current, Voltage, Ambient temperature, Box temperature, Oil temperature, Oil level, Ambient humidity, Box humidity, Dissolved Gas, Moisture content, Partial Discharge (PD) data etc., helps identify the early stages of insulation failure, allowing for timely interventions that can prevent complete breakdowns. Machine learning (ML) and deep learning (DL) techniques are used in PD diagnostics for detection, localization, and recognition. AI can generate automated alerts for maintenance personnel based on predictive insights.

Vegetation management, particularly for overhead lines can be effectively done with AI-enabled systems with vast number of videos and images. Utilities are already taking advantage of drones and high-definition videos. Such information is always not structured and it is difficult for humans to process in a reasonable amount of time. AI model can augment human expertise.

Models are trained to recognize normal operating conditions. For example, AI can continuously monitor the oil temperature of a transformer, quickly identifying deviations that may indicate issues, allowing for timely intervention.



Energy Theft/Unauthorised use Detection with AI tools:

AI systems analyse usage patterns to detect anomalies that may indicate energy theft. This helps utilities to minimize losses and ensure fair distribution of energy. Overall transmission & distribution losses in India are more than 20%, whereas, World average is about 10%. Various analysis suggests that majority of electricity distribution loss in India is due to theft and/or unauthorised use of electricity from utility network. Higher distribution losses directly impact financial health of electricity distribution companies. The accumulated losses of distribution companies and power departments in our country are Rs 6.48 lakh Cr. One of the major reasons for such high revenue losses is energy theft and/or unauthorised use of electricity from utilities.

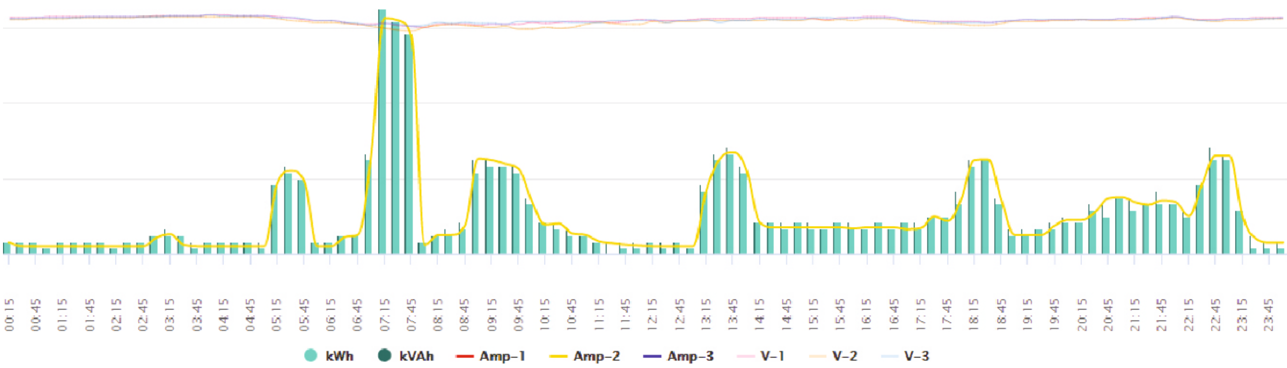
Revamped Distribution Sector Scheme (RDSS) has a nationwide Smart Meter program under implementation, by Government of India. 250 million conventional meters will be replaced by smart meters across the country. One of the main objectives is to reduce the AT&C (Aggregate Technical & Commercial) losses to pan-India levels of 12-15%. Till date about 20 million smart meters have already been installed in various utilities. Smart meters data analytics are proposed for: -

- energy audit that will provide automatic feeder loss report (HT Feeder Head reading minus summation of all DT meters readings and HT Consumers, if any); Automatic LT Energy loss report (DT meter reading minus summation of readings of all those LT consumer meters served by the selected DT) etc.
- tamper alert that will check consumption and compare (daily / seasonal variation…) and filter out suspect cases

AI-based theft detection can drill down to the premises level, discovering theft patterns in behind-the-meter energy consumption to find tariff misuse, direct theft, meter tampering, and other non-technical loss.

Consumption data over days:

Consumption in a day:



AI processes data from smart meters in real time to detect inconsistencies. Machine learning can classify normal usage versus potential theft. A machine learning model can be trained on historical energy usage data to recognize legitimate patterns, allowing it to flag suspicious activities such as energy bypassing.

AI systems can analyse patterns of energy data and check whether the consumption is for the purpose (whether domestic/commercial…), as categorised in the bill. Consumers having supply as domestic but using for commercial purpose can be checked by analysing pattern of energy consumption.

AI systems can proactively identify defective meters with smart meter data.

Improved Customer Service with AI tools:

AI-driven chatbots and virtual assistants provide customers with real-time information regarding outages, billing inquiries, and energy usage. This significantly improves customer engagement and satisfaction.

AI in Call Centres is emerging as a pivotal innovation, offering a way to revolutionize how utility providers manage customer interactions and communications during crisis period. AI-driven analytics offer deep insights into call patterns, customer concerns, and potential operational bottlenecks. These insights can enable utility companies to continuously refine their customer interactions, ensuring high-quality service.

AI can enhance customer engagement by providing tailored recommendations based on energy usage patterns. Virtual assistants and chatbots can be used to address customer inquiries, guide energy efficiency decisions, and promote demand-side management programs, encouraging consumers to participate actively in energy conservation.

Customers have energy choices today, and they want to save money. They also demand more real-time information about their power usage—how much it costs them to charge their EV fleet (or battery in the case of a single consumer) or how much energy their solar panels are producing. This is where AI can be particularly helpful by gathering this data and proactively advising customers on energy usage in predicted off-peak hours, so customers can charge those EV batteries at a lower rate and avoid tariff shock.

Using AMI data for AI applications:

Advanced Metering Infrastructure (AMI) is an important part of modernising the utility industry and using artificial intelligence (AI) may considerably improve its functioning. AI is very useful in data analytics and predictive modelling. AI algorithms can rapidly handle and analyse the huge quantity of data provided by smart metres, allowing for the discovery of consumption habits, trends, and abnormalities.

AI improves client interaction and billing procedures inside the AMI ecosystem. Customers can better understand and control their energy use thanks to AI's personalised insights. Automated billing solutions powered by AI improve operations, lowering mistakes and increasing overall client happiness. As a result, incorporating AI into Advanced Metering Infrastructure is a game-changer for a smarter and more efficient, and responsive energy environment.

RDSS scheme, as mentioned above, is targeting installation of 250 million smart meters in the country. Such meters are capable of providing Voltage Current, Energy consumption data for each 30-minute interval of every consumer. There is huge potential of AI applications, apart from theft / unauthorised detection, with large volume of data in the area of load forecasting, customer segmentation, peak load management, network planning, enhancing customer service etc.

GoI has approved a scheme - PM Surya Ghar: Muft Bijli Yojana on 29th February, 2024 to increase the share of solar rooftop capacity and empower residential households to generate their own electricity. Under the scheme, the residential consumers get Central Financial Assistance (CFA) for installation of RoofTop Solar PV (RTSPV) Power Plants and the target is to reach 10 million households by March 2027. With acceleration of RTSPV integration into electricity distribution system, there is opportunity to leverage AI for such energy transition. AI can predict the impact of RTSPVs on the grid including the impact of voltage and reliability. This information can help to ensure that the grid is able to accommodate such sources without any problems. There may be need, in future, to optimise their operation to ensure that they are working in harmony with the grid.

Challenges:

The use of AI in utilities sector is not without difficulties. To begin, adopting AI systems and connecting them into present structures incurs large upfront costs. This cost can be prohibitive for certain utility firms, particularly those with tiny budgets.

Second, the utility industry handles a large volume of sensitive data, such as grid information, consumer information, and operational details. The security of this data is critical, and AI systems must be secured against cyber-attacks and breaches.

Furthermore, there is a scarcity of educated AI workers that understand both the energy industry and AI technology. This lack of experience can hamper the widespread use and growth of AI solutions in the sector, making it critical to invest in education and training to close the gap.

Way forward:

Overall, the integration of AI in electricity distribution systems leads to enhanced operational efficiency, reduced costs, improved service quality, and a greater ability to manage a transition towards a more sustainable energy future.

The applications of AI in electricity distribution are vast and varied, fundamentally reshaping how utilities manage energy distribution. From improving operational efficiency to enhancing customer experience and ensuring grid reliability, AI technologies present exciting opportunities for the future of energy management. As the energy landscape evolves, leveraging AI will be crucial in addressing the challenges of increasingly complex, decentralized, and renewable-driven energy systems. As utilities continue to invest in AI-driven solutions, the potential for improved sustainability and resilience in electricity distribution will only increase. AI in power sector is complicated and fast growing, necessitating a workforce with specific skills and knowledge in machine learning, data science, cyber security, computer programming, regulatory compliance and power system. The integration of artificial intelligence) with utilities represents a turning point in the energy sector's evolution.

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AI for Boiler Risk Assessment

Er Boben Anto Chemmannoor
ExactSpace.co, Co founder and Director

Er Boben Anto Chemmannoor started his journey initially from NTPC, worked in feasibility study of many projects for Design & Engineering. He has vast experience in O&M, evaluation of projects, conducting PGT, R&M, Gas Plants. He Joined RAG, Germany and worked in 40 countries. He has started a start up to develop perfect industrial application of AI in the field of Power, Cement, Steel, Aluminum Industries, Water solution & Defence sector.

