एनटीपीसी NTPC

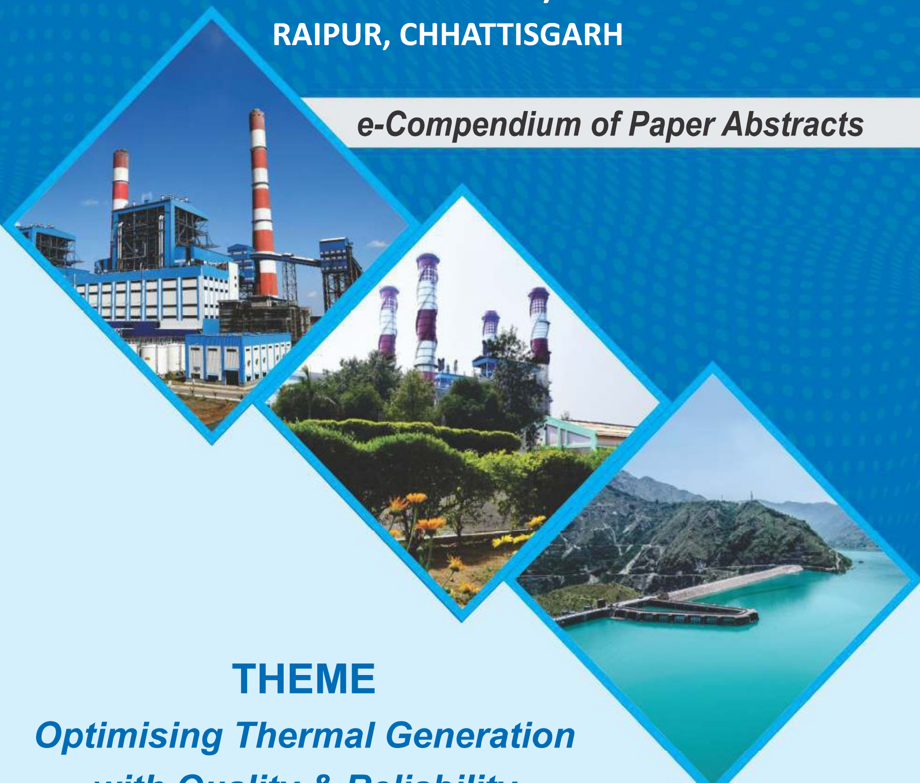
Indian Power Stations 2026

INDIAN POWER STATIONS
O&M Conference
IPS 2026

13th to 15th February 2026

RAIPUR, CHHATTISGARH

e-Compendium of Paper Abstracts



THEME

Optimising Thermal Generation with Quality & Reliability

एनटीपीसी
NTPC

GEM
Girl Empowerment Mission
Giving Wings To Their Dreams

Talaipalli

NSPCL Bhilai

एनटीपीसी
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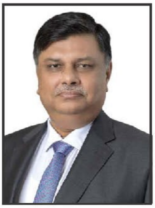

MESSAGE FROM DIRECTOR (OPERATIONS)

NTPC, India's leading integrated power utility with an installed capacity of over 86 GW, continues to reinforce its commitment to building a sustainable, reliable, and secure energy future. While India remains firmly focused on achieving 500 GW of non-fossil fuel-based capacity by 2030, the evolving energy landscape necessitates greater emphasis on efficient, adaptable, and resilient thermal generation, which is essential for achieving India's clean energy goals while maintaining grid stability and reliability.

NTPC organizes the annual International O&M (Operation and Maintenance) Conference every year on 13th February, commemorating the commencement of operations of NTPC's first unit at Singrauli in 1982. In the same context, NTPC is organizing the International O&M Conference (IPS-2026) from 13th to 15th February 2026.

The theme of the conference **"Optimising Thermal Generation with Quality & Reliability"**, highlights the need for optimizing thermal generation while ensuring consistent quality and reliability in the evolving power scenario. The conference invites best minds from India and abroad to deliberate & brainstorm on critical challenges and emerging technologies concerning the power industry. Concurrently, the "Techno Galaxy" exhibition allows vendors and professionals to showcase the latest and the most innovative technologies and solutions.

It is a pleasure to note that this year also, IPS has elicited overwhelming response in paper submission, both national and international. I congratulate all the authors on their invaluable contributions at a time when the power sector stands at a pivotal inflection point, playing a crucial role in accelerating India's economic growth. The NTPC COS team has compiled an e-compendium featuring abstracts of selected papers submitted by these experts. I am confident that this e-compendium will serve as a valuable repository for further research, concept actualization and actionable outcomes that will benefit the industry as a whole.

I once again express my heartfelt gratitude and extend a warm welcome to all authors, paper presenters, delegates from India and abroad. I wish the Conference & Exhibition great success and hope it proves to be a rewarding and enriching experience for everyone involved.

(RAVINDRA KUMAR)

Corprate Identification Number L40101DL1975GOI007966

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बिद्या नंद झा
कार्यकारी निदेशक (ओएस)
Bidya Nand Jha
Executive Director (OS)

नवा रायपुर / Nava Raipur

MESSAGE FROM EXECUTIVE DIRECTOR (OPERATION SERVICES)

It gives me immense pleasure to release this E-Compendium on the occasion of O&M Conference of Indian Power Stations, ***"IPS-2026"***. This conference is held every year from 13^{th} - 15^{th} February, to commemorate synchronization of first unit of its flagship project at Singrauli. I am pleased to know that this year too there is overwhelming response from major players in the industry and foreign entities including CEA, EPRI, IPPs, academia & NTPC stations. I congratulate the selected authors on their valuable contributions. I am certain that the paper presentations will be received well by an enthusiastic audience during the technical sessions.

The theme for current year, ***"Optimizing Thermal Generation with Quality & Reliability"***, is aptly selected since during this crucial phase, the country is seeing unprecedented rate of renewables integration. The coal-based units are facing the challenge of irregular scheduling patterns, while simultaneously providing primary and secondary frequency response through automated mechanisms to ensure grid stability. The gas-based units are also experiencing daily start-stops for additional support during solar transition periods, consuming residual life. While we all share the optimism of a vibrant power sector going green, the need to conserve toiling Thermal Power Plants with due diligence is more relevant than ever before, since they are still the backbone of power sector.

The challenges associated with the above scenario require detailed deliberation and careful consideration, with close attention to every aspect. I am confident that practical and innovative solutions will emerge from this conference through the active participation of delegates, particularly emerging professionals.

NTPC always values its partnership with technology firms in the market, who are striving to improve their products and services for the betterment of industry. ***"Techno Galaxy-2026"*** is an excellent platform for such companies to showcase their repertoire, competing with improved quality enhancing overall safety and productivity. I wish for a successful outcome for this concurrent event also, for both end-users and suppliers.

May this conference trigger renewed commitment to excellence for all participants. I am certain that this compilation of conference paper abstracts will be a valuable reference for budding professionals as well as a decision-support resource for policymakers.

(BIDYA NAND JHA)

Contents

Session – 1:

Optimising Thermal Generation with Quality and Reliability

Flexibilization in coal-based plants: Operational and reliability challenges

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Both flexibility and heat rate are key drivers of thermal plant competitiveness and supporting pillars of energy transformation. Navigating this transformation presents industry with several complex and nuanced challenges, with diverse objectives and varying levels of resources, requiring flexible and scalable approaches. Holistic programs integrating heat rate and flexibility initiatives must include proactive approaches for cost-effectively managing flexible operations and performance associated with a transforming energy system. Power plants designed to operate base load with maximum efficiency are not optimized to operate in varying operational modes. Electricity markets are becoming increasingly volatile, having to respond to greater capacity offered by variable, often non-dispatchable electricity sources. As a result, existing large-scale generators need to be able to operate with variable outputs and more stop-start cycles. This change introduces significant challenges in terms of managing, maintaining, and optimizing across fleets of power plants, both from an engineering and technical viewpoint, as well as from a cultural perspective. This presentation will highlight some of the EPRI related research, tools, and results from benchmarking studies with a focus on thermal generating assets.

Strategies for Optimizing Thermal Generation with Quality and Reliability in Emerging Power Scenario

Biswadeep
PWC

In the study, an attempt has been made to highlight the impact of solar integration in the grid on the thermal loading factor. It has been observed that, without storage, the thermal loading factor may significantly drop below 55% in low-demand months by 2032. This is alarming, as operating the thermal fleet below 55% loading can lead to irreversible damage, which in turn results in an increase in equivalent forced outage.

The study also quantifies the damage cost, heat rate degradation, and auxiliary power consumption (APC) losses associated with a reduction in thermal loading from 55% to 40%. In addition, the impact of SCUC payments made to thermal stations operating below MTL for maintaining grid reliability has been analyzed to assess the true cost of solar integration.

Further, the study highlights the breakeven cost of RE-RTC required for it to achieve parity with the cost of thermal generation, along with the timeline for achieving this breakeven, using a learning-curve-based equation derived from recent RE-RTC tenders awarded in 2025. The Study also highlights the cost comparison between installing the BESS versus Deep thermal flexing up to 40%.

Finally, the paper identifies various strategies for sustaining the thermal loading factor above 55%, while ensuring quality and reliability of power supply in the emerging power scenario.

Analysis of Co-Firing of Biomass in Coal Based Thermal Power Plants: Case Study and Long-Term Implications for India

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This research paper intends to quantitatively analyze the reduction in farm fires/stubble burning, savings of CO_2 emissions, increase in farmers income, renewable energy generated from utilization of biomass pellets through case study utilizing data sets of National Capital Region (NCR) Thermal Power Plants (TPPs). Based on the analysis, projection for NCR is made for timeline for elimination of farm fires, increase in farmers' income, increase in renewable energy generated, savings in CO_2 reductions, and utilization of biomass in NCR TPPs for a decade period. Further, this paper highlights the major challenges faced by stakeholders, infrastructure and market-based recommendations, and long-term implications for India.

SBS Injection™ System for Flexible Operation

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Flexible operation of a thermal power plant means adjusting its power output to match demand, which is necessary to integrate intermittent renewable energy sources like solar and wind. This involves more frequent startups/shutdowns, lower minimum loads, and faster ramping rates, but it can cause increased wear and tear equipment, higher operational costs, and potential damage if not managed correctly.

Key Challenges:

I. SO_3 concentration above 10 ppm leads to high corrosion rates.
II. Low flue gas temperature and flow lead to
  a. Lower APH Average cold end temperature which corrodes APH faster. Currently designing APH maintains the average cold temperature.
  b. Acid Dew shifts to Hot Intermediate layer which is currently lie in cold end layer. HI layer metal temperature and element design to check based on low load conditions.

This paper covers two aspects, first, how the efficient removal of SO_3 and second to maintain the APH average cold end temperature can produce valuable benefits for the thermal power plants.

A. Efficient removal of SO_3
By removing the SO_3 from flue gas, we are eliminating the possibility of acid corrosion.
Quick, efficient removal of SO_3 can provide a host of valuable benefits while successfully eliminating all environmental impacts of sulfuric acid emissions.

B. Maintain the APH average cold temperature
To maintain the APH average cold end temperature for flexible operation, APH elements need to upgrade and use the close channel profile in HI layer. Slight duct modification to achieve the following requirements.

• Temperature increases in Flue Gas Outlet
• Temperature increases in Primary Air

Improving Flexible Operation of Coal-Based Supercritical Units Using A Dual-Boiler Turbine Configuration

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The growing integration of renewable energy into the power grid has compelled thermal power plants to operate flexibly, often at significantly reduced loads depending on grid conditions and time-of-day requirements. Conventional coal-based units face major challenges during such low-load operation-typically around 40% or lower—including the shift of the boiler from dry to wet mode and the need for fuel switching from coal to oil or substantial oil support. These technical constraints make prolonged low-load operation inefficient and operationally unattractive. To address this, BHEL proposes an alternative configuration for 660 MW and 800 MW units, wherein the turbine is fed by two boilers instead of one. This dual-boiler scheme significantly improves operational flexibility, enabling the unit to operate reliably at loads as low as 20% without requiring mode changeover or fuel switching. As flexible operation demands are relatively recent, this configuration is not widely adopted in coal-based supercritical plants and lacks Indian references. This present paper evaluates the potential advantages and inherent limitations of the proposed boiler–turbine arrangement and discusses the solutions to overcome these challenges, thereby demonstrating its feasibility and benefits for utilities seeking enhanced flexibility.

Enabling Flexible Thermal Operations Through Battery Energy Storage Systems

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India's target of achieving 500 GW of non-fossil capacity by 2030 is accelerating large-scale integration of solar and wind power, introducing significant variability and operational challenges for grid stability. Coal-based power plants, which supply bulk of India's electricity, are therefore required to operate flexibly—frequently backing down during solar hours and ramping steeply to meet the demand profile. Such operating regimes lead to frequent cycling, increased thermal stress, efficiency loss, higher emissions, and elevated maintenance requirements.

These challenges are more pronounced in India due to coal characteristics and operating constraints. High ash content (45–50%) in Indian coal limits stable low-load operation, with flame stability becoming a critical concern below 55% Technical Minimum Load (TML), increasing risks of flame failure, boiler trips, and forced outages and undermining plant reliability.

This paper evaluates integration of BESS with coal-based power plants as a practical solution to enhance flexibility and mitigate the impacts of low-load operation and frequent cycling. With present flexibility needs largely in the 2–4-hour range, BESS presents a technologically mature and commercially deployable solution. Co-located BESS can absorb Un-Requisitioned Surplus (URS) during solar and off-peak hours and discharge during peak demand, enabling thermal units to operate closer to stable load levels. The study shows that BESS integration can reduce cycling severity, improve efficiency, reduce emissions, enhance reliability, and support grid stability, positioning BESS-enabled thermal plants as resilient assets in a renewable-rich power system while deferring the need for new thermal capacity solely for peak power requirements.

Session – 2:

Safety in Power Plants

PTW Tracker: Modernizing Industrial Safety with a Digital Permit-to-Work System

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The permit authorizes isolation of "Mill-A Oil Pump B, Unit 1." The operator is standing at the identical "Mill-A Oil Pump B" in Unit 2. Or perhaps he is in the correct unit but mistakes "Mill-B" for "Mill-A" just meters away. He isolates the wrong equipment. The control room has no idea until it's too late.

Industrial permit-to-work systems remain anchored in paper-based workflows that create dangerous operational blind spots. Control rooms lack real-time visibility into field activities, operators can inadvertently isolate or normalize wrong equipment due to identical labelling across twin units, and critical cross-permit conflicts go undetected until accidents occur. This paper presents PTW Tracker, a digital permit verification system deployed at NTPC North Karanpura that addresses these systemic vulnerabilities.

The system introduces three breakthrough mechanisms: (1) Physical Verification through QR code scanning that provides mathematical proof of operator presence at the correct equipment—eliminating location-based errors entirely; (2) Automated Cross-Permit Detection that performs real-time database queries before normalization and (3) Live Status Visibility that replaces 20-minute phone confirmation delays with instant dashboard updates showing task progress.

The system integrates seamlessly with existing SAP workflows while enabling parallel task execution by specialized electrical and mechanical operators—reducing permit completion time by 50-60%. The two-scan verification workflow creates an immutable audit trail, tracking every action with operator identification and timestamps.

The system catches human error at the critical moment before it becomes an incident. Ultimately, everyone goes home safely. That is the only metric that matters.

Smart Shunting-Revolutionizing Locomotive Safety with AI

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This paper presents a safety innovation implemented by NTPC Bongaigaon, the largest thermal power station in North-East India, to address critical hazards in industrial railway logistics. Coal transportation at the plant involves complex shunting activities across a 25KM track network, where limited locomotive visibility and reliance on manual signalling have historically posed risks of accidents and operational delays. Aligning with NTPC's core value of safety, this study details the development of a "Smart Shunting" ecosystem.

The solution deploys two integrated technologies: a Crew Voice & Video Recording System (CVVRS) and a Real-time Cloud-Based Monitoring System (RCBMS). These systems utilise IP-rated AI cameras and edge computing to provide NTPC loco-pilots with real-time rear visibility and obstacle detection capable of identifying humans or track anomalies up to 50 meters away. The initiative, piloted successfully at NTPC Bongaigaon, has effectively mitigated blind spots during coupling and reversing, reducing the reliance on ground staff. A pilot implementation demonstrated that this cost-effective solution successfully mitigates human error, secures coal assets, and optimises rake turnaround time. Furthermore, the paper outlines NTPC Bongaigaon's roadmap for scaling this technology using private wireless networks for cloud-based remote monitoring, demonstrating a low-cost, high-impact model for industrial rail safety. This innovation not only mitigates accident risks but also reduces demurrage, establishing a new benchmark for railway safety that is now being replicated across other NTPC facilities.

Transforming Maintenance at Heights: A Safer, Smarter Approach

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Maintenance at heights within Coal Handling Plants (CHP) presents persistent safety and access challenges. This paper presents a case study of painting high-rise conveyor structures at IGSTPP, APCPL, where IRATA -certified rope access methods replaced conventional scaffolding and man-lifters. The initiative improved safety, reduced costs, accelerated deployment, and enabled access to geometrically complex areas with minimal operational disruption. We outline triggers, qualification and contracting strategy, procedures (planning, rigging, rescue readiness), comparative analysis versus conventional methods, learnings, and application potential across thermal power plants. Incident trend analysis over five fiscal years and cost-benefit estimates reinforce the need for structured adoption of rope access for high-rise maintenance.

Integrated Digital safety compliance and PTW Platform

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PRAHARI is a transformational digital Permit-to-Work (PTW) and safety compliance platform designed to modernize safety governance at NTPC power plants. Built on the foundational principle of “No Compliance, No Permit,” PRAHARI integrates contract management systems, worker compliance databases, permit workflows, and real-time safety monitoring into a unified ecosystem. The platform leverages AI-enabled risk assessments, automated checklists, and real-time safety scoring to shift NTPC’s safety management from manual, EIC-centric verification to digitally enforced, data-driven accountability. This paper outlines PRAHARI’s architecture, key features, technological innovations, and the significant benefits it delivers to NTPC’s operational efficiency, worker safety, and regulatory compliance.

Session – 3:

Generator & Electrical Systems

Utilizing Data Analytics for Predictive Maintenance of 200MW Generator Rotor Brush Gear Assemblies to Prevent Unit Outages Caused by Fire or Sparking Incidents

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Sparking and fire incidents in generator rotor brush gear assemblies are primarily caused by worn or misaligned brushes, improper brush pressure, contaminants, and excessive current. Even when these factors are addressed, uneven current distribution can lead to localized overheating in specific zones of the brush gear assembly. If the temperature exceeds the threshold limit, it can result in fire or sparking. To address this, we employed thermography to detect these high-temperature zones and developed a five-step model using data analytics for precise preventive maintenance. The model involves: (1) digitizing brush gear thermography data from registers & notebooks, (2) conducting comparative analysis across three units with similar systems, (3) employing mathematical modelling to identify temperature abnormalities, using qualitative thermal measurement techniques to calculate threshold values, (4) creating an automated VBA-based alert email system to notify team members of abnormalities, and (5) planning maintenance activities based on the identified anomalies.

Implementation of this model at NTPC Farakka & NTPC Dadri has provided valuable insights into permissible temperature variations in brush gear assemblies. The automated alert system ensures concise and targeted communication of abnormalities, enabling predictive maintenance to prevent recurring high-temperature conditions in identified zones.

Generator Transformer Fault Gases Analysis - A Case Study

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Generator transformers (GTs) are critical capital equipment and high value assets in power stations. Any failure of GT can lead to equipment damage, generation / financial losses and extended restoration time due to long replacement/procurement time. Early and accurate fault detection is essential to ensure system reliability and asset longevity. Conventional protection schemes such as differential protection, restricted earth fault (REF) and Buchholz relays provide reliable protection during major/severe faults, detection of incipient and slowly developing faults remains a challenge.

This paper presents NTPC's operational experience, analysing and predicting the cause of fault in generator transformers based on dissolved gas analysis (DGA), which measures fault gases concentration in transformer oil, and electrical parameter i.e. current flowing through GT. The proposed methodology improves early fault identification, safeguard high value asset from failure/damage, enhances decision-making for planned maintenance and reduces Maintenance cost and time. Case study from NTPC Vindhyachal super thermal power station (VSTPS) is discussed to demonstrate the effectiveness of the approach.

From Failures to Frameworks: Standardized Seal Oil System Guidelines for Hydrogen-Cooled Generators

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Seal oil system reliability is a critical determinant of operational safety and performance in hydrogen-cooled turbogenerators. This paper presents a multi-unit diagnostic study of recurrent seal oil failures across three high-rating generator units (210–660 MW), where repeated disturbances were observed immediately after synchronization and post-overhaul commissioning, leading to severe oil ingress, unstable differential pressures, high seal oil flows, and substantial oil accumulation in liquid level detectors, ultimately causing multiple forced outages and significant generation loss. In early 2025, a 210 MW hydrogen-cooled generator experienced repeated seal oil disturbances immediately after synchronization, leading to severe oil ingress and multiple forced outages, despite prior seal ring replacement and end-shield leakage rectification. The unit exhibited unstable seal oil flows, reduction in Main Oil Tank (MOT) level, and significant oil accumulation in the Leakage Level Detector, while another unit suffered catastrophic leakage within hours of post-overhaul commissioning, collecting nearly 180 liters of oil in four hours and resulting in a prolonged outage and substantial generation loss. Additionally, repeated failures over several years in a third unit, culminating in extensive white-metal wear, revealed chronic misalignment of the seal body with the end shield, collectively indicating systemic maintenance- and alignment-related deficiencies rather than isolated operational events. What initially appeared as isolated operational anomalies were found to be systemic failures driven by contamination in the seal oil circuit, improper overhaul and clearance practices, geometric misalignment of seal components, and missed or non-functional alarms; The paper outlines the diagnostic methodologies employed, lessons learned, and actionable recommendations for design improvements, precision overhaul practices, and predictive monitoring strategies to enhance generator reliability and prevent catastrophic seal oil failures.

Virtual Machine-Base Substation Automation System: A Practical Solution for Rapid Restoration and OEM-Independent Operation

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Substation Automation Systems (SAS) is the digital backbone of switchyard, enabling real-time monitoring, control, protection, and event analysis. Although conventional SAS architectures—including IEC 61850 process bus–based systems—have proven reliable, their rigid, hardware-centric design increasingly limits long-term viability. Tight coupling of hardware, operating systems, databases, and OEM tools results in hardware and OS obsolescence, long restoration times, cascading upgrades, strong OEM dependence, and rising cybersecurity and lifecycle costs, ultimately reducing flexibility, resilience, and sustainability.

This paper presents a Virtual Machine (VM)–based SAS as a practical solution to these challenges. By decoupling SAS applications and operating systems from physical hardware, virtualization allows legacy, OEM-certified systems to run unchanged on modern servers. Hosting SAS functions as virtual machines enables rapid image-based recovery, easy hardware refresh, and restoration within minutes, while maintaining performance and functionality equivalent to conventional systems.