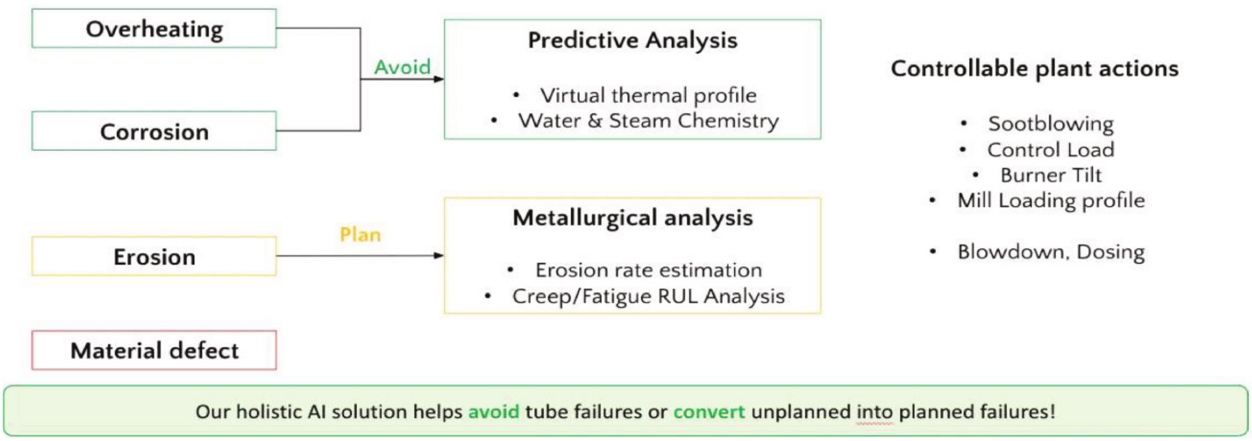
1. Boiler Risk Assessment

Boiler Tube Leaks have been one of the most disruptive issues faced by thermal power plants, especially in the recent past, given the flexible operations requirements. With fluctuating load, the stress on boiler pressure parts is elevated and we've observed that prolonged periods of stressful operations leads to an eventual tube failure.

Boiler Tube Failures occur majorly due to one of the following causes: Overheating, Corrosion, Erosion or Material Defect. A lot of discussions in the AI sphere has been around accurately predicting time or location of a possible failure. However, after looking into data of atleast 100 different tube failures over the past years, ExactSpace believes that there is a strong role for AI to play in improving boiler operations that can definitely help in reducing the number of BTLs and increasing the MTBF.

2. BTL Avoidance vs Prediction

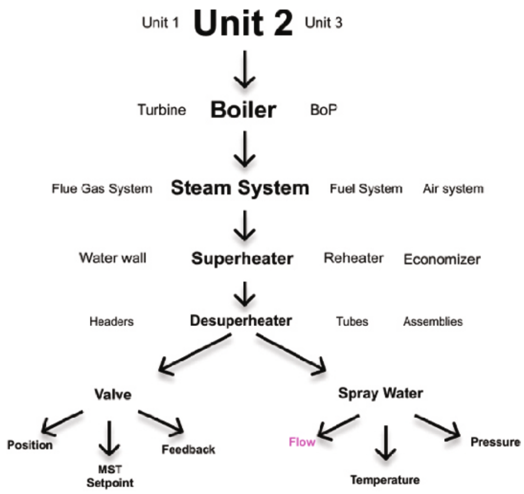
Tube failures could be due to any of the following reasons (Overheating, corrosion, erosion and material defect). Our philosophy is to reduce the periods of 'high-risk' boiler operations and eventually reduce the occurrences of failures. AI for Boiler Operations



This entails avoiding failures due to overheating and corrosion and be able to manage the risk due to erosion (cannot be entirely avoided). Failures due to material defect/weld joints are erratic/abrupt and cannot be predicted or controlled.
This is quite different from BTL prediction/detection where a system gives an early indication of a possible failure – in these cases, one is not actively trying to reduce the stressful operations but only planning for an eventual shutdown.

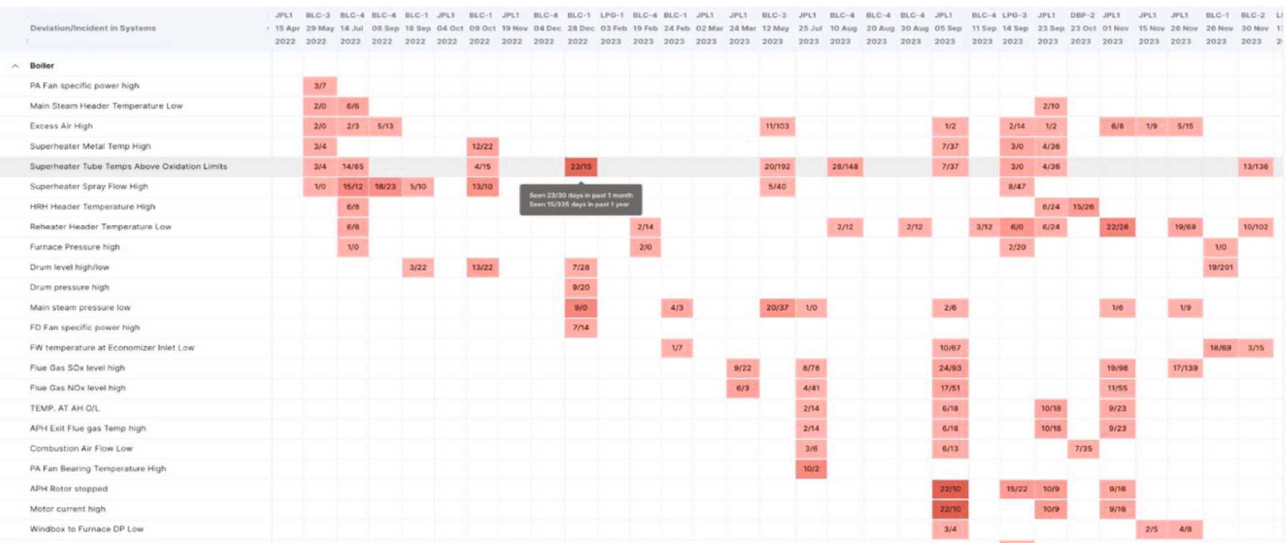
To address overheating and corrosion, we help with the following:

I **<u>Learning from the past</u>:** Over the past 5 years, we've observed around 100 tube leaks across 50+ plants. This covers varied boiler sizes, fuel, combustion types, different reasons and locations of failures. Put together without context, this is just a heap of numbers which could not possibly tell a coherent story. However, as part of Pulse, we ensure standardized contextualization of data to start with (like giving varied sensor tag IDs standard hierarchical description like below).



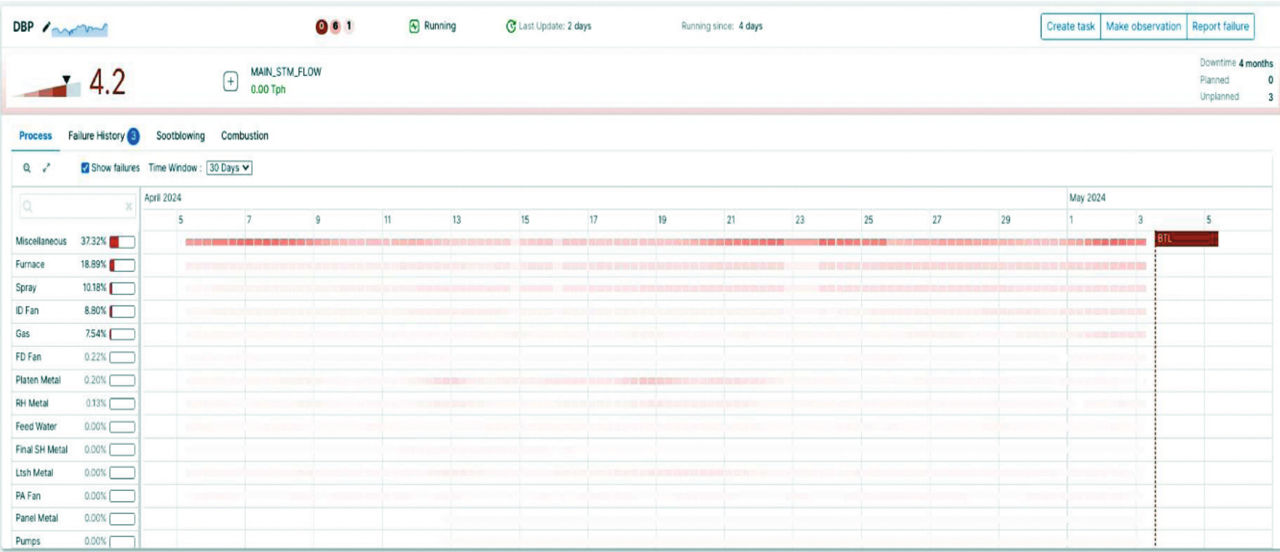
And, gradually, these failures had multiple recurring patterns. This led us to collectively looking at failures in similar boilers under a common analytical engine which analysed patterns rather than data – patterns of parameters in the days and weeks leading up to the failure, novelty of such patterns and similarities with other boilers. This became the most powerful AI exercise

we've undertaken to create a map of such patterns.



ii. <u>Risk Computation</u>: Once the BTL pattern map is in place, we build a super-set of multi-variate predictive models (around 200-250) for the major parameters of a boiler. These models help with identifying abnormalities in individual parameters which are used to compute section-wise risks (like Furnace, Platen SH, LTSH, APH, ID Fans, etc) using additional components like degree of deviation, duration of deviation, rate of change, similarity to a past failure pattern, etc. This eventually leading us to a Boiler risk score which is a single number between 1-5. This is a complex task as a boiler consists of upto 1000 sensor signals and finding the right signals in this becomes challenging. This is where our combination of domain and modelling expertise aids a lot.

This risk score helps get an operator's attention to the most deviating section before deciding on the next best action. This also considers changes observed during transients (ramp up, ramp down) or non-adherence to usual guidelines for startup and shutdown (like hp/lp bypass operations, other valves, oil firing, etc).



iii. <u>Metallurgical Study</u>: To address erosion management, we conduct a detailed metallurgical study using tube thickness surveys to identify the rate of erosion and specific tubes that are closer to end of life. This study also includes studying LM parameters and creep/fatigue analysis to help plant identify the most at-risk sections of the boiler.
However, the process of erosion cannot be arrested and related failures cannot be avoided completely. Below is an example of how we perform a detailed metallurgicalassessment for each section of the boiler.