The paper validates this approach through a real-world VM-based SAS case study of Talcher-III. Comprehensive testing confirms full functional performance, cybersecurity compliance as per SAS requirement, IEC 61850 process bus compatibility, and precise time synchronization, with no operational compromise. A practical migration pathway and key technical precautions are also outlined in this paper. The results establish VM-based SAS as a future-ready, resilient, and cost-effective foundation for next-generation substation automation.

Session – 4:

Steam Generator and Aux. Systems

First Posiflow Benson Boiler Got Another 20 Year New Life

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In May, 2002 the 300 MWe Unit No 1 at the 30-year-old Yaomeng Power Plant, in the People's Republic of China, (PRC), completed its 168-hour consistency run following the refurbishment of the boiler. This was a very significant milestone both for Mitsui Babcock and the power generation industry alike, the culmination of a retrofit programme in which the boiler was converted to use low water mass flux, vertical ribbed tube, once through boiler technology, and a world first for its application in the field of commercial power generation.

The benefits delivered by this technology include better thermal efficiency, a better load following characteristic, enhanced turndown without fuel oil support, improved plant availability and part load efficiency, and reduced feed pump power draw, all leading to savings in the costs of power generation.

Having endured a decade of operating difficulties with the unit, including the need to de-rate the power output by 10%, inflexibility of operation, an inability to maintain stable operation at less than 70% load, and countenancing the prospects of more onerous impending emissions legislation the operator, Yaomeng Power Generation Limited (YPGL), was faced with plant closure. Instead, they chose an upgrade that has given a 20-years design life extension.

This paper describes the technology used for the refurbishment of the plant, and with reference to the very significant improvements in operational performance seen over 18 months following the refurbishment, illustrates the clear benefits of boilers designed or converted to low water mass flux technology. It also demonstrates the natural progression from sub-critical units and application of the technology to supercritical boilers at today's state of the art steam conditions.

Advanced Monitoring, Diagnostics, and Performance Optimization of Vertical Roller Mill / Pulverizer Using an R&D Test Facility

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In coal-fired thermal power stations, Vertical roller mills form a vital part delivering pulverized coal with the fineness and throughput required to maintain stable boiler operation and reliable power generation. As a result, pulveriser mill reliability, and performance has a direct impact on plant availability, heat rate, and overall power quality and reliable power generation.

This paper presents a structured framework to improve pulveriser/Vertical Roller mill (VRM) reliability and performance through integrated process and condition monitoring. This paper details patented advanced sensing solutions and techniques—such as a real-time bed level sensor and a stop-bolt impact/load sensor, Hydraulic Tilt in/Tilt out system—together with VRM performance validation in a dedicated R&D test facility. These innovations enable more reliable condition monitoring, early fault detection, optimized operating parameter control, reduced maintenance effort and time, and improve overall generation reliability.

The methodology establishes a repeatable test plan and a time-aligned data process to link operating conditions and coal feed variability with mill stability and grinding performance. A practical, rule-based multi-signal diagnostic logic is defined to enable early warning of abnormal states such as choking, airflow limitation, and bed collapse/empty-bed conditions, with provisions for robust threshold selection and false-alarm reduction.

Overall, the work provides a foundation for developing operating maps, alarm limits, and maintenance triggers that can support coordinated set point optimization, reduce unplanned downtime, and improve mill availability and energy performance; The tests in R&D test facility will quantify the contribution of each sensor signal and confirm the proposed indicators under control upsets and with representative coal condition.

Applications of Electromagnetic-Based NDE Methods for Inspection of Straight Boiler Tubes and Bends of Ferritic and Austenitic Steel in Power Plants

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Coal-based thermal power plants rely on extensive networks of boiler tubes, heat exchangers, and condensers that operate under high temperatures (up to ~600°C), pressures, and chemically treated water environments. These tubes, extending for kilometres with thousands of joints, are exposed to flue gas and coal ash at varying temperatures across different zones. Consequently, they undergo multiple degradation mechanisms such as creep, fatigue, corrosion, erosion, pitting, and cracking. Ensuring their structural integrity and operational efficiency requires regular inspections, where Non-Destructive Testing (NDT) plays a vital role during both erection and service life.

Ultrasonic Testing (UT) remains the primary Non-Destructive Evaluation (NDE) technique for thickness mapping and integrity assessment of boiler components due to its quantitative output and reliability. However, UT-excluding guided waves-requires direct access and contact, and its highly localized sensitivity may limit usefulness when inspecting large volumes or lengths, such as extensive boiler tube circuits or numerous bends requiring pit detection. In such cases, electromagnetic methods offer significant advantages.

Electromagnetic NDE techniques are effective not only for flaw detection and thickness assessment but also for evaluating post-weld heat treatment (PWHT), coating health, and blockages in tube bends. However, with numerous available methods-such as conventional and advanced Eddy Current Testing (ECT), RFET, NFT, LFET, SLOFEC, ECA, PEC, MCF, FSECT, and MBE-utilities and service providers often struggle to select the most suitable technique, leading to suboptimal inspections.

This paper addresses these challenges by examining advanced electromagnetic methodologies, outlining their applications, advantages, limitations, and providing guidance to ensure safe, reliable, and efficient power plant operation.

Enhancing Boiler Reliability: Maintenance Strategies to control boiler waterwall failures of subcritical and supercritical units

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The reliable operation of coal-fired power plants, particularly the waterwall pressure parts, has been severely challenged by the necessity for flexible cycling operation driven by increasing renewable energy integration. This paper details the experience of NTPC Sipat (2,980 MW capacity) in mitigating recurring waterwall tube failures, which resulted in a cumulative financial loss of approximately {₹}150 crores across its 660 MW (Stage-1, supercritical) and 500 MW (Stage-2, subcritical) units. Analysis identified weld joint defects and attachment fatigue as the predominant failure mechanisms.

A. Weld Joint Failure Mitigation (Stage-1, 660 MW)

The initial approach using Phased Array Ultrasonic Testing (PAUT) to detect weld defects proved inadequate due to inherent technical limitations in this specific application. A strategic shift was made during the 2024 Unit-3 overhaul.

B. Attachment Failure Mitigation (Stage-2, 500 MW)

Attachment failures, particularly in burner peepholes, persisted despite prior design recommendations (e.g., extension of attachment ends and slit cutting of seal boxes). A definitive solution was implemented.

C. Fin-Attachment Reliability (Stage-1, 660 MW)

The paper also highlights a successful baseline practice: the TIG welding process used for fin welding on the Stage-1 (Doosan make) units has resulted in zero fin-attachment failures, confirming the importance of superior original weld quality in resisting fatigue damage from cycling.

The successful implementation of Radiography Testing for weld joint integrity and Targeted Tube Replacement for fatigue-susceptible attachment zones offers a replicable, data-driven methodology. These practices are essential for enhancing the long-term reliability of boiler pressure parts and mitigating significant financial losses associated with forced outages in power plants operating under flexible cycling loads.

Boiler Tube Leakage Reduction via Boiler Combustion Optimization at Gadarwara STPP

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The Gadarwara STPP (2X800 MW), has experienced recurrent boiler tube leakages (BTL) resulting in eight forced outages during 2025–26. The station focused on mitigating the contributing causes through systematic Failure Mode and Effects Analysis (FMEA), combustion optimization, and enhanced monitoring. Post-revival of Unit #1 in November 2025, early-warning indicators such as excessive temperature differentials (>120°C) between Vertical Water wall (VWW) and peak VWW tube metal temperatures (MTM >560°C) were observed. A structured chronology of corrective actions—including SOFA yaw angle adjustments, burner tilt optimization, mill performance checks, excess O□ curve realignment, ramp rate reduction, and enthalpy-based separator outlet control—was implemented in collaboration with BHEL, COS, and CenPEEP. These measures reduced VWW MTM spread between Max & Min MTM temperature across all Vertical Water from 150°C to 80°C and contained Avg VWW MTM temperatures below 490°C. Also, Platen MTM are maintained within safe range below 480°C. These Boiler combustion tuning actions are in favorable directions and underscores that operational factors can significantly improve reliability and sustainability of supercritical boiler operations.

Session – 5:

Digital Initiatives/AI/ML for Power Plants

Integrated Framework for Flexible Operation Combining Coal Sourcing, Blending, Inventory Analytics, & Ancillary Services Optimization

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Flexible operation has become a defining requirement for coal-based thermal power plants due to increasing renewable energy penetration and dynamic grid conditions. For non-pit head (NPH) stations operating predominantly at part load, flexible operation is no longer a control-room-only challenge. Fuel quality variability, coal logistics, blending practices, inventory behaviour, and grid-driven Automatic Generation Control (AGC) requirements together exert a compounded impact on efficiency, deviation penalties, and Energy Charge Rate (ECR).

This paper presents an integrated, data-driven operational framework for mastering flexible operation in a non-pit head thermal power plant. The proposed framework combines coal blending optimization, inventory and supply chain analytics, coal quality monitoring, and AGC performance analysis to enable sustained efficiency and profitability under part-load operation. Coal blending and ECR optimization are addressed using Multi-Criteria Decision Making (MCDM) based Fuzzy Goal Programming, allowing simultaneous consideration of conflicting objectives such as coal cost, gross calorific value (GCV), ash, and moisture under conditions of uncertainty. Inventory cost control and supply chain optimization are supported through machine learning–based classification models developed in the Anaconda environment, enabling prediction of inventory risk and supply chain stability under flexible operating regimes. Statistical Process Control (SPC) techniques are applied for coal quality monitoring and yard management to detect variability, quality drift, and source-wise deviations. Further, regression-based analysis is employed to assess the impact of coal quality variability and ramping behaviour on AGC performance and unit gain stability.

The study demonstrates that flexible operation is a system-level problem requiring coordinated optimization across fuel sourcing, inventory management, combustion performance, and grid interaction. The proposed framework provides practical insights for non-pit head stations to reduce APC, improve AGC compliance, stabilize combustion, and enhance overall operational profitability.

Algorithmic Paradigm in Predicting Motor Health

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The industrial sector is experiencing a paradigm shift toward Industry 4.0, utilizing the digitization of physical assets. This paper analyses the application of Artificial Intelligence (AI) in predicting the health of electric motors (Induction and Permanent Magnet Synchronous Motors), which consume roughly 45% of global electricity. The analysis tracks the evolution of technology from manual feature engineering to end-to-end Deep Learning (DL), and finally to hybrid systems utilizing Physics-Informed Neural Networks (PINNs) and Large Language Models (LLMs) along with its application onsite. Key challenges addressed include domain adaptation, edge computing constraints (TinyML), and the interpretability of AI models. By benchmarking performance across standard datasets such as CWRU, Paderborn, and Ottawa, this document provides a holistic view of the current capabilities and future frontiers of AI-driven predictive maintenance.

Ash Leakage Detection and Alarm System

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NTPC operates over 65 coal-based power stations, generating significant quantities of fly ash and bottom ash. Efficient ash handling and the achievement of 100% ash utilization remain key operational priorities across all stations.

Ash leakage remains a recurring operational challenge, impacting safety, equipment reliability, housekeeping, and environmental compliance. Silos, conveying lines, hoppers, and transfer points are particularly vulnerable due to wear, choking, gasket failures, and pressure fluctuations, leading to reduced visibility, health concerns, maintenance issues, and potential equipment malfunction.

Traditional detection methods, including manual inspection and continuous CCTV monitoring, are constrained by human limitations such as operator fatigue, poor visibility, and the requirement to monitor large areas simultaneously. As a result, leakages may remain undetected until they escalate into significant safety or maintenance concerns.