Section	Expected life	Metallurgy	Min life remaining	Max life remaining	% of tubes with at least 15k hours remaining
U1 Platen RH	115893 hr	SA 213 T22	0 hrs	36984 hrs	90%
U1 Final RH	115893 hr	SA 213 T91	0 hrs	67080 hrs	96%
U1 Panel SH	115893 hr	SA 213 T22	2232 hrs	25704 hrs	93%
U1 Platen SH	115893 hr	SA 213 T91	0 hrs	50520 hrs	68%
U1 Final SH	115893 hr	SA 213 T91	0 hrs	54504 hrs	47%
U1 LTSH	115893 hr	Low Carbon Steel	0 hrs	17664 hrs	29%

iv. **Preventive Actions**: Eventually, the operator has the following actions to control the thermal profile in the boiler and bring the boiler in a less risky operations zone. These are provided to the operator as a recommendation using our optimization modules:

a. Sootblowing (selective sootblowing)
b. Mill loading (top vs bottom)
c. Air flow
d. Burner Tilt
e. Blowdown/dosing (to control water chemistry)

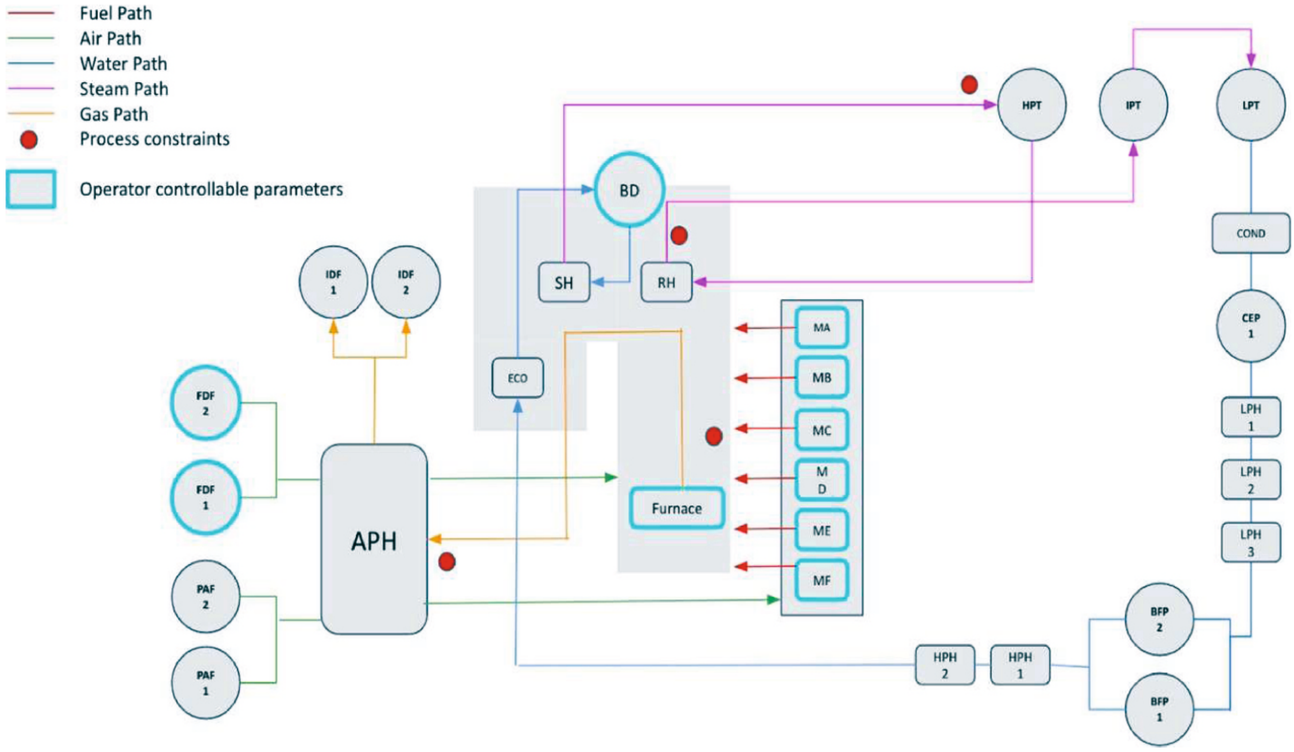
3. Boiler Optimization

Today, most power plants are governed by control systems to automate how the process must react to changes. This is achieved through implementation of control loops. However, the efficiency of a plant or its reliability is still driven by hourly/daily decisions made by operators on critical inputs based on which the loops will respond. Any sub-optimal decisions on these decisions can lead to losses which manifest as increased energy spend, incomplete processing, safety hazard etc.

Boiler optimization helps plant operators make the best decision to achieve a goal (like maximizing efficiency, minimizing overheating, etc) within a constraint (like parameters must be within certain limits).

The optimization engine in Pulse was designed to learn from historic context of complex processes and provide operators with real-time interventions in the form of setpoint recommendations (of controllable parameters) any time the process is deviating from the stated objectives.

Consider a Power Generation plant:



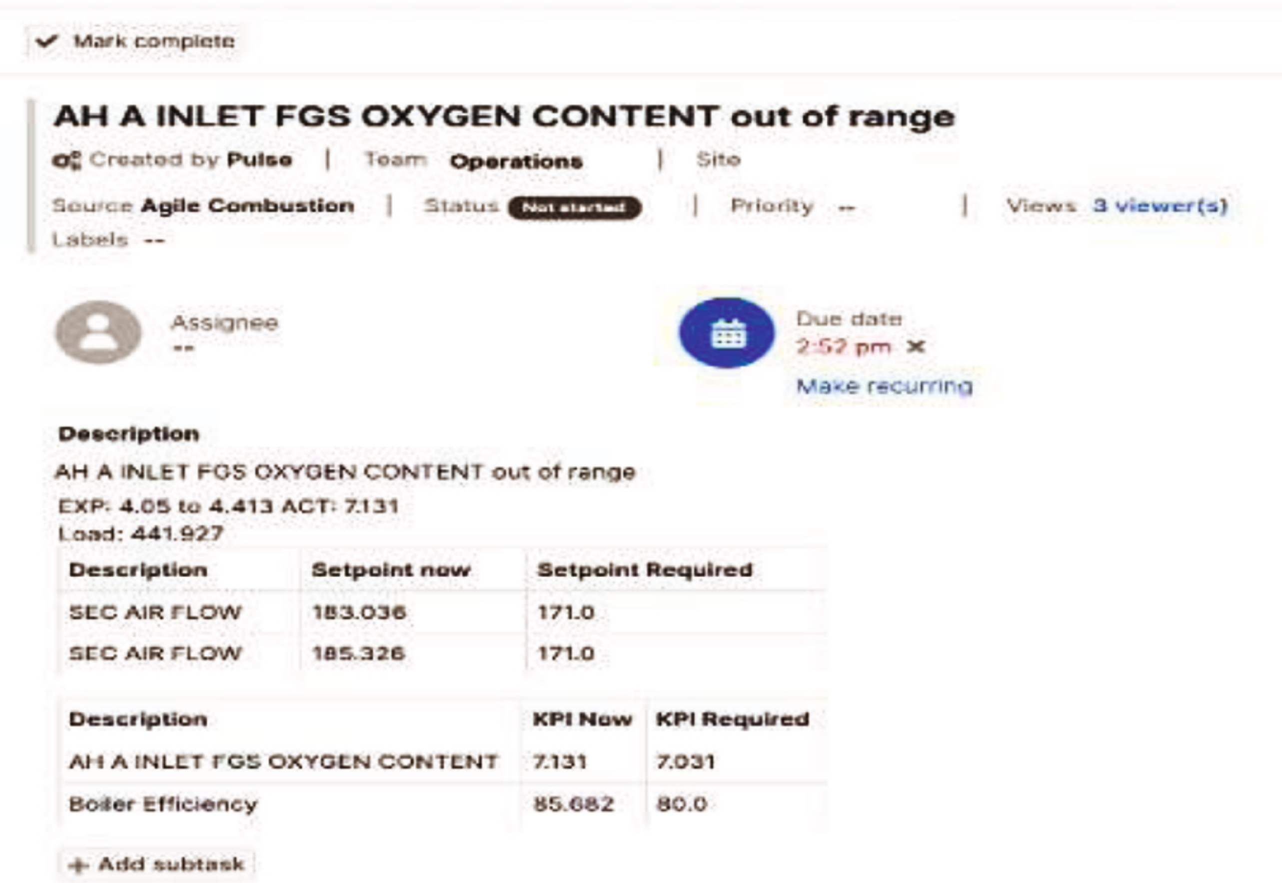
This is one of the more complex industries where there is an interaction between various media like Fuel (solid/liquid), Air (for combustion), Water (to convert to steam), Steam (to convert to rotational energy) and Flue Gas (to exchange heat) covered by 1000+ parameters. Actions in this needs to balance both the performance (efficiency/fuel consumption) and reliability (thermal profile) aspects of boiler operations.

Optimizations available for:

- **Air-fuel**: Volume of air required for combustion, FD Fan blade pitch or damper position to minimize LOI and Dry Flue Gas Losses

- **Fuel loading across all mills**: Depending on the availability of various mills, the ideal combination that would minimize APC consumption while maintaining the required process stability
- **Pressure optimization**: If there is a possibility to control steam pressure to minimize overheating in specific sections, especially during low load operations
- **Sootblowing Optimization**:
  Recommends ideal time and locations for sootblowing based on individual surface heat pick-up while optimizing for the number/frequency
  of sootblowing cycles. This helps maintain the ideal heat profile as well as bring down the flue gas temperature at APH and reducing spray.