To overcome these challenges, a Video-Analytics-based Ash Leakage Detection and Alarm System has been conceptualized and implemented to provide proactive and automated monitoring. The system integrates AI-driven computer vision algorithms with existing CCTV infrastructure at critical ash-handling locations. Trained models detect ash-leakage signatures such as dust plumes, particle dispersion, opacity variations, and abnormal motion patterns, to intelligently differentiate actual leakages from operational dust, steam, and shadows to minimize false alarms.

Upon detection, real-time audio-visual alarms and control-room notifications are automatically triggered, enabling prompt corrective action. Also, Centralized event logging helps in further RCA.

Through early detection and continuous surveillance, the system enhances safety, reduces environmental exposure, improves O&M efficiency, and supports NTPC's digitalization objectives.

Application of AI/ ML for quantification of Boiler health and delaying/ mitigating Boiler tube failures

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Boiler tube leak (BTL) is a major contributor to forced outages in NTPC thermal power plants, directly affecting unit availability and overall performance. While NTPC has well-established practices for BTL investigation and root cause analysis based on operational experience and detailed incident reports, traditional methods are largely reactive in nature. The emergence of data analytics–based predictive tools has enabled the analysis of large volumes of operational data and identification of complex relationships among multiple parameters. Such techniques have been successfully applied in process industries to predict critical failures and provide early warnings. This study focuses on combining NTPC's extensive BTL failure data with data-driven analytical methods to develop an early warning framework aimed at reducing BTL-related forced outages and improving plant reliability.

This paper also elaborates on the model that was deployed in Ramagundam Unit-7 and Kahalgaon Unit-7 for quantifying boiler health and predicting the BTL date that can be advanced till the upcoming OH date by working on the anomalies. The paper also put a thought on way ahead for various boiler tube failure mechanisms.

Real-Time Biomass Feeding Monitoring System

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The Indian power sector stands at a definitive crossroads, balancing the rapid expansion of base load generation with the urgent decarbonization mandates of the "Panchamrit" goals. In this context, the Ministry of Power's SAMARTH Mission has institutionalized biomass co-firing as a strategic imperative. However, the operationalization of this directive is currently hampered by an "Operational Blind Spot" which is the lack of real-time visibility into the biomass-to-coal ratio on high-speed conveyors feeding the Pulveriser Bunker. There is no feedback of any sort to operation desk engineer of what kind of fuel is being fed into the Pulveriser, what is the percentage of biomass blend. This opacity leads to severe safety hazards, specifically Mill Duct Ruptures (MDR) caused by the differential devolatilization of biomass, and chronic asset degradation via Boiler Tube Leakage (BTL) due to alkali-induced corrosion.

This paper details the design and deployment of a Real-Time Biomass Feeding Monitoring System intended to bridge this operational gap. Leveraging Edge Computing (hardware placed right on top of the conveyor on the Bunker floor), the system employs a Raspberry Pi 4 (microprocessor) combined with a Global Shutter vision camera. It utilizes the HSV (Hue, Saturation, Value) colour space algorithm to detect the percentage of biomass with a detection confidence of 98% and a latency of under 0.5 seconds. The system detects the percentage of biomass mixed in coal, along with feeding start time and end time.

This data, combined with bunker level and feeder feed rate, tells exactly when a feeder is in biomass mode and helps prevent critical hazards. To ensure immediate data availability, the research outlines a dual-phased integration strategy. Presently, the system utilizes LoRa P2P (Long Range Point-to-Point) technology to establish a lightweight, private wireless link between the bunker floor and the control room. This allows for the rapid deployment of a standalone dashboard, providing operators with immediate visibility into "slug" formation without the need for extensive cabling infrastructure. However, the ultimate strategic goal is to close the control loop by integrating this process data directly with the plant's Max DNA Distributed Control System (DCS). By converting the biomass blend from an unmonitored variable into a precise process parameter, this frugal digital intervention serves as a linchpin for the safe and scalable implementation of biomass co-firing across the whole NTPC thermal fleet.

Session – 6:

Power Plant Efficiency

Current Status of Computational Fluid Dynamics (CFD) Analysis in Coal-Fired Power Plant and Its Contribution to Decarbonization

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This paper reviews Computational Fluid Dynamics (CFD) analysis applied to coal-fired power plants, including its definition, objectives, analytical targets, and modelling approaches, and introduces representative application examples. The paper is particularly focused on the behaviour of fly ash in pulverized coal-fired boilers, with detailed CFD case studies presented. In addition, the role of CFD in biomass and ammonia co-firing, which are expected to become important options for decarbonization in the future, is clarified. Furthermore, the challenges and limitations associated with the use of CFD as a design-support tool are discussed.

Online Power Plants Performance Analysis in Practice

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The presentation concerns with performance analysis of operating power plants by the on-line monitoring (OLM). OLM nowadays is based mostly on methods of Data Validation and Reconciliation (DVR). DVR uses mathematical models of industrial processes like mass and energy balancing, thermodynamic modelling, etc., followed by a thorough statistical analysis of measured process data. In this way the possible errors in models or gross measurement errors can be revealed and eliminated. Results of DVR (consistent data, parameters of models, parametric sensitivities) are useful during the performance analysis, equipment diagnostics or process optimization.

Using DVR in practice is not easy. Many DVR methods were developed by scientists from the academic strata with limited experience in the harsh industrial environment. The centroid of the presentation is in showing the most important problems of application of DVR in the process of OLM and the power plant performance analysis. Besides that, we will try to show also some new horizons in front of performance analysis – how to recast better knowledge of plants into better economy of the power generation. We will mention relation of OLM to Process Data Driven Simulation, Digital Twins and Smart Process Plants.

Aerodynamic Efficiency and Structural Reliability of Cooling Tower Fans

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Low Pressure Axial flow fans, sometimes referred to as Propeller fans or Cooling fans, are used in a variety of industries such as oil and gas, power plants, HVAC, et cetera for cooling purposes. The diameter of such fans varies from as small as 6 inches, typically used in data centre cooling, up to 40 feet, used in Air-cooled Condensers and Cooling Towers. With the concern about energy savings becoming grave and the government-imposed standards and subsidies, designing an optimum efficiency fan has become very valuable. Research engineers have been striving hard to strike a balance between airflow produced and power consumed that will make the fan of optimum efficiency. Hence, it is very valuable for everyone dealing with axial fans to understand the various parameters involved in designing an efficient axial fan. This paper focuses on delineating the few fundamental design considerations and methodology that can be adopted for development of high efficiency and improved reliability axial flow fans which are used in Cooling Towers. The author's intention is to direct attention to the aerodynamic design, sizing and optimization, structural design and destructive testing involved in manufacturing a reliable fan.

Leveraging Dynamic Heat Balance Diagram for Efficiency Gap Analysis during Flexible Operation in a 500 MW Coal-Fired Unit

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With the increasing integration of renewable energy (RE) into the grid and inadequate energy storage facilities, coal-fired power plants are increasingly required to operate in a flexible manner. Efficiency gap analysis at full load is no longer sufficient as part-load operation is increasing day by day. This calls for dynamic analysis of efficiency parameters and comparison with predicted design parameters at a given load condition. Therefore, a thermodynamic model was created for a 500 MW coal-based power plant, which predicts a complete heat balance diagram at any given load. This Load varied Heat Balance Diagram is a powerful tool for diagnosing performance gaps in thermal power plants at any operating load and not just full load. This paper explores the advantages of using a structured Excel-based heat balance model, detailing its role in predictive analysis, operational benchmarking, and root cause identification. Real-world use cases demonstrate how this tool supports efficiency improvement and reliability enhancement.

A Case study on improvement in Cooling Tower performance by installing Helper cell

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Cooling tower is vital component of any Thermal Power plant. The primary task of a cooling tower is to reject heat into the atmosphere. About 55% of total heat input to the plant is finally dissipated as waste heat. In a steam power plant, due to increase in cold water inlet temperature to condenser the performance deteriorates, and the heat rate increases to a considerable amount which causes financial losses and in adverse situation it affects capability i.e. plant generation. In Rihand Stage-3, Induced draft counter flow cooling tower is having 36 numbers Cells (18 CT fans in each unit). Helper cell cooling Towers (CT) for Unit-5 & 6 at NTPC Rihand were constructed to augment the performance of Stage III Cooling towers (5.29°C short fall in cold water temperature). FRP (Fiber Reinforced Plastic) based Cooling tower (CT) of helper cell has been constructed for stage III at NTPC Rihand. The helper cell cooling tower was designed to handle a water flow of 40,000 m /hr 20,000 m from each units 5 & 6 thereby improving condenser performance by reducing cold water temperature by 5.29°C. Heat rate improvement of 27 kCal/kWh and 9.3 Cr per year net saving will be achieved after installation of Helper Cell.

Session-7:

Virtual (International) EPRI

Digitalization, OPAI, and AI Road-mapping for Power Utilities

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This session will introduce EPRI's Open Power AI (OPAI) framework, which helps utilities prioritize and implement high value digital and AI use cases across their fleets. The presentation will describe a structured roadmap process: identifying business problems, assessing data readiness, selecting appropriate analytics and AI techniques, and defining governance and cybersecurity requirements. Real world examples—such as AI driven boiler tuning, predictive maintenance for critical components, and anomaly detection in renewables and storage—will illustrate achievable benefits in reliability, efficiency, and safety. Attendees will leave with a practical view of how to move from isolated pilots to an integrated digital strategy that aligns analytics investments with corporate objectives and resource constraints.

Battery Energy Storage Systems

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This session will showcase EPRI's capabilities in supporting utility scale battery energy storage projects, including those that integrate with large solar and wind parks—a critical capability as utilities balance rapid renewable growth with grid stability and dispatchability requirements. The presentation will walk through the full BESS lifecycle: use case definition and value modelling (identifying which services—capacity, energy arbitrage, frequency response, or voltage support—drive project economics); technical specification and vendor procurement; commissioning and factory acceptance testing; and long term operational and safety management. Drawing on EPRI's field experience with multi hundred-megawatt storage deployments and its Battery Energy Storage Fire Prevention and Mitigation program, the session will highlight best practices in system sizing, grid interconnection, and co optimization with co-located renewables. Critical topics will include hazard mitigation analyses, site specific emergency response planning, thermal management and degradation modelling, and lessons learned from real world incidents. For utilities considering entry into the storage sector or expansion of existing BESS portfolios, EPRI's playbooks, RFP templates, and safety toolkits provide de risking frameworks that accelerate regulatory approval, build stakeholder confidence, and ensure that storage assets deliver reliable, flexible capacity over their full decades-long operating lives. Attendees will understand how best practices can transform BESS from a novel, high risk venture into a standard component of the modern generation fleet.

Hydrogen and Emerging Fuel Technologies for Power Generation and Heavy Transport

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This session will examine how hydrogen and other emerging fuel technologies (EFT)—such as ammonia, synthetic methane, and low carbon liquid fuels—can be integrated into the existing power and industrial ecosystem to reduce emissions while preserving firm capacity. The presentation will draw on EPRI's cross sector research to show how large generators can co fire or convert units to burn low carbon fuels, and how the same production pathways can serve hard to abate uses in heavy industry and transport. Key topics will include fuel production and logistics (electrolysers, reformers, storage), combustion and materials considerations for retrofitting gas and coal units, and the operational role of these fuels in balancing high renewable penetrations. Attendees will gain insight into realistic deployment timelines, cost and infrastructure hurdles, and how to structure pilot projects that de risk future large scale adoption. The session will also outline planning approaches that treat hydrogen and EFT demand as flexible, high value loads—capable of absorbing surplus renewable energy and providing grid services—thereby aligning decarbonization of power, industry, and transport within a unified strategy.