The output from the optimization engine is a recommendation as below:



Mark complete

AH A INLET FGS OXYGEN CONTENT out of range

Created by **Pulse** | Team **Operations** | Site

Source **Agile Combustion** | Status Not started | Priority -- | Views 3 viewer(s)

Labels --

Assignee
--

Due date
2:52 pm

Make recurring

Description

AH A INLET FGS OXYGEN CONTENT out of range

EXP: 4.05 to 4.413 ACT: 7.131

Load: 441.927

Description	Setpoint now	Setpoint Required
SEC AIR FLOW	183.036	171.0
SEC AIR FLOW	185.326	171.0

Description	KPI Now	KPI Required
AH A INLET FGS OXYGEN CONTENT	7.131	7.031
Boiler Efficiency	85.682	80.0

+ Add subtask

✔ Completed

Excess Power Consumption Detected

Created by **Pulse** | Team **Operations** | Site

Source **Smart Combinations** | Status Done | Priority -- | Views

Labels --

Assignee
--

Due date
12:39 am ✕
Make recurring

Description

Excess Power Consumption Detected

Current Total Coal Flow: 65.06

Description	Setpoint now	Setpoint Required
COAL FEEDER A FEED RATE	8.041	0.028
COAL FEEDER B FEEDRATE FEED BACK	22.085	23.108
COAL FEEDER C FEEDRATE FEED BACK	22.035	22.632
COAL FEEDER D FEEDRATE FEED BACK	12.07	19.256
COAL FEEDER E FEEDRATE FEED BACK	0.022	0.006
COAL FEEDER F FEEDRATE FEED BACK	0.059	0.03

Description	KPI Now	KPI Required
Total Power Consumed	696.088	523.416

Conclusion:

While the concepts behind the BTL problem is widely established, the technology to marry this with AI techniques, especially around risk scoring in a 'noisy' boiler operations dataset is not very straightforward. This is an area that we have extensively researched over 4-5 years to marry the domain expertise with the right AI techniques to arrive at the 'Boiler Manager' application in the shape it is in today. The output from this has been able to establish a clear potential for using AI to manage BTLs in power plants better.

Concept of Artificial Intelligence for Predictive Maintenance, Operation & Control and Energy Efficient Grid with Smart Decision-making Capabilities

Er Satyendra Kr. Sahoo, Er Uday Shankar Baral, Er Vikas Singh & Er D.N Tripathy
Damodar Valley Corporation

Er Satyendra Kumar Sahoo *is working as Manager (E), currently posted at Transmission Head Office Maithon, Damodar Valley Corporation. He is having 14+ years of experience in Grid Operation and Maintenance department. He has vast experience in substation maintenance & transmission line maintenance work.*

Er Uday Shankar Baral *completed B. Tech. (Electrical) from Techno India, Kolkata in 2008 and successfully executed GIS Project digitizing the transmission network of DVC. He has valuable 14+ years of experience in Electrical Power Transmission sector, adept in formulating and finalizing contracts and execution of capital renovation and augmentation projects in outdoor substations within scheduled deadlines. He is skilled in Problem Solving, adaptability, time management, handling pressure, critical thinking and possess good leadership quality in project execution and implementation.*

His area of present work involves Design, contracting, inspection and ensuring retrofitting of Capital Substation equipment in DVC, currently executing R&M projects, new 220kV Tr. Lines construction Projects and other capital projects of DVC. He is winner of Talent Championship award of Top Ten in DVC in 2016. He has also worked as Field Operations and Panel Engineer in Reliance Industries Limited

Er Vikas Singh *completed PGP in Renewable Energy (UPES Dehradun), M. tech in Integrated Power system (NIT Nagpur), B.E. Electrical. (Mumbai University).An accomplished, dynamic and versatile Electrical Engineer with 11+ years of experience with exceptional project management and technical skills in power sector, especially in the field of transmission line construction from 33 KV level to 440 KV level, erection of sub-station electrical equipment's, operation & Maintenance work of Sub-station. Presently Posted as Sub-Station In-charge at 220/33KV Sub-station, Parulia under GOMD-VI, Durgapur. His research Papers was presented at international conference in "Innovations in the power sector towards sustainable development goals" held in 2023-24 at Kolkata, India organized by DVC, Won DVC Talent Championship Award -2013 on "Green Energy Clean Energy"*

Er D.N Tripathy *is having 13+ Years in Grid operation and maintenance department in Damodar Valley Corporation. He has vast experience in sub-station maintenance & transmission line maintenance work. Currently he is posted at Transmission System Construction wing as Assistant Manager. Earlier he was Working at TATA STEEL, JAMSHEDPUR in Plant Maintenance.*

Abstract:

India is the third largest electricity producer in the world. In-spite of this fact, India is still a developing country, and its electricity consumption is increasing day by day. As per CEA, total installed capacity of India till 31.05.2024 is 417.668GW and still growing. Electricity demand in the country has increased at a CAGR of about 5% during the period 2017-22. During the period 2022-24, electricity demand has increased at a CAGR of about 9.46%. To meet all the objectives, a robust & huge transmission network is required to establish the link between generating stations and load and its maintenance is going to be a key challenge for all utilities working in this filed. Sub-stations at various level plays a key role to meet all consumer goals and grid stability depends on sub-station control and operation. For smooth and energy efficient operation & control of substation, Artificial intelligence can become boon for all of us. However, it is still in progressive stage and with advancement of technology, it will have greater impact. This paper illustrates the key role and benefits of use of Artificial Intelligence (AI) at sub-station level for predictive maintenance, smart decision making, lower down time, less equipment failure and how an AI enabled sub-station can function on their own with smart decision making.

Keywords: grid performance, optimize resource utilization, Carbon Footprint, grid stability, Demand Side Management

1. Introduction:

To ensure the safe and reliable operation of a sub-station it is necessary to keep the HV apparatus in good condition. In the past, this was accomplished through breakdown maintenance and time-based maintenance. As the communication and computer technology improved, condition-based maintenance was made possible through online monitoring system and live measurement instruments. In India many of the power utilities are now a days adapting the online monitoring methods such as installing SAS (Sub-Station Automation System) upgrading conventional sub-stations into smart sub-stations enabling us to gather more online data and communication with master control room for better decision making through continuous monitoring of system parameters. This is the concept of a smart sub-station. However, concept of an AI enabled sub-station is one step ahead. An AI enabled system can take smart decisions on its own to maintain system reliability and automatically raise an alarm or isolate such equipment which is showing signs of any abnormality and adjusting the system to more stable condition.

2. System Architecture Smart sub-station vs AI enable Sub-Station:

Fig-1 illustrates the typical Sub-station automation system with data acquisition and data sharing system enabling users to monitor continuous system parameters which results in better decision making.

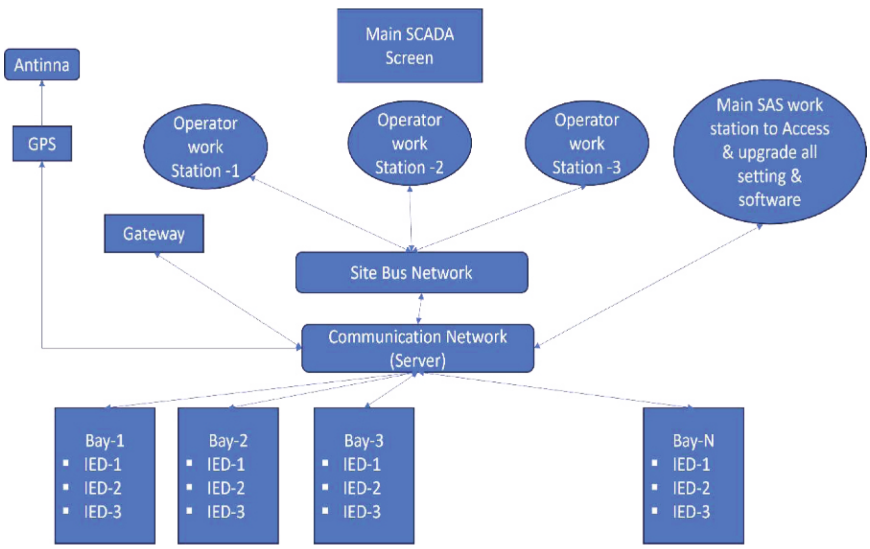


Fig-1. Typical components of SAS automation system & Data Acquisition system

Such architectural system is smart but such a system is only sufficient enough for condition monitoring of equipments and cannot take decision itself. However, it can raise an alarm to alert requiring human intervention for further analysis.

3. AI enabled System Architecture:

Fig-2 illustrates the concept of AI enabled system architecture of Substation. Apart from the sub-station automation system, field sensors provide data of equipment health condition and field parameters and AI image processing and data processing system analyze the data 24*7 and store the data in cloud server for further data pattern analysis thus ensuring minimum equipment failure and down time of equipment and the system is self-sufficient for making decisions thus running the system smoothly with minimum human intervention.