Operational and Maintenance Implications of Electrolyze Cycling Under Renewable Driven Power Variability

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The increasing penetration of variable renewable energy resources has intensified the need for flexible loads capable of supporting grid stability. Water electrolysers—traditionally operated at steady state conditions—are emerging as promising assets for dynamic grid balancing due to their ability to modulate power consumption rapidly. However, frequent power cycling introduces new operational and maintenance (O&M) considerations that can influence system reliability, lifetime, and economic performance.

This work evaluates how transient operation—such as rapid ramping and repeated on/off cycling—affects key durability drivers in PEM and alkaline electrolysers. Cycling can accelerate voltage rise, catalyst degradation, membrane stress, and gas crossover risks in stacks, while also increasing wear on power electronics, cooling systems, and water purification components. These effects raise O&M costs by shortening maintenance intervals and reducing long term efficiency. Despite these challenges, electrolyser cycling remains a valuable tool for integrating variable renewables. The study highlights mitigation strategies, including optimized cycling profiles, improved thermal management, and enhanced monitoring, to support reliable grid balancing performance while minimizing O&M impacts.

Equipment Health Monitoring and Diagnostics for Thermal Generation

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This session will focus on EPRI's comprehensive approach to online and offline equipment monitoring, condition assessment, and predictive diagnostics for thermal power plants. The presentation will demonstrate how modern sensor networks, data analytics, and automated alarm systems can detect early signs of component degradation—such as bearing wear, corrosion, fouling, and mechanical looseness—before they escalate into forced outages. Drawing on EPRI's work in vibration monitoring, thermography, acoustic sensing, and oil analysis, the session will show how utilities can transition from reactive, time-based maintenance to condition-based strategies that align maintenance activities with actual equipment health. Attendees will learn how to integrate disparate monitoring data streams, apply machine learning for anomaly detection, and use prognostic tools to predict remaining useful life and optimize outage planning. Case examples will illustrate how systematic equipment health monitoring has helped utilities reduce unplanned downtime, extend asset life, and improve operational safety and efficiency across boilers, turbines, generators, and cooling systems.

Testing a Novel Chemical Injection Strategy for Reducing Corrosion in Air-Cooled Condensers

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Ethanolamine (ETA) is a neutralizing amine that can be used to increase pH and reduce two-phase flow accelerated corrosion (FAC) in the steam and water cycle to enhance protection beyond the capabilities of typical ammonium-only treatment. Limitations to ETA's effectiveness include thermal decomposition in the steam superheater before reaching the Air-Cooled Condenser. Direct ETA injection to the steam turbine exhaust could overcome this limitation and this presentation will provide a summary of results of a full-scale test, including recent inspection photographs. In addition, potential impacts on condensate polisher resin will be discussed and an overview of the test plan to investigate this impact will be provided.

Session-8:

Asset Management

Innovative Reliability Practices for Coal-Based Power Plants

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This paper presents an integrated reliability management framework deployed in a SAP-enabled operations and maintenance (O&M) environment. The program combines daily defect notification analysis, quarterly bad-actor reviews, structured Failure Modes and Effects Analysis (FMEA) mapping, and disciplined Root Cause Analysis (RCA) with 5-Why for rapid learning. A comprehensive preventive maintenance (PM) regime spans ~12,000 PM tasks annually across 159 equipment categories, with risk-based frequencies and condition-based monitoring (CBM) plans. Maintenance codification has been enhanced to 10 notification types, 1,500 cause codes and 600 damage codes for precision diagnostics, all embedded in SAP. A formal Task Force mechanism orchestrates accelerated issue resolution, while a multi-gate Management of Change (MOC) governance ensures safe, compliant design and maintenance modifications. Reliability metrics (MTBF, MTTR, MTTF) are tracked monthly for critical assets, and biennial single-point-failure (SPF) reviews sustain system resilience. Peer-plant surveys support benchmarking and proactive risk discovery. The framework enables faster closure of repeat failures, better PM effectiveness, and traceable action implementation through SAP-driven workflows and cross-functional governance.

Centralized Asset Management as A Tool for Operational Efficiency In NHPC

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Large hydropower utilities operate geographically dispersed, capital-intensive assets where systematic asset management is critical for reliability, safety, and cost-effective operation. NHPC Limited manages a wide portfolio of hydroelectric generating units, balance-of-plant equipment, and protection and control systems across multiple power stations exposed to diverse hydrological, environmental, and grid conditions. Under traditional decentralized practices, asset data is often fragmented across local systems and dependent on individual experience, resulting in limited visibility, delayed decision-making, and largely reactive maintenance. This paper presents the design and implementation of a Centralized Asset Management (CAM) framework at NHPC and evaluates its impact on operational efficiency and reliability. The CAM architecture integrates asset information from enterprise platforms such as SAP-based ERP, SCADA, remote data acquisition systems, automated fault analysis tools, and digital knowledge repositories into a single organization-wide environment. Centralization enables near real-time asset visibility, standardized and auditable maintenance workflows, improved asset lifecycle tracking.

The results demonstrate that CAM significantly reduces manual data handling and improves the consistency and effectiveness of maintenance activities. More importantly, it facilitates a transition from time-based and reactive maintenance to condition-based and predictive strategies supported by high-quality, governed data. Pilot implementations indicate improvements in equipment availability of up to approximately 15 percent, reductions in fault response and diagnosis times of 30–40 percent, and measurable gains in overall plant reliability and operational resilience.

The paper concludes that centralized asset management is not merely an IT upgrade but a key enabler of operational excellence and digital transformation for large hydropower utilities.

Knowledge-Based Audits (KBA) for Boilers and Associated Piping: A Critical Strategy for Plant Life Extension and Reliability

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India's thermal power plants, particularly aging sub-critical units, are increasingly exposed to flexible, cyclic, and low-load operations driven by large-scale renewable energy integration and stringent regulatory requirements.

These operating regimes amplify degradation mechanisms creep-fatigue interaction, flow-accelerated corrosion (FAC), oxidation, erosion-corrosion, and thermal fatigue which conventional inspection and risk-based methodologies often fail to detect at early stages.

Knowledge-Based Audits (KBA) provide a structured, data-driven asset management framework that integrates operational analytics, metallurgical evaluation, condition assessment, and predictive modelling to optimize boiler reliability and thermal performance.

This paper presents the application of KBA for comprehensive boiler integrity management, encompassing pre-KBA operational profiling, KBA diagnostic assessment, and deployment of targeted mitigation measures. The methodology combines transient load analysis, cyclic-stress evaluation, NDT datasets, oxide-scale measurements, and historical failure trends to identify high-risk components. A dynamic PoF–CoF risk matrix is used to prioritize inspection scopes and maintenance interventions.

Case evidence demonstrates the effectiveness of KBA: identification of creep-fatigue in final superheater tubes (oxide ~0.4 mm), FAC-driven thinning in feed water elbows, and erosion-corrosion in water wall zones near burner throats. Targeted actions including selective material upgrades (T91/P22), erosion shields, optimized water-chemistry control, and soot-blower sequencing resulted in stabilized thermal profiles, elimination of tube leaks for over three years, improved heat transfer, and a validated 12-year life extension beyond design life.

KBA thus emerges as a critical enabler for the Indian thermal fleet, strengthening reliability, reducing heat-rate deterioration, minimizing forced outages, and supporting the IPS:2026 vision of high-quality, dependable thermal generation in a renewable-dominant energy landscape.

Enhancing Cable Asset Reliability with Online Assessment, Offline Diagnostics and Precise Fault Location

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The cable system is a critical part of any electrical network, and its reliability directly affects service quality and operational efficiency. Cables need to be monitored while in service and, when necessary, taken out of operation for detailed health checks to maintain a high level of reliability. Weak points along the cable can be identified well before a failure occurs, helping utilities prevent unplanned outages. Aged cable networks can also be assessed to understand their current condition and to ensure the asset is used safely and effectively.

Integrating SAP Plant maintenance with industry 4.0 technologies: A framework for smart maintenance operations in mining

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In this study, we examined the operational impact of integrating SAP PM with Industry 4.0technologies in a mining environment. The results demonstrated a clear shift from manual data entry and paper-based workflows to a connected, automated, and data-driven maintenance model. Real-time equipment data, sensor-based hour meter readings (HMR), and automated work order generation have streamlined maintenance execution, improved compliance, and reduced downtime. The SAP Plant Maintenance module, when integrated with Industry 4.0 technologies, is significantly enhancing to manage maintenance operations. Technologies such as telematics, artificial intelligence(AI), machine learning (ML), web applications, and diagnostic tools like MCCASY are enabling smarter and faster maintenance practices across sectors including mining, manufacturing, automotive and logistics. SAP PM supports real-time monitoring of asset health, facilitates the structured planning of preventive maintenance tasks, minimizes unexpected equipment failures, and better control over spare parts inventory.

In simple terms, SAP PM with Industry 4.0 transforms traditional, manual maintenance into a smarter, faster, and fully connected system using real-time data, sensors, and predictive tools.

Computational Fluid Dynamics for Boosting Energy Savings in Thermal Power Plants

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This paper presents the application of Computational Fluid Dynamics (CFD) as an Energy Efficiency Optimization tool in Thermal Power Plants. Thermal Power Generation involves complex interactions between Fluid Flow and Heat Transfer. Major issues such as Fluid Turbulence in Ducts, Uneven Thermal Distribution and Pressure Drop across components significantly affect operations and increase the overall Energy Consumption of these systems. By simulating and analysing a digital twin of such systems, such inefficient areas can be pinpointed, and a small modification can be proposed so that aforementioned problems can be solved, increasing the Energy savings of the overall plant and the life and wear and tear of components.

The CFD analyses are demonstrated for key power plant components including first and second pass of Boilers/Furnaces, Combustion Analysis, Air Pre-Heaters and Waste Heat Recovery Systems, Flue Gas Ducting, Coal Mill Performance, Economizer Outlet to Electrostatic Precipitator Inlet, Electrostatic Precipitator Outlet to ID Fan Inlet, ID Fan Outlet to Stack, and Cooling Tower Flue Gas Dispersion Analysis. Similarly, Pressure drop in Ducts, Duct Erosion Rate, Coal Mill Fan Performance and Erosion rate are also analysed and optimized. The simulations capture the velocity, pressure and temperature profiles to identify the non-uniform flow distribution, recirculation zones, excessive pressure drops and heat transfer limitation. Based upon such insights, deign modification can be supported towards operational improvements aimed at reducing system losses and auxiliary power consumptions, hence enhancing overall plant efficiency.

This paper discusses such CFD methodology including the turbulence modelling, boundary conditions, mesh quality and result validation along with before and after modification case. Such case studies establish CFD as a reliable tool for Performance Enhancement and Energy Optimization in Thermal Power Plants.

Session-9:

Nuclear and Hydrogen: A pathway to Energy Transition

Nuclear Options to Support an Energy Transition

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This session will explore how modern nuclear technologies can complement renewables by providing firm, low carbon capacity, high temperature process heat, and grid stabilizing services. Building on EPRI's Global Advanced Nuclear research, the presentation will cover evolutionary large light water reactor designs, Small Modular Reactors (SMRs), and advanced concepts suited for flexible operation and integration with hydrogen production or district heating. Specific focus will be placed on lessons learned from international deployment efforts, licensing and regulatory trends, and approaches to cost and schedule risk reduction. Participants will see how utilities can systematically evaluate nuclear options as part of long-term resource planning, including siting considerations, workforce and supply chain needs, and potential partnership models.

Leveraging Thermal Power Expertise on the Secondary Side of Indigenous 700 MWe PHWR Units

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India's accelerating decarbonisation agenda, reinforced by the IPS 2026 theme, foregrounds nuclear power—and particularly the secondary side of 700 MWe PHWRs as a logical, low carbon progression for India's established subcritical/supercritical coal ecosystem. At the policy level, recent atomic energy amendments announced in the Union Budget seek to open the sector to broader partnerships and capital, creating new entry points for industry participation in the upcoming nuclear build out.

Against this backdrop, the paper traces an integrated system engineering workflow spanning utility and contractor perspectives, with a strong focus on how secondary side support systems and power supply philosophy underpin operational safety and high plant availability. An auxiliary boiler feed water system is developed as a nuclear grade case study, illustrating how safety central to the distinction between nuclear and fossil plants is systematically translated into design decisions. Its configuration and power supply logic secure decay heat removal under trip, seismic, and blackout conditions, while the graded electrical scheme shapes pump sizing, control, and transients ensuring safety drives all secondary side design aspects.

The discussion examines key secondary side subsystems: main steam system (safety/dump valves), moisture separator reheater, and steam generator blow down for solids / contamination control. Material choices are benchmarked against thermal plants to highlight nuclear requirements. It closes with Indian industry opportunities: localising nuclear equipment, scaling EPC for balance-of-plant, specialised O&M, and redeploying thermal expertise into 700 MWe PHWRs extending India's thermal competence to advance nuclear in the energy transition.

Nuclear Energy: Powering India's Net Zero Future

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India's Net Zero 2070 ambition demands an energy transition where nuclear power becomes a central pillar alongside renewables. With renewable capacity touching 200 GW in 2024 and a target of 500 GW non-fossil capacity by 2030, India has already reached 50% non-fossil generation. Yet nuclear contributes only 3%, with 8.7 GW installed. The Nuclear Energy Mission aims for 100 GW by 2047, a twelve-fold scale-up.

India's nuclear roadmap follows three pathways. PHWRs, developed indigenously, have delivered strong performance with 80% average capacity factor. Light Water Reactors with France, Russia, and the U.S. diversify technology and expand capacity. Fast Breeder Reactors, led by the 500 MW PFBR at BHAVINI, advance India's three-stage program and enable long-term fuel security.

Nuclear's grid value is unmatched, it provides inertia for stability in renewable-heavy systems, and each unit of nuclear electricity avoids roughly 1 kg of CO_2 versus coal. Even a 1% rise in nuclear use can cut emissions up to 0.16% over time.

Small Modular Reactors mark the next frontier. The Union Budget 2025–26 allocates ₹20,000 crore for indigenous SMRs, targeting five units by 2033. Designs include the BSMR-200, a 55 MW unit, and a 5 MW high-temperature reactor for hydrogen production, an emerging $20 billion market. As an ITER partner contributing 9% of costs, India is also positioned for future fusion breakthroughs.

With electricity demand set to triple by 2047 and coal still dominant, nuclear power is not optional, it is a strategic necessity for a secure, decarbonised future.

Water Management in Power Plants: Role of Dry Cooling in Supporting India's Energy Transition and Net-Zero Goals

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India's commitment to achieve net-zero emissions by 2070 and its planned expansion of nuclear power capacity to 100 GW by 2047 require the adoption of sustainable and resource-efficient technologies. Water availability has emerged as a critical constraint for power generation, particularly for thermal and nuclear plants located at inland sites. Conventional wet cooling systems account for a major share of freshwater consumption in the power sector, making future capacity addition increasingly challenging in water-stressed regions.

India's freshwater resources are approaching their sustainable limits due to competing demands from agriculture, domestic use, and industry. Nuclear power plants, operating on the Rankine cycle, reject higher quantities of heat per unit of electricity generated compared to coal-based plants, resulting in significantly higher cooling water requirements. This challenge is further intensified for inland nuclear sites where access to perennial water sources is limited.

This paper examines water management challenges in power plants with a focus on dry cooling technologies, including Direct Dry Cooling using Air-Cooled Condensers (ACC) and Indirect Dry Cooling systems employing Natural Draft Indirect Dry Cooling Towers (NDDCT). A techno-economic assessment for a representative 700 MW Pressurized Heavy Water Reactor (PHWR) under Indian climatic conditions indicates that indirect dry cooling can reduce freshwater consumption by approximately 80–90% compared to conventional wet cooling systems.

The study also evaluates performance impacts, capital cost implications, turbine design considerations, and long-term sustainability benefits. The findings demonstrate that indirect dry cooling provides a technically feasible and environmentally sustainable pathway for inland nuclear power plant deployment, supporting India's energy transition, climate resilience, and ESG-driven decarbonization objectives.

Engineering feasibility study to replace LDO with renewable Methane synthesized on-site via a fully integrated CO_2 capture, Green H_2 and Sabatier Reaction

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This engineering feasibility study evaluates the retrofit of the Kudgi 800-MW supercritical coal-fired power plant with an integrated CO_2 capture and on-site methane synthesis system designed to fully eliminate Light Diesel Oil (LDO) consumption during boiler startup. The proposed configuration combines post-FGD CO_2 capture (2,200 kg/h), 20 MW alkaline electrolysis producing 400 kg/h of green hydrogen, and multi-stage Sabatier methanation yielding 800 kg/h of renewable methane. This synthetic methane is supplied to modified low-NO_x burners, enabling reliable boiler startup without fossil fuels.

The system allows precise control of methane flow to replicate the thermal behaviour of LDO, ensuring seamless operability and compliance with CERC's SCUC startup-time requirements. Results confirm high technical feasibility, as all major subsystems—CO_2 capture, electrolysis, methanation, gas storage, and burner modifications—are commercially mature and compatible with existing plant operations. Two 150-ton, 10-bar methane storage vessels provide flexibility and eliminate spillage and contamination risks associated with LDO. Environmental performance improves substantially, with 27,000 tCO_2/year of direct avoided emissions, an 80% reduction in NO_x, and near elimination of soot and particulate formation. This contrasts with LDO combustion, which produces high resistivity carbonaceous particulates that degrade ESP efficiency, foul APH baskets, and elevate corrosion risk.

Economic analysis indicates moderate viability, achieving an estimated 8.1-year payback contingent on renewable electricity pricing (~₹ 3/kWh) and monetization of carbon credits under India's Carbon Credit Trading Scheme for fuel switching and synthetic green fuel substitution. The overall implementation timeline is 21 months, with electrolyser procurement forming the critical path.

As the first application of on-site green-methane startup fuel in an operational coal unit, this project serves as a scalable, flagship model for decarbonizing auxiliary fuel use across India's thermal fleet while enhancing operational reliability and regulatory compliance.

Evaluation of 20kWe Hydrogen Generation Pilot Plant using High temperature Steam Electrolysis (HTSE)

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Solid Oxide Electrolytic Cell (SOEC) based High Temperature Steam Electrolyser (HTSE) constitutes an advanced concept enabling ultrapure steam electrolysis at high temperatures (~ 850°C), which results in higher efficiencies compared to alkaline or PEM electrolysers. SOEC has a theoretical minimum stack efficiency advantage of 16%, assuming optimal low-temperature conversion. The SOE system produces hydrogen (H_2) from steam (H_2O) and electricity (e.g., renewable sources such as solar, wind, etc.). The SOE system has planar stacks, with an operating temperature of about 800°C. The system is generating H_2 with a minimum net outflow capacity of 45 Nm^3/hr with minimum discharge pressure of 30 -40 mbar (g). Possibility to couple with high-temperature processes (like Fischer-Tropsch, Haber-Bosch) to generate chemicals, fuels, steel etc. The study has been carried out to estimate exergy and LCOH based on the installation and operation of the 20 kW SOE system.

Session-10:

Control & Automation in Power Plants

Design Matrices & Implementation of Cyber Resilient Ot (Operational Technology) Infrastructure

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The primary objective of cybersecurity in Operational Technology (OT) is to safeguard human life, industrial processes, and critical assets from cyber threats that can cause physical damage, operational disruption, or financial loss. The evolving threat landscape has rendered traditional assumptions such as air-gapped systems, isolated networks, and limited attacker knowledge of OT and safety systems, obsolete. OT cybersecurity must therefore be treated as a core element of industrial safety and business resilience.

A robust OT cybersecurity strategy requires aligning the Confidentiality, Integrity, and Availability (CIA) triad with Health, Safety, and Environment (HSE) objectives. Given the time-critical nature of industrial control systems, availability assumes paramount importance, with risk management focused on minimizing impacts to life, process continuity, and business operations.

Adherence to established frameworks such as NIST, IEC 62443 is essential when developing cybersecurity policies, baselines, procedures, and governance structures, while ensuring alignment with business continuity planning and regulatory compliance. This includes systematic asset identification, risk assessment, implementation of controls based on target security levels, and ongoing management through change control, audits, and incident recovery. Given the diversity and complexity of OT environments, proactive continuous monitoring and workforce capability development are critical.

Considering these design principles, this paper presents the key initiatives undertaken to enhance the resilience of NTPC's OT infrastructure. In this endeavour, relevant international standards, industry best practices, and applicable statutory and regulatory guidelines/frameworks have been leveraged as guiding references to design and implement a secure and resilient OT architecture tailored to NTPC's operational environment.

Leveraging Technologies for Flexibility and Efficiency

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The drive for modern power generating assets to provide enhanced grid stability and respond to highly dynamic load profiles necessitates a fundamental evolution of legacy Instrumentation and Control (I&C) designs. This paper presents a comprehensive analysis of practices being adopted to transition power plants from conventional base load operation to highly flexible operation under the demanding constraints of grid intermittency.

This study commences with an outline of current I&C practices in a thermal power plant, establishing the groundwork upon which transformation is built. A key focus is placed on the field layer, detailing the engineering of Profibus-based devices, explaining their advantages in reducing installation complexity and improving diagnostic capabilities, while also addressing the inherent challenges associated with integration into Distributed Control Systems (DCS).

The core control strategy required for achieving operational flexibility is investigated through the implementation and performance of Co-ordinated Master Control (CMC). CMC is analysed as the critical mechanism for harmonizing the fast-acting demands of the turbine-generator (TG) unit with the slower thermal response of the steam generator during rapid load manoeuvres. Furthermore, the paper explains the impact of flexible operation on existing control systems, highlighting the necessity for enhanced control & monitoring algorithms.

A Study on Distributed Temperature Sensing Technology(DTS) based temperature monitoring and fire detection in CHP conveyors and bearings at NTPC VSTPS

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Coal conveyor systems in thermal power plants are vulnerable to fire hazards arising from bearing failures, frictional heat, and coal dust accumulation. These fire hazards can be avoided by early detection of temperature rise. The existing system uses LHS based fire detection and protection system with acts after start of fire. Technology is available to avoid any possibility of fire. VSTPS is always keen to adopt new state-of-the-art technology in its various systems to maintain in pioneer position.

This paper covers the implementation of a Distributed Temperature Sensing (DTS) solution using the Yokogawa DTSX3000 platform at NTPC VSTPS for continuous, meter-level temperature monitoring along conveyor runs and pulley bearings. The Fiber-optic DTS approach eliminates blind spots inherent to discrete sensors, providing rapid anomaly detection and early fire warnings through seamless integration with DCS/SCADA. A pilot project has been done at VSTPS Coal handling plant in coordination with PE C&I and M/s YIL. The pilot covered interconnected conveyors (69A/69B and 70A/70B) with approximately 1,300 m single-side sensing coverage. Rigorous OTDR-based cable health checks and calibration have been done for trial operation of 3 months.