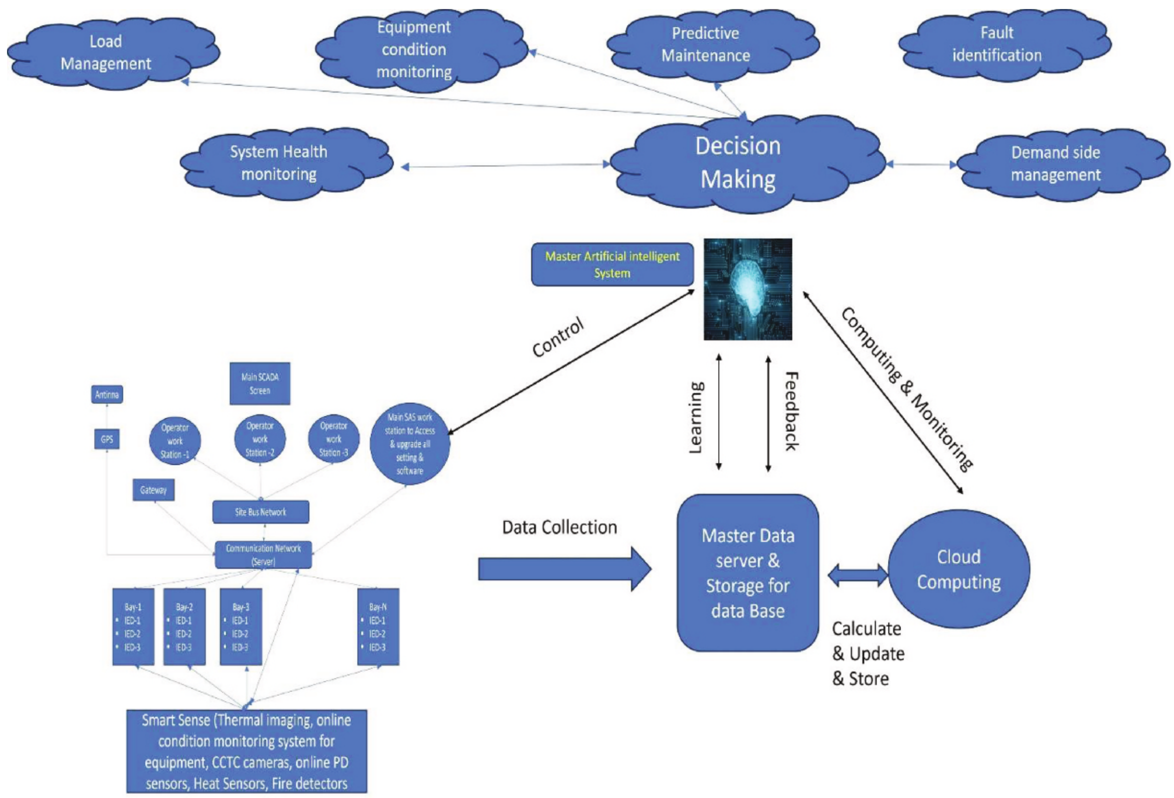


Fig-2. AI Enabled System Architecture

4. KEY Benefits of AI

4.1 Demand Side Management:

Artificial Intelligence based demand side management of power system is a very fascinating idea and has lot of potential which could help us to reduce carbon footprint & fuel consumption. However implementation requires Data collection at each stage of Grid, smart meters with communication and control capabilities at each stage of power system. Fig.3 shows the very basic key structure of Demand side management system with AI where all the smart meters are sending load data to their nearest load distribution network servers and further data is stored and analyzed at master server data base, with huge computational power. The AI system will analyze the data and create load patterns and based on the data governing the load generation and by real time monitoring of load and generation, regulating the power generation through different power stations such as thermal, Hydro, Wind, and solar such an artificial based system could help save millions of tons of fuel by optimizing load and generation at the same time. However, there are lots of challenges like Data collected and transmitted by intelligent infrastructure must be cyber-protected. For the protection of grid infrastructure and consumer data, encryption, access restrictions, and intrusion detection systems are required. Standardization and interoperability are vital to the success of smart infrastructure powered by artificial intelligence. Common protocols and standards enable component integration, interoperability of vendors and stakeholders, etc. Standardization of data formats, communication protocols, and software interfaces is necessary to achieve harmony in the smart grid ecosystem.

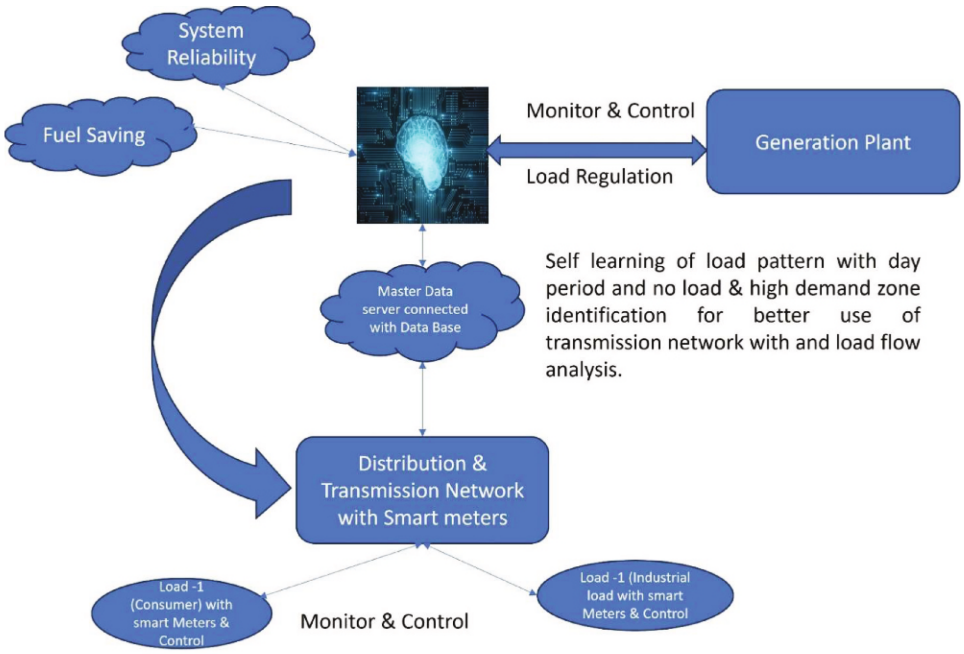


Fig-3. Simple architecture for AI enabled Demand Side Management

4.2 Electrical System condition monitoring using AI:

To ensure the safe and reliable operation of a power system it is necessary to keep the HV apparatus in good condition. In the past, this may have been accomplished through breakdown maintenance and time-based maintenance. As communication and computer technology improves, condition-based maintenance was made possible through online monitoring systems and live measurement instruments. The conventional well-established time-based maintenance method requires removal of the equipment from service; however, the live measurement and continuous monitoring may be carried out directly if online monitoring method is adopted like Equipment condition Based Monitoring (ECM) which can be further divided into four categories:

1. Visual Inspections based fault detection.
2. Any abnormal sound (hearing based)
3. Continuous monitoring of parameters
4. Testing based (Equipment testing either offline or online)

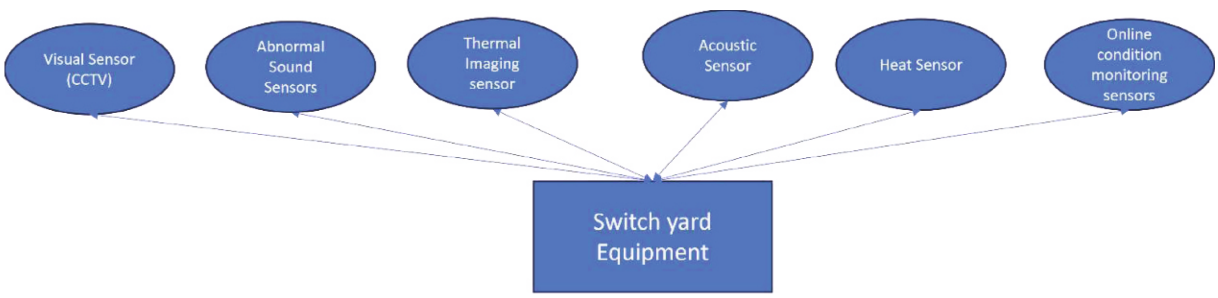


Fig.4- Key steps for equipment condition-based monitoring

By real time monitoring of system parameters along with equipment condition monitoring sensors, AI can detect early abnormality in equipment like hotspot which is very common in switchyard or any other abnormality and AI can take decision of regulating load or islanding the component or diverting the bay through bus coupler which ever solution is feasible and suitable which will reduce down time, equipment failure thus enhancing system reliability and grid stability. The Key challenges are device functions, interfaces, communication protocols are different from company to company. It is difficult to build an online monitoring system based on different companies and different products in one substation

4.3 Fault prediction & Predictive Maintenance:

In conventional smart automated systems, real time data is monitored by humans and data is stored in server however analysis of the gathered data is paramount challenge and creating patterns is even more difficult for humans but an AI based super computer can analyze & compute data since it has the capability of trillions of calculations per second & based on the available data and previous trend, AI can predict fault at an early stage and can take necessary steps to ensure system stability and can raise an alarm for maintenance ensuring minimum human intervention thus no hazardous accidents.

4.4 Other Key Benefits:

AI has the potential to increase the overall efficacy of electric grids. With the assistance of smart infrastructure powered by artificial intelligence, the distribution and effectiveness of energy could ensure a significant transformation. Intelligent smart grids employ innovative sensing and monitoring technology. Distributed sensors and meters collect data on generation, consumption, and other significant characteristics in real time. Data analytics is used to evaluate the efficacy of the infrastructure and identify inefficient areas. Decisions based on collected data regarding load balancing, voltage regulation, and defect detection may enhance the power grid's performance and efficiency. Intelligent grids driven by artificial intelligence (AI) employ prediction and decision-making systems based on machine learning. These formulas analyze historical data to forecast future electricity consumption.

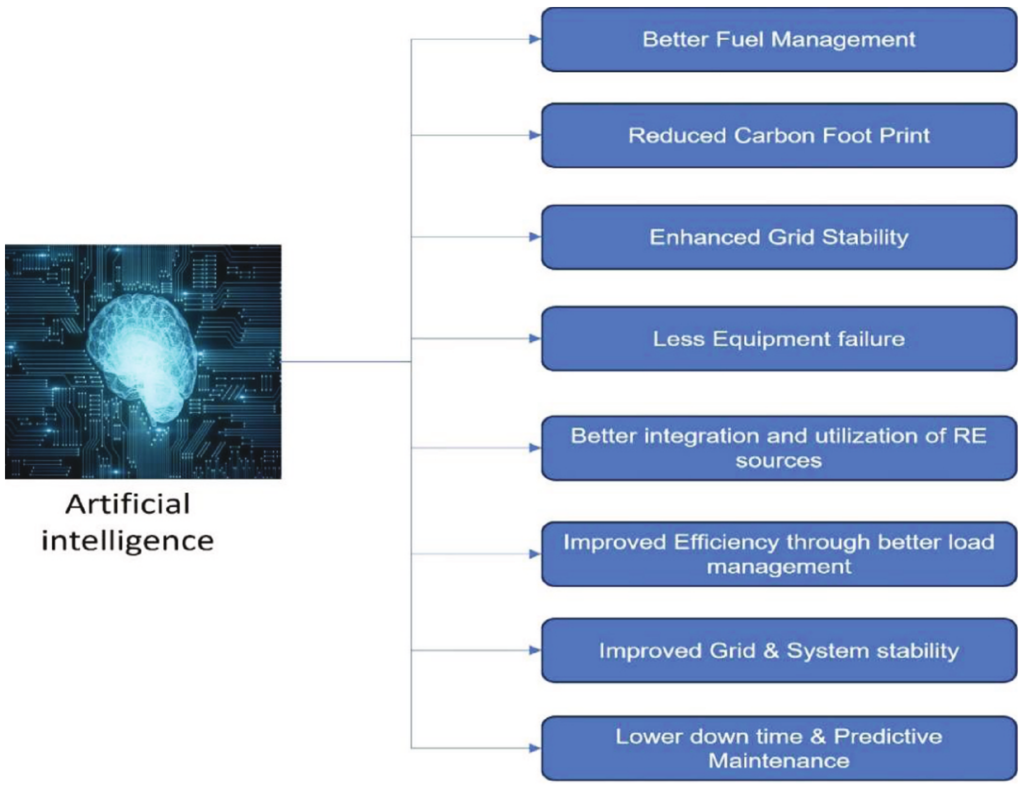


Fig.5- Key Benefits of AI in Power System

AI can enhance energy production and distribution in various ways, including better-anticipating energy demand, reducing reliance on fossil fuels, and enhancing the integration of renewable energy sources. Real-time alterations to energy distribution are made using machine learning to balance the demand and reduce system inefficiencies. The AI-driven efficiency gains of smart infrastructure are only the tip of the iceberg.