Operational results demonstrate warning and critical thresholds at 45°C and 65°C respectively, with end-to-end response time under 5 seconds. The deployment enhanced safety, reduced downtime, and established a foundation for predictive maintenance. Future extensions include AI-driven alerts, advanced SCADA analytics, and modular sensor mounting on bearings to further simplify maintenance and improve reliability.

Loop Tuning Initiatives Undertaken at NTPC Khargone (2x660mw) For Stability and Performance Improvement

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Consistent efforts are put in Loop Tuning at NTPC Khargone to meet the challenges of metal temperature variations, parametric variations, and to achieve improvement in ramp/AGC performance, to provide fast and sustainable primary frequency response in compliance with grid code.

Metal temperature excursions are the primary cause of component failures, boiler tube leakages, thereby resulting in forced outages. After in-depth analysis it was concluded that the major factor contributing to metal temperature excursions was variation in PA Header pressure. The logic of PA header pressure Set Point was modified which stabilized the PA Header pressure and in turn mitigated the Secondary/Tertiary metal temperature excursions.

Maintaining degree of superheat is essential to achieving Ramp Performance. The Degree of Superheat Controller (Water separator inlet temperature Control) was incorporated and compensation based on spray was introduced in feed water flow. These improvements resulted in achieving Ramps without operator intervention.

In-line with EPRI guidelines, loop tuning has been carried out for reducing pressure variations and stabilization of Spray Control loop. Also, elevation of Sliding Pressure SP Curve (rated pressure at 90% load) and optimization of Boiler to Turbine Lags have further helped in achieving ramps and improvement in Primary frequency response and AGC performance without over-firing thereby stabilizing parameters.

It is pertinent to mention that the C&I PG test of both the units was successfully conducted with these modifications in place.

Future-Ready Open Systems for Process Automation: NTPC's Success story

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This paper presents NTPC's adoption of the Open Process Automation Standard (O-PAS) to develop a vendor-independent, interoperable, and secure automation architecture for Automatic Generation Control (AGC) in thermal power plant operations. Developed at the ViSPARC facility of COS-C&I at NTPC WR2HQ Nava Raipur, the in-house AGC system has been operating at NTPC Barauni TPS Stage-2 since November 2025 without requiring design review or encountering operational issues. O-PAS enables multi-vendor interoperability and open interfaces, addressing challenges of proprietary OEM ecosystems, high upgrade costs, and rigid hardware–software integration. The implementation integrates legacy DCS assets with commercial off-the-shelf components such as Phoenix AXL I/O, InfluxDB, Grafana, and an ELK-based SIEM, aligned with IEC cybersecurity and interoperability standards. Cost optimization emerged as a major outcome, with reduced O&M expenditure, upgrade cost savings, and economical scaling. By decoupling hardware, software, HMI, and integration layers, NTPC improved flexibility and minimized lifecycle expenses. Field validation including open-loop and closed-loop AGC trials demonstrated interoperability, enhanced monitoring, and advanced analytics. This paper outlines NTPC's engineering approach, cost benefit insights, and a roadmap for utilities pursuing future-ready open automation.

Session-11:

Fuel Management

AI-Powered Optimization of Coal Logistics and Energy Charge Rate for Thermal Power Generation

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Coal remains the primary fuel source for the country, and thermal generation is essential for maintaining Base power demand, grid stability, even amidst increasing renewable capacity. Optimizing this landed cost is a complex challenge, particularly for Rail fed stations, as it relies on balancing numerous dynamic factors across production, logistics, handling capacity, weather and energy demand.

Traditionally, coal planning and procurement involve extensive manual intervention using spreadsheets, sourcing data from over 15 disparate sources, making the process prone to manual error and highly person specific, resulting in efficiency and reliability limitations. To overcome this, an in-house pilot was undertaken by CC-FM executives to optimise ECR and reduce landed coal cost using machine learning and AI. Coal requirements were forecast using a SARIMAX model based on three years of daily consumption data, generating weekly and monthly forecasts with an accuracy of ±10%. These forecasts enabled optimisation of coal sourcing by prioritising cheaper supplies and avoiding high-cost sources such as BCCL and ECL in H1 of FY 2025–26. The pilot demonstrated significant potential for cost and ECR savings through AI-driven planning.

Building on this success, the proposed solution seeks to further modernise NTPC's fuel management and coal logistics systems by integrating data from all relevant sources to enhance forecast accuracy and by leveraging real-time analytics, predictive modelling, and scenario-based planning. A Proof of Concept (PoC) is currently underway at Dadri, Barh, and Kudgi stations in collaboration with an external consultant. The present and expected outcomes include a measurable reduction in coal costs, enhanced supply reliability, maintaining optimal stock buffers, and improved overall profitability by ensuring reduced landed costs.

Optimization of Stacker cum Reclaimer's Bucket Wheel D.E Bearing Replacement Time by Shaft & Sleeve Upgradation

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This thesis presents an engineering modification to the stacker cum reclaimer (SCR) bucket wheel shaft assembly at the SEIL P 1 Coal Handling Plant (CHP). Formerly, replacement of the Drive End (DE) bucket wheel bearing required complete dismantling of the bucket wheel from the shaft, resulting in approximately five days of machine outage and significant resource demand.

By redesigning the shaft and introducing split sleeve, the DE bearing can now be installed directly from the DE side without dismantling the bucket wheel. This modification has reduced task duration from five days (≈120 hours) to two days (≈48 hours), lowered manpower requirements by nearly 60%, improved equipment reliability, delivered substantial cost savings, and minimized execution risks. The modification not only streamlines maintenance practices but also enhances operational resilience, offering a scalable solution that can be replicated across similar assets to standardize efficiency gains.

Innovative Approach to Address Design and Other Critical Issues of CHP Equipment Enabling Overall Enhancement of System Availability at NTPC Mouda

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Innovative Approach to Address/Eliminate Root Cause of Critical Equipment Breakdown Specially Wagon Tippler, Crusher & Stacker at CHP, NTPC Mouda.

This paper presents a series of innovative, low-cost engineering modifications implemented at NTPC Mouda's Coal Handling Plant (CHP) to address chronic equipment failures and improve overall system availability. Key interventions targeted critical equipment such as apron feeders, wagon tipplers, crushers, and stacker-reclaimers. Design shortcomings like stress concentration, inadequate structural support, improper chute profiles, and undersized fasteners were identified as root causes of repeated breakdowns. Solutions included adding metallic washers to prevent roller misalignment, chamfering counter shafts to eliminate fatigue failure, strengthening plummer block supports, increasing coupling bolt diameters, reinforcing wagon tippler pivot flanges, modifying crusher chute inclination, and structurally strengthening stacker-reclaimer frames and rail supports. These modifications significantly reduced failures, maintenance frequency, and downtime, while improving reliability, safety, and housekeeping. Many improvements were reviewed and accepted by OEMs and adopted as standard practice, demonstrating how site-driven engineering solutions can deliver substantial performance gains without major capital investment.

Application of Solver Method to Achieve Cost-Effective Blending of Multigrade Coal. A Strategic Approach Toward Quality and Reliability

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Coal-fired thermal power plants in India face persistent challenges in managing multigrade coal with wide variations in GCV, moisture, and ash content. These inconsistencies adversely impact combustion efficiency, Specific Coal Consumption (SCC), and boiler reliability. This paper presents a Coal Stockyard Management System (CSMS) integrated with an Excel Solver-based optimisation framework to scientifically determine daily coal blending quantities under multiple property constraints. Using GRG non-linear programming within Excel Solver, the system computes optimal proportions of coal from different sources to achieve target GCV while minimizing cost, subject to limits on ash, moisture, imported coal share, and stock availability.

The Solver-driven blending plan transforms traditional trial-and-error practices into a structured, data-based process, ensuring consistent fuel quality and reliable boiler operation. By embedding grade-wise segregation, GCV mapping, FIFO reclaiming, and systematic monitoring into the CSMS, the approach enhances transparency and operational discipline in coal yard management. Preventive measures against weathering and predictive monitoring of coal piles further safeguard fuel quality.

Results demonstrate that the Excel Solver-based methodology reduces Energy Charge Rate (ECR), stabilises SCC, and lowers ash handling loads, thereby improving both economic efficiency and environmental compliance. More importantly, this integration of Solver optimisation with coal yard practices adds a new dimension of quality assurance and reliability in power generation, offering a replicable model for utilities striving to balance cost-effectiveness, fuel security, and sustainability in India's evolving energy landscape.

Automation and Integration of Coal Supply Chain-A Digital Leap in Thermal Power Efficiency

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This paper presents the conceptualization and implementation of a fully integrated digital platform for automating the coal supply chain at the 2×300 MW GMR Warora Energy Limited (GWEL) thermal power plant. The initiative addresses inefficiencies in conventional coal logistics, which relied on manual processes for documentation, weighment, sampling, and reporting resulting in delays, data inaccuracies, and operational bottlenecks.

The solution introduces end-to-end digitization of coal movement across rail and road modes, integrating multiple subsystems and advanced technologies, including:
• OCR-enabled challan digitization at mine-end to eliminate manual entry errors.

• FastTag and Facial Recognition System (FRS) for digital gate pass and security.

• Man-less weighbridge automation for accurate gross/tare weight capture.

• Geo-fenced GPS tracking for trucks to ensure route compliance.

• Laboratory Information Management System (LIMS) for real-time coal quality analytics.

• Integration of Third-party coal sampling data from mines at loading end.

• Wagon Tippler API integration for automated rail unloading data.

• Automated GRN process with SAP

• Auto-generated MIS dashboards for coal quality, consumption, and logistics performance.

• Form 15 generation for statutory compliance.

• AOP (Annual Operating Plan) integration for planning and performance tracking.

• Ash Portal for ash reporting and compliance.

This transformation sets a benchmark for coal supply chain automation in India, delivering measurable gains in efficiency, cost optimization, and governance. It demonstrates how AI-driven automation, IoT-based tracking, advanced analytics, and seamless ERP integration can revolutionize resource management in the power sector, paving the way for scalable adoption across other generating units.

Session-12:

Power Plant Chemistry

Enhancing Reliability of Condensate Polishing Systems through Modified Mixed Resin Storage Vessel (m-MRSV) Integration

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Maintaining stringent steam-water chemistry in sub-critical and super-critical thermal power plants is essential for operational reliability, equipment longevity, and efficiency. Condensate Polishing Units (CPUs) play a pivotal role in achieving high-purity feed water by removing suspended and dissolved contaminants. However, the existing regeneration schemes employing CONESEP technology pose significant challenges, including clogging of fragile porous discs due to crud accumulation and mechanical stress during cleaning cycles, leading to compromised functioning, failure and high maintenance costs.

This paper proposes an innovative modification to the CPU regeneration system by incorporating a Modified Mixed Resin Storage Vessel (m-MRSV). The m-MRSV serves as a pre-cleaning vessel for crud-laden exhausted resin, equipped with air blowing and backwash features, thereby reducing resin caused fouling before separation in the Anion Regeneration Unit (ARU). This approach safeguards the CONESEP disc, minimizes regeneration time, and enhances system reliability. A proposed pilot study at NTPC Korba demonstrates that the proposed scheme can significantly reduce operational risks and avoid expenditure on mandatory spares, estimated at 32(appox.) crores across stations during last seven year. The integration of m-MRSV ensures sustainable CPU performance, improved operational flexibility, and compliance with stringent chemistry standards, thereby supporting uninterrupted power generation.