Conclusion:

Smart sub-stations have demonstrated many desirable characteristics due to the integration of cutting-edge sensing and monitoring systems, data analytics, machine learning algorithms, and decentralized control mechanisms. High accuracy, efficiency, and cost savings can be achieved by employing AI technology to enhance grid performance, optimize resource utilization, and promote a stable and sustainable energy environment. Several obstacles must be surmounted to guarantee the successful spread of AI-enabled intelligent infrastructure. Among these are concerns regarding data privacy, integration with emerging technologies, standards, deployment complexity, and regulatory frameworks. Smart grids powered by artificial intelligence have the potential to revolutionize the energy sector by enhancing grid reliability, promoting the incorporation of renewable energy sources, and meeting the increasing demand for more cost-effective and environmentally friendly power sources.

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A brief discussion on AI Applications in Thermal Power Plants

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The advancement in information communication technologies has led to the measurement, communication, and storage of the data collected by state-of-the-art sensors installed at various locations of industrial processes. The data stored in supervisory information systems is precious since it contains key information about industrial processes carried out under sustained operating constraints. Artificial Intelligence (AI)-based modelling algorithms are necessary to mine the value out of the stored volumes of data.

Furthermore, AI-driven conclusions drawn from the lab-scale and pilot plant studies are of limited relevance to large industrial complexes since their design space and operation modes are significantly different. Thus, the true potential of AI-based modelling algorithms is critical to be exploited for large industrial complexes like coal power plants to contribute to the solutions of big problems like climate change, net-zero and sustainability. Coal-based power generation systems contribute a major share in the national energy mix of emerging and underdeveloped economies. The transportation and electrical sectors account for the major share of total CO_2 emissions; coal alone causes a significant percentage of CO2 emissions.

Artificial Intelligence (AI) is increasingly being integrated into thermal power plants to enhance operational efficiency, predictive maintenance, and environmental sustainability. Here are the key applications of AI in this sector. Such as **a.** Predictive Maintenance, **b.** Operational Optimization, **c.** Fault Diagnosis and Detection, **d.** Energy Management, **e.** Environmental Impact Reduction,

In the case of thermal power plants already running, AI systems are utilized to predict the remaining useful life of critical components such as turbines, generators, and boilers. By analyzing operational and maintenance data, AI can estimate the time to failure for these components, allowing for timely replacements during planned outages. This proactive approach minimizes unplanned downtimes and optimizes maintenance schedules, ultimately reducing operational costs and improving reliability

AI algorithms analyze real-time operational data to optimize various processes within thermal power plants. AI can optimize the operation of pumps and other equipment based on real-time conditions, ensuring maximum efficiency. Optimization can lead to better fuel utilization and reduced emissions.

AI models can adjust combustion processes based on temperature, pressure, and flow rate data to enhance heat-rate efficiency, and also lead to substantial cost savings in fuel consumption.

AI plays a crucial role in diagnosing faults within power plants. Advanced algorithms can detect anomalies in operational data that may indicate potential failures. This capability is essential for maintaining the reliability of power generation systems.

AI-based systems have been developed to predict boiler trips by analyzing a wide range of operational variables, thereby enhancing safety and performance. AI can predict the remaining useful life of power plant equipment.

AI predicts the remaining useful life (RUL) of power plant equipment through several advanced methodologies that leverage data from sensors and operational logs. AI systems collect vast amounts of data from various sources, including Sensor Data (Continuous monitoring data from equipment sensors, which measure parameters like temperature, pressure, vibration, and acoustic emissions) Operational Logs (historical performance data that document equipment usage and maintenance activities) etc.

AI enhances energy management by accurately forecasting energy demand based on historical data, weather patterns, and economic indicators. This allows power plants to adjust their output dynamically, reducing unnecessary energy generation and optimizing resource allocation within the grid.

Furthermore, AI facilitates the integration of renewable energy sources by optimizing their coordination with traditional generation methods.

AI technologies contribute significantly to reducing the environmental footprint of thermal power plants. By optimizing combustion processes and energy usage, AI helps lower emissions such as NOx and CO_2. For example, digital twins—virtual representations of physical systems—can simulate various operational scenarios to identify strategies that maximize efficiency while minimizing emissions.

In addition to operational improvements, AI systems can assess vulnerabilities in operational technology networks and respond to potential threats in real-time, thereby mitigating risks associated with many factors such as Fire Hazards, Thefts and many other attacks.

Maintaining the energy-efficient and smart operation of the coal power plant can be quite challenging given the coordinated and integrated operation of energy devices from components (pumps, compressors, belts, conveyors etc.) to system level (boiler, steam turbines, generator etc.). The operating space becomes truly hyper-dimensional, and the nonlinearity and interactions among the variables further complicate the management of the power generation. Therefore, the development of accurate first-principle models to such a level of complexity and operational level is difficult and the model-based optimization analysis can be computationally prohibitive. To overcome this problem, data-driven AI-based models are widely deployed by the research community that are computationally cheap to develop and can speed up predictive and optimization analyses. However, the quality of data, selection of modelling algorithm, evaluation of modelling performance and the optimization analysis guided by domain knowledge are the key challenges to exploit the true potential of AI-based models.

Amongst the available modelling algorithms, Artificial Neural Network (ANN) is an excellent functional approximator and can effectively construct the functional mapping between the hyperdimensional input space and the output variable. The algorithm can also mine the nonlinearity and develop the causal relationships among the variables from the volumes of data. The algorithm is computationally inexpensive, requires less memory storage, and can be fed with medium to large-size datasets for model development. These key features of the Artificial Neural Network (ANN) algorithm can deal with the complexity of the power generation operation of coal plants and thus are utilized to model the power production under various generation capacities of the power plant.

In 2013 Mr X. Liu, Mr X. Kong, Mr G. Hou and Mr J. Wang developed a fuzzy neural network for a 1000 MW ultra-supercritical power plant based upon large number of operating variables. The model exhibited good merit of efficacy in modelling the hyper-dimensional power generation operation.

In 2019 Mr H. Zhang, Mr X. Liu, Mr X. Kong and Mr K.Y. Lee developed a stacked auto encoder simulating model for a 1000 MW ultra-supercritical boiler-turbine system. The model exhibited better predictive performance in comparison with the multi-linear regression.

In 2020 many AI researchers modelled the power production operation of a 660 MW plant on the large number of operating parameters using ANN Later on in 2022 they modelled the power generation from a 660 MW power plant by support vector machine and extreme learning machine. The response surface methodology technique was applied to simulate the operating values of the input variables for efficient power production.

In 2021 Mr A. Haddad, Mr O. Mohamed, Mr M. Zahlan and Mr J. Wang performed a multi-objective optimization analysis for the parametric optimization of the coal-based power plant. Genetic algorithm and particle swarm optimization techniques were utilized for the analysis. The utilization of AI-based modelling and optimization analysis for conducting the performance enhancement of a 660 MW supercritical coal power plant is the novelty of this work. The industrial data of the power generation operation is taken and deployed for the development of the ANN model.

In most of the studies focus has been to model the power production from the power plants by AI models. However, the deployment of the model for conducting the plant-level performance analytics and estimating the improvement in the power generation operation is missing. Thus, the true potential of AI-based models for the performance enhancement of coal power plants is essentially lacking in the literature so far available that needs to be investigated and the findings backed by the domain knowledge should be communicated to the industrial community. Furthermore, the step-by-step methodology explaining the details/procedure in conducting the AI-based modelling and optimization analysis on the industrial data should be presented that the industry may benefit from to support the smart operations of their industrial complexes and contributes to the industry for smart operation management.

The determined optimized values of the input variables for maximum power production are verified on the power generation operation which is the main novelty of this work thereby demonstrating the reliability of AI-based modelling and optimization analysis. The improvement in the plant-level performance measures like thermal efficiency and the reduction in emissions (CO_2, CH_4, N_2O, SO_2 and Hg) discharge is also calculated signifying the utilization of the AI model for industrial competitiveness. Moreover, the optimization problem considering the maximum power production and the emissions discharge constraint is solved by the Natural Language Processing technique (NLP is a machine learning technology that gives computers the ability to interpret, manipulate, and comprehend human language) and the maximum power production of the power plant is estimated that is the novel AI model-based analysis to estimate the capacity of the power generation. The operation excellence, performance enhancement and informed decision-making based on AI-based modelling and optimization analysis contribute to the net-zero goal from the coal power plant that constitutes the key novelty of these works depicting the potential of AI model for big industrial complexes.

CONCLUSION

The integration of AI in thermal power plants offers transformative benefits that enhance efficiency, reliability, and sustainability. As technology continues to advance, the role of AI is expected to expand further, driving innovation in energy generation and management practices across the industry.

Can AI & Renewable Energy be a New Power Couple ?

Er J. Chakraborty & Er R. Ghosh

Er Joy Chakraborty is a Renewable Energy Professional working in a state owned company in Kolkata & Er Rima Ghosh is an IT Professional working in a multinational IT farm in New Delhi. Other than their professional works, they do research on climate resilient technologies, energy conservation, renewable energy, AI integration, eclectic mobility and green cooking practices. They have joint publications in such areas of technology intervention.