A Novel High-Performance Thermal Analysis Method for Active Content Determination of Cooling Water Treatment Chemicals

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This paper presents a novel and robust method for determining the active content of phosphonate anti-scalants and acrylic polymer dispersants using simultaneous thermal analysis (STA). The method identifies active components and impurities based on their characteristic thermal decomposition and mass-loss behaviour at different temperatures. Validation using reference standards demonstrated good accuracy and robustness. Compared to conventional analytical approaches, the STA method is simple, rapid, and suitable for routine quality assessment of cooling water treatment chemicals.

The STA-based method enabled reliable quantification of active content in water-based cooling water treatment chemicals containing approximately 40–60% water. Mass loss observed up to 150 °C was primarily attributed to free water and water adsorbed onto the polymer matrix, including loosely and tightly bound fractions, as well as minor volatile organic impurities. Consequently, the residual mass at 150 °C was considered the true active content of the products. For acrylic polymer dispersants, the STA thermograms exhibited a distinct thermal event with a characteristic peak in the range of 140 to 146°C, corresponding to the presence of residual monomer impurities (acrylic acid). The intensity of this peak and the associated mass loss enabled clear differentiation between the true polymer fraction and unreacted monomers, which are known to adversely affect dispersant performance and fouling control. This approach enables effective screening of raw materials and ensures high-quality chemicals are used in the cooling water system for high performance and cost effectiveness.

Cooling Tower Effectiveness Improvement by Online Chemical Cleaning Using LABSA

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Cooling tower (CT) fills in coal-fired thermal power plants progressively foul due to carbonate scaling, mixed silicate deposition, and biofilm accrual, which increase hydraulic resistance and reduce evaporative heat rejection. We present an online chemical cleaning methodology employing Linear Alkyl Benzene Sulphonic Acid (LABSA) as a dual-function acidic surfactant. Laboratory soaking of representative fouled fill coupons across LABSA–water dilutions (1:1–1:6) and field implementation at APL, Tirora demonstrate a performance optimum at 1:4 (~23% w/w LABSA), producing ~25% mass reduction on test coupons and measurable improvements in circulating water (CW) outlet temperature, condenser vacuum, and station heat rate (SHR). Mechanistically, deposit removal is attributed to proton-promoted dissolution of calcium carbonate and disruption of biofilm matrices, with surfactant action facilitating detachment of entrained solids. The procedure mitigates damage risk associated with mechanical cleaning, is operationally efficient, and yields an economic payback of ~29 days for one unit. We discuss safety controls, environmental handling, limitations of the present dataset, and a research agenda for statistically robust validation and scale-up.

Enhanced Condensate Polishing Plant Design for Air-cooled Condenser Based Thermal Power Plants

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Condensate polishing systems in air-cooled condenser (ACC) based thermal power plants present unique operational challenges distinct from water-cooled condenser configurations. This paper presents systematic design improvements in Condensate Polishing Plant (CPP) systems based on comprehensive operational learnings from early ACC installations in India.

During initial phases of operation of these supercritical units, critical issues were observed: (1) dramatically increased frequency of mixed bed (MB) regenerations due to rapid resin exhaustion, leading to severely decreased Output Between Regenerations (OBR) - only 3-4 days actual versus 30 days design expectation; (2) higher than anticipated loading of ammonia (used for pH control), crud (corrosion products), and total dissolved solids (TDS) in the CPP influent stream, particularly during startup and load variations; (3) premature MB resin exhaustion due to direct exposure to cationic contaminants without upstream protection; and (4) regeneration bottlenecks in multi-unit configurations with shared facilities.

Based on root cause analysis, major design modifications have been standardized: (1) Addition of dedicated lead cation exchanger vessels upstream of each mixed bed polisher, creating a two-stage polishing configuration that protects MB resins from ammonia, hardness, and sodium loading, extending service runs from 3-4 days to guaranteed 30 days (720 hours); (2) Enhanced pre-filtration with 3x50% auto-backwashable cartridge filters (20 μm for commissioning, 5 μm for normal operation); (3) Dual-stream regeneration system for multi-unit configurations with independent processing capabilities for MB and lead cation resins; and (4) Refined influent quality specifications based on actual operating data.

The enhanced design delivers: more than 7x improvement in MB OBR, reduction in MB regeneration frequency, reduction in chemical consumption, improvement in resin operational life, and increase in system availability. These improvements represent evolutionary advancement in CPP design philosophy for ACC-based power plants, ensuring improved reliability, reduced lifecycle costs, and consistent achievement of stringent water quality requirements for modern supercritical boilers.

Enhancing Boiler Feedwater Pretreatment Performance through Ceramic Ultrafiltration: A Power Plant Retrofit Case Study

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Zhejiang Hengyang Thermal Power Company, a 60 MW coal-fired power plant in Zhejiang Province, China, experienced persistent operational challenges with its existing polymeric ultra-filtration (PUF) system used for boiler feed water pre-treatment. Frequent membrane fouling, fibre breakage, sub-optimal permeate quality, and high chemical and maintenance requirements led to repeated system downtime and adversely impacted the performance and lifespan of the downstream reverse osmosis (RO) system—particularly during periods of high turbidity and peak operational demand.

To overcome these limitations, the plant retrofitted its pre-treatment process with Acuriant ceramic ultra-filtration (CUF) CUF|Shield membranes. The retrofit replaced the PUF and multimedia filtration units while retaining most of the existing infrastructure, including pumps, piping, and backwash systems. Due to the significantly higher flux capability of ceramic membranes, only half the number of UF modules were required to meet both current and peak capacity demands, enabling a compact and efficient system upgrade with minimal mechanical modification. Following implementation, the CUF system delivered substantial improvements in performance and reliability. The plant achieved consistent operation at twice the throughput of the previous polymeric UF within the same footprint, with stable permeate quality characterized by SDI values below 2 and turbidity typically under 0.1 NTU. Overall water recovery increased to over 95 percent, while cleaning frequency was reduced from monthly to semi-annual intervals. These enhancements resulted in lower chemical consumption, reduced operating costs, extended RO membrane life, and significantly improved operational resilience, demonstrating ceramic ultra-filtration as a robust and cost-effective pre-treatment solution for thermal power plant applications.

Session-13

TG & Auxiliaries

Advanced Vibration Diagnostics for Fluid-Induced Instability in Steam Turbines

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Fluid-induced instabilities such as oil whirl, oil whip, and steam whirl continue to pose significant operational challenges for large steam turbine–generator units operating under high-load and flexible dispatch conditions. These instabilities are characterized by self-excited, sub-synchronous vibrations originating from cross-coupled fluid forces in journal bearings, seals, and steam flow paths, and are largely independent of rotor unbalance. Although the underlying mechanisms are well established in classical rotor dynamic theory, correlating analytical stability criteria with field behaviour in large utility machines remains limited.

This paper presents a unified interpretation of fluid-induced instability based on complex dynamic stiffness concepts, explicitly linking direct and quadrature stiffness degradation to the threshold of stability. The theoretical framework is validated using detailed field evidence from multiple 660 MW utility steam turbine units operating at high load. Load-dependent bearing unloading, reduction of effective damping, and increased seal-induced cross-coupled forces are shown to collectively reduce stability margin and trigger sub-synchronous instability. Diagnostic signatures derived from vibration spectra, orbit plots, shaft centreline behaviour, and bearing metal temperature trends are presented and correlated with stability theory. Practical mitigation measures aimed at restoring damping and shifting the stability threshold beyond the operating range are discussed. The combined theoretical–experimental approach provides a robust diagnostic methodology applicable to large utility steam turbines operating under modern flexible duty cycles.

Reliability Improvement by Eliminating Water Accumulation in ACC Hot Duct

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This paper presents a case study of a critical technical issue encountered during the initial operation of the unit at PVUNL Patratu. It also highlights the various operational challenges faced in the Air -Cooled Condenser (ACC) system at PVUNL Patratu.

During the initial operation of the unit, repeated incidents of water accumulation were observed in the hot duct and hot box of the ACC during High Pressure (HP) heater charging. This accumulation occurred on multiple occasions, with water levels rising to approximately 8–10 m. The excessive water head generated severe mechanical forces on the bellow joints, leading to the failure of the longitudinal joints of the compensators. The issue was prominently noticed during the unit tripping on complete power failure, when the water circulation by means of drain pumps stopped. This failure occurred twice prior to trial operation and posed a serious risk of collapse of the entire duct system, potentially resulting in extensive damage to the ACC.

A detailed investigation was carried out to identify the root cause of the issue, which included improper sizing of the drain tank, incomplete commissioning of drain tank discharge and RC circuit. It was determined that the water accumulation in the hot box was caused by an increase in the enthalpy of water in the drain tank due to the ingress of high-enthalpy steam from the HP heater alternate drips during charging. This led to evaporation within the drain tank, resulting in abnormal water carryover and subsequent accumulation in the ACC hot duct and hot box. The similar issue was also faced at other NTPC stations.

Based on the analysis, several operational and engineering modifications were implemented to prevent such evaporation in the future. These engineering interventions have successfully ensured safe operation of the unit. Following the modifications, the HP heaters have been charged multiple times without any recurrence of the issue.

This paper discusses in detail the analysis of operating parameters, observations, and engineering considerations that led to the identification of the root cause and the development of an effective, reliable and sustainable solution.

Steam Turbine Operational Issues and Design Considerations for Super critical Units

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The rapid expansion of supercritical 660 MW and 800 MW steam turbine fleets has brought significant improvements in power generation efficiency; however, it has also introduced new reliability challenges under elevated pressure–temperature operating regimes. The availability of these high-capacity turbine-generator sets is strongly dependent on their ability to perform consistently across all operating conditions, including transients and part-load operation. This paper presents a detailed failure analysis of an uncommon yet critical field issue observed at MUNPL Meja 660 MW Toshiba unit, where severe circumferential surface damage was detected on the Intermediate Pressure Turbine (IPT) rotor at the oil deflector regions of Bearings #3 and #4 during a planned overhaul. Inspection revealed a deep groove of approximately 36 mm width and 37 mm depth at Bearing #3, along with a comparatively smaller groove of 25 mm width and 11 mm depth at Bearing #4.

The investigation establishes that the damage mechanism was progressive and multi-physics in nature, driven by lubricating oil carbonization at the oil deflector fins. Air ingress into the deflector pocket enabled contamination by insulation dust and airborne particles, accelerating oil degradation and forming hardened deposits ("oil cake"). These deposits reduced clearances, initiating soft rubbing that escalated into sustained metal-to-metal contact. Under high contact stress and elevated local temperature, adhesive wear (galling) developed rapidly due to the inherent galling susceptibility of 12% chromium martensitic steel, resulting in deep grooves, smearing, and raised material lips.

The paper further compares galling behaviour of 12-Cr martensitic steel with Low-Cr–Mo–V steel and recommends practical preventive measures, including oil quality control, oil deflector design optimization, contamination ingress prevention through air sealing, and surface engineering solutions to enhance long-term turbine reliability.

Steam Turbine Heat Conservation System – A Solution for Increased Operational Flexibility

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With the increasing shares of renewable energy in the grid, thermal power plants are required to operate far more flexibly than originally engineered, with more frequent load cycling and a higher number of start-ups. To remain competitive in modern power markets, operators must simultaneously reduce start-up times, limit lifetime consumption of critical components, and lower operating costs. A key challenge in this context is the growing number of steam turbine cold starts, which are associated with long start-up durations, increased thermal stresses, accelerated rotor lifetime consumption, and elevated start-up costs.

This paper presents the development of the Steam Turbine Heat Conservation System that provides a measure to help reduce the number of cold starts by enabling a shift towards warm start-up operation.

The Steam Turbine Heat Conservation System concept uses controlled heating and thermal management of the steam turbine during shutdown and standstill periods to maintain the rotor and casing within a favorable