Climate change is more about real and tangible changes in everyday lives than some catastrophe waiting to happen in the future. The World Health organisation has confirmed that 2024 was the warmest year on record. It was the first year to pass the 1.5 degree Celsius global warming limit. Massive heat waves were witnessed by the people of India and Pakistan. People on Election duty have suffered death. People on daily work on roads died in Delhi in significant numbers. It was the combination of temperature and humidity. It creates long term damages like kidney damage, which may start in the young. Such damages affect the quality and duration of life. Industries ranging from tea to carpets are impacted .In 2024, in many places the average temperature of 40 degree Celsius was for more than 45 days for which the entire value chain was impacted. At least 242 million children in 85 countries had their schooling interrupted last year because of heat waves, cyclones, floods, the UN Children's Fund has said in its latest report in January, 2025. The number of students affected by climate related school disruptions in India last year was 54.7 million. And the effect is more pronounced on poor people. It affects our workforce who cannot work in such hot days. It is much worse for hot countries and hot countries are where poor people live. So, reducing the fossil fuel dependency and enhancing Energy Efficiency and Renewable Energy penetration have become need of the hour to save the human civilisation on this planet earth.

Power systems are becoming vastly more complex as demand for electricity grows and decarbonisation efforts ramp up. In the past, grids directed energy from centralised power stations. Now, power systems increasingly need to support multi-directional flows of electricity between distributed generators, the grid and users. The rising number of grid connected devices, from electric vehicle charging stations to residential solar installations, makes flows less predictable. Meanwhile, links are deepening between the power system and transportation, building and industrial sectors. The result is vastly greater need of information exchange and more powerful tools to plan and operate power systems as they keep evolving. On other hand, AI guzzles electricity — a single ChatGPT query requires ten times as much as a conventional web search. As usage increase, its energy requirement will rise and if demand outstrips supply, the technology's development will be strangled. AI's electricity usage is projected from four Terawatt-hours in 2023 to 93 Twh in 2024— more than Washington State used in 2024.To mitigate such issues, different countries are installing new nuclear power stations, restore abandoned hydro power stations, install Solar Power stations in the land of at abandoned collieries.

While AI holds considerable potential to improve power generation, transmission, distribution and consumption ; the energy sector in both emerging markets and advanced countries continue to face multiple **challenges** in terms of efficiency, transparency, affordability, the integration of RE in power systems.

- While AI Companies have expertise in math and computer science, but they often lack the knowledge needed to understand the specifics of power systems.
- Such systems rely on constant data communication, so a lack of reliable connectivity is a substantial impediment in areas where cellular network coverage is spared or limited.
- The digital transformation of the power grid has made it a target for hackers.
- Integrating different data sources and ensuring representatives given the diversity within the data will be challenging.

AI with Sustainable Energy: can enhance the better choice for consumers & utility

1. Predictive Maintenance: AI-powered sensors can monitor equipment health in a more effective manner, which can reduce downtime and can increase system efficiency. AI optimizes energy storage systems, such as batteries, to maximize efficiency and reduce costs.
2. Enabling more options for consumers' choice: AI algorithms can predict energy demand and renewable energy output, enabling both the consumer and grid management to find most useful solution for using RE. **It can be in grid –interactive mode, it can also be in self combination mode. It can also be a useful combination of the both**
3. Convergence of new energy use pattern: The RTS can be used with storage for electric cooking and EV charging which can be a new era of **green to green transformation** replacing the existing **grey to green transformation.** AI can play a pivotal role in forecasting & integration of availability and optimal use pattern for propagation of such practices.

There has been an imbalance in priorities and therefore, investments in smart meters are more as compared to investments in smart grids. Much attention has fallen on smart meters compared to smart grids. If appropriately used, the smart meter can provide benefits to consumers and distribution companies. Smart grids , by contrast are less about consumers and more about making quick adjustments to ensure electricity flows as efficient as possible, for instance in case of disruption or imbalances due to variable renewable energy penetration. **Advanced AI is both the objective and part of the solution.AI systems can see things which humans do not, as DeepMind A (a leading AI research organization acquired by Alphabet, the parent company of Google, in 2014) has demonstrated when it has successfully reduced energy use for data centre cooling upto 40%. We must take advantage of such capabilities. AI should be deployed to identify and develop new ways to improve data centres' efficiency and can realise the RE potential.**

The path to AI has been marked by unexpected achievements and paradigm shifts. The task now is to harness the sustainable power needed to propel this new era of innovation in a more intelligent and useful manner. On one hand, we have to make the AI systems more energy efficient. On other hand, we have to harness Renewable Energy potential in much effective manner with AI to reduce our fossil fuel dependency and to meet the enhanced energy demand for AI propagation. Our policies, regulations and priorities should be guided by a more informed AI powered mechanism. The integration of AI and Renewable Energy has the potential to be a game changer to transform the energy sector, enabling a more sustainable, efficient, and resilient energy future for this planet earth.

AI-Controlled Real-Time Monitoring Fire Protection System of Coal Handling Plant

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Er Nehali Das *did her B-Tech in Mechanical Engineering from WBUT in 2015. Her specialization is in the field of Engineering Design, Detail Engineering, and Consultancy services in the area of Piping and Static Equipment for Thermal Power plants, Steel Plants, Aluminium Plants, etc. She had good experience in the projects of Fire Detection and Protection systems of various fire-prone segments of the plants.*

Coal handling plants are critical in power generation and other industrial processes that rely on coal as a primary energy source. These facilities handle the movement, storage, and processing of large quantities of coal, which is inherently combustible and prone to ignition under the right conditions. A fire protection system in a coal handling plant is crucial to ensure safety, prevent damage, and minimize downtime. Coal handling plants (CHPs) are indeed recognized as the most fire-prone zones within thermal power plants due to several inherent risks associated with coal. The nature of coal and operational practices create a high potential for fire and explosion hazards.

Coal is highly combustible, and its handling involves significant risks. It can easily ignite, leading to catastrophic events if not managed properly. The fine particles of coal dust generated during handling can create explosive atmospheres. When suspended in air, can form an explosive mixture that is highly flammable, these dust particles can ignite from a spark or flame, causing powerful explosions.

Coal piles can self-ignite due to heat buildup from oxidation processes. This risk is particularly acute in storage areas where coal is piled high and not adequately monitored. Equipment such as conveyor belts and crushers can generate heat through friction. If this heat is not managed, it can ignite coal dust or the coal itself, leading to fires. Faulty electrical equipment can also serve as an ignition source.

Electrical equipment, motors, and mechanical parts that become overheated can serve as ignition sources for coal dust or coal piles. Overheating components or sparks from electrical failures pose significant fire risks in CHPs.

Without a reliable Artificial intelligence (AI) controlled Real-Time monitoring fire protection system, these fire risks can lead to catastrophic fires or explosions, causing damage to equipment, significant production delays, and even harm to humans.

Why Controlled Real-time Fire Protection Systems are Critical in Coal Handling Plants?

Protection of Personnel and Equipment, the complex machinery and infrastructure of a coal handling plant are expensive to repair or replace. Fires can lead to extensive damage to conveyors, crushers, and storage areas. A well-maintained AI-controlled Real-Time fire protection system can mitigate this risk by detecting and extinguishing fires quickly, minimizing equipment damage.

AI-controlled Fire protection systems monitored automated suppression systems, leading to the zero risk of fire spreading, reducing potential downtime, and ensuring continuous operations. Need compliance with Safety Regulations Coal handling plants must adhere to strict safety regulations and standards set by regulatory bodies. These standards require plants to implement comprehensive fire protection systems, including detection, suppression, and emergency response protocols. Non-compliance can lead to severe penalties, legal action, and increased scrutiny from authorities. AI-integrated robust fire protection system ensures that the plant meets these legal requirements and avoids costly fines.

Early Fire Detection and Prevention Coal fires can escalate quickly, especially in the presence of large amounts of coal dust. Fire protection systems provide early detection of fire hazards, allowing operators to take preventive measures before the situation worsens. Modern fire detection systems can monitor key areas of the plant, such as conveyors, transfer points, and storage facilities, identifying potential ignition sources like overheating or friction.

Protection against Explosions In coal handling plants, the fine coal dust generated by the movement and processing of coal can create an explosive atmosphere. A spark or small fire can ignite suspended coal dust, causing a powerful explosion that could devastate the plant. Fire protection systems designed to suppress coal dust fires prevent the buildup of explosive mixtures and reduce the risk of such incidents.

Spontaneous Combustion Mitigation Coal in storage piles is particularly susceptible to spontaneous combustion due to Oxidation, which generates heat, makes to oxidation, which generates heat. When coal storage piles are not regular. When these ignite without warning. Fire protection systems equipped with temperature sensors and monitoring systems can detect early signs of spontaneous combustion and activate cooling or suppression systems to prevent fires from breaking out.

Minimized Environmental Impact Fires in coal handling plants can have a significant environmental impact, releasing pollutants into the air and potentially contaminating water sources. Fire suppression systems reduce the risk of uncontrolled fires, helping to minimize air pollution from smoke and toxic gases. In addition, a properly managed fire protection system can prevent coal waste or hazardous materials from spilling into the environment during fire-fighting efforts.

An effective fire protection system for a coal handling plant consists of several AI-integrated components designed to detect, suppress, and control fires before they become unmanageable. These components include:

Smoke and Heat Detectors/ collapsible Bulb Detectors, Thermal sensors, Linear Heat Sensing Cables, infrared detectors, etc. devices are placed in high-risk areas to detect the presence of smoke, abnormal heat levels, or flames. Early detection helps trigger alarms and allows for swift action to prevent fires from escalating. All the detectors are integrated with the Main Fire Alarm Panel (MFAP) through Local Fire Alarm Panels (LFAP) /Local Control Panels (LCP). All the Panels are AI-integrated.

Infrared and Thermal Cameras: Used to monitor coal piles for signs of spontaneous combustion by detecting unusual heat signatures. Infrared cameras and cloud-based technology detect fires at an early stage, and the company says its system even works in challenging environments. Since the system uses proprietary cloud technology through the MFAP and AI server.

Water Sprinkler/Spray (High-Velocity Water or Medium Velocity of Water) Systems as applicable: Sprinklers/Spray Nozzles are installed in strategic areas such as conveyor belts, crushers, and storage facilities to extinguish fires by auto spraying water or foam after the signal is received from the Detectors. All the integrated deluge valves actuate to suppress fire and shall immediately inform the Main Fire Alarm Panel and AI server.

Automatic Dry Chemical Suppression Systems: For electrical rooms or sensitive equipment, dry chemical systems are often used to suppress fires without causing water damage. The Deluge valves of the Automatic Dry Chemical Suppression Systems are also integrated with the AI-controlled MFAP.

Automatic Carbon Dioxide (CO2) Suppression: CO2 systems can be used in enclosed spaces, such as control rooms, to quickly extinguish fires by displacing oxygen. Automatic Carbon Dioxide (CO2) Suppression Systems are also integrated with the AI-controlled MFAP.

Continuous Monitoring Systems: These systems continuously monitor temperature, smoke, and other fire risk factors across the plant. If a potential fire is detected, the system triggers an alarm, activates suppression systems, and notifies the plant operators.

Emergency Alarms and Evacuation Procedures: Audible and visual alarms must be installed to alert personnel in case of fire. Clear evacuation routes and procedures should be established to ensure the safe exit of all workers.

Auto Dust Suppression Sprays: Misting systems are used to reduce the amount of coal dust generated during handling processes, thus minimizing the risk of coal dust explosions. This dust suppression system is installed beside the Coal Conveyor system as a stand-alone system.

Stand-alone Ventilation Systems: Proper ventilation reduces the concentration of coal dust in the air and helps prevent the buildup of flammable mixtures.

The cloud-based architecture allows the system to detect and communicate real-time alerts within milliseconds to building occupants and first responders if hot spots are detected.

When a hot spot is detected, the AI alerts an operator via voice and text messages or email. The system uses a web browser to display an interactive map that shows exactly where the fire is, allowing employees and first responders to locate the potential danger. First responders receive the map via text or email, can monitor the situation as it develops, and locate the hot spot before a fire breaks out.

The detection system through an intelligent gateway does have an integrated fire suppression system, so it can be used remotely.

Machine Learning Algorithms can analyze historical fire incident data to identify patterns and predict future fire risks. The AI integration allows for the connection of multiple sensors and devices across the facility. By processing real-time data from various sensors, these algorithms can assess the likelihood of fire based on current conditions and alert personnel accordingly. This connectivity facilitates rapid communication of safety alerts to personnel through various channels such as voice/text messages, emails, etc.

Conclusion

Fire protection and detection systems are an essential part of coal handling plants, protecting against the many fire hazards associated with coal storage, processing, and transportation. These systems not only safeguard workers and valuable equipment but also prevent costly production delays, ensure compliance with safety regulations, and reduce environmental impact. By investing in a robust fire protection system, coal handling plants can operate more safely and efficiently, with reduced risks of fire-related disasters. Continuous real-time AI-controlled monitoring of temperature and other risk factors is essential to prevent spontaneous combustion and ensure compliance with safety regulations.

Power Sector Transformation: AI-Driven Innovations with Pulse

Er Boben Anto Chemmannoor
ExactSpace.co, Co founder and Director

Er Boben Anto Chemmannoor started his journey initially from NTPC, worked in feasibility study of many projects for Design & Engineering. He has vast experience in O&M, evaluation of projects, conducting PGT, R&M, Gas Plants. He Joined RAG, Germany and worked in 40 countries. He has started a start up to develop perfect industrial application of AI in the field of Power, Cement, Steel, Aluminum Industries, Water solution & Defence sector.

The global power sector is at a crossroads, struggling with challenges like operational inefficiencies, aging infrastructure, and stringent environmental regulations. As industries work toward greater sustainability and reliability, traditional tools such as thermodynamic models are no longer sufficient. This is where Artificial Intelligence (AI) emerges as a game-changer, offering real-time insights and predictive analytics to address complex industrial needs.

Pulse, an advanced AI-powered platform by ExactSpace, is at the forefront of this transformation. Pulse has redefined how industries approach maintenance, optimization, and decision-making, improving operational efficiency and enhancing asset reliability.

Challenges in the Power Sector

The power sector faces critical challenges that demand innovative solutions:

- **Operational Inefficiencies**: High auxiliary power consumption and suboptimal asset utilization.
- **Unplanned Downtime**: Equipment failures causing significant production losses.
- **Environmental Compliance**: Stricter regulations require reduced emissions and improved energy efficiency.
- **Data Silos**: Fragmented data systems hinder real-time decision-making.
- **Aging Infrastructure**: Outdated equipment leads to higher maintenance costs and inefficiencies.

While valuable for scenario analysis, traditional tools are static, and reactive, and lack the predictive capabilities to manage these challenges effectively.

Pulse: AI-Powered Transformation

Pulse addresses these issues through a unique blend of AI-driven insights, real-time monitoring, and advanced optimization capabilities. Here's how Pulse stands out:

1. Predictive Maintenance and Risk Mitigation

- **Boiler Risk Scoring**: Early detection of potential failures ensures timely intervention.
- **Rotating Equipment Monitoring**: Identifies anomalies in turbines and compressors, preventing costly downtimes.
- **Asset Health Indexing**: A unified view of equipment health for informed decision-making.

2. Operational Optimization

- **Combustion Optimization**: AI fine-tunes air-fuel ratios, improving efficiency while reducing emissions.
- **Soot Blower Optimization**: Automates cleaning schedules, enhancing heat transfer without excessive wear.
- **Energy Efficiency Enhancements**: Minimizes energy wastage in auxiliary systems.

3. Scenario Simulation and Dynamic Modeling

- **Boiler Performance Optimization**: Simulates combustion scenarios for better thermal efficiency.
- **System Balancing**: Combines thermodynamic models with AI for optimal configurations.

4. Centralized and Scalable Operations

- **User-Friendly Dashboards**: Real-time and historical data at your fingertips.
- **Industry Adaptability**: Pulse extends beyond power to cement plants, steel rolling mills, and more.

Use Cases: Pulse in Action

Pulse has demonstrated remarkable success across industries:

- **Power Plants**: Combustion optimization reduces NO_2emissions and boosts efficiency.
- **Steel Rolling Mills**: Predictive analytics prevent cobble incidents, enhancing safety and productivity.
- **Cement Plants**: Kiln operations are optimized for fuel efficiency and reliability.
- **Water Treatment Plants**: Continuous monitoring ensures reliability and energy savings.

Why Pulse Outperforms Traditional Tools

Feature	Traditional Tools	Pulse
Data Input	Manual	Real-Time
Predictive Maintenance	Limited	Advanced AI-Driven Predictions
Operational Optimization	Static Modeling	Dynamic AI Optimization
Flexibility Across Domains	Power Sector Focused	Multi-Industry Applicability
Interfaces	Basic	Advanced User-Friendly Dashboards
Scalability	Restricted	Highly Scalable
Simulation Capabilities	Hypothetical Scenarios	Real-Time and Historical Data Analysis

Stakeholder Benefits

Pulse's AI-driven capabilities deliver measurable benefits to operators, managers, and business leaders-

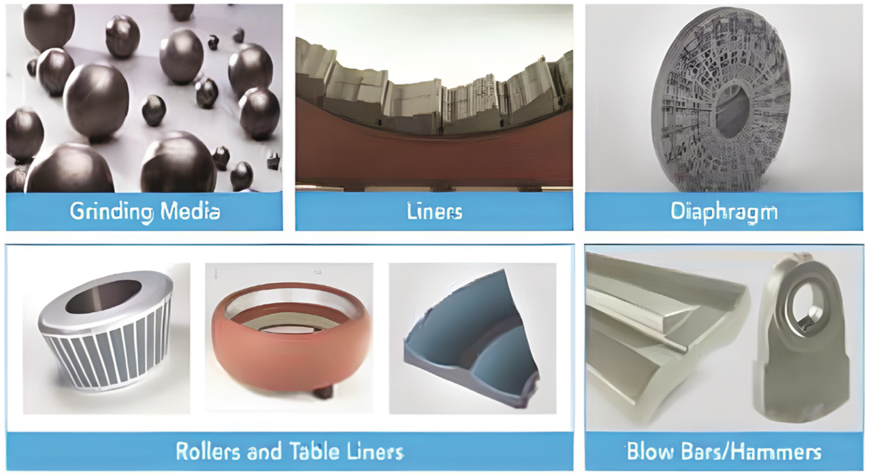
- **Efficiency Gains**: Reduced energy wastage and costs.
- **Enhanced Reliability**: Predictive maintenance minimizes downtime.
- **Environmental Compliance**: AI-driven optimization lowers emissions.
- **Real-Time Insights**: Actionable dashboards empower operators and decision-makers.

Conclusion: Shaping the Future of Industrial Operations

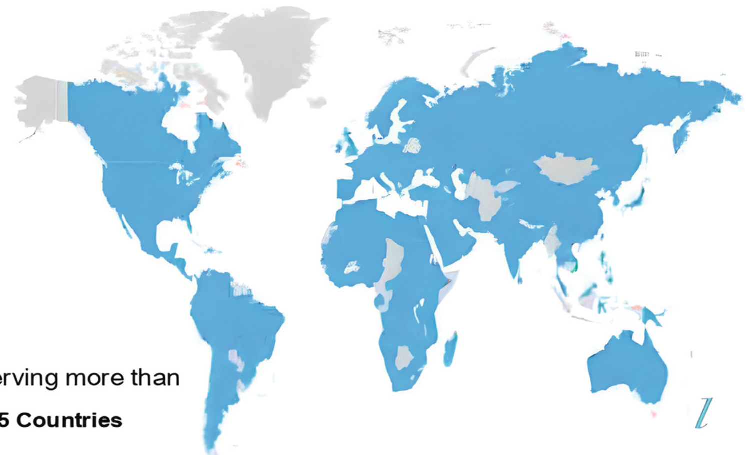
As industries embrace digital transformation, AI platforms like Pulse are revolutionizing the power sector and beyond. By combining advanced data modeling, thermodynamic insights, and predictive analytics, Pulse offers a comprehensive solution to enhance efficiency, reliability, and sustainability.
Whether optimizing combustion in power plants or improving productivity in steel mills, Pulse represents the future of industrial operations. For stakeholders navigating a rapidly changing landscape, Pulse provides the tools to innovate, compete, and thrive.

ExactSpace's Pulse is not just a solution—it's a strategy for sustainable, intelligent growth in the power sector and beyond.

PRODUCT PORTFOLIO
PRECISION ENGINEERED CASTINGS



OUR GLOBAL COVERAGE



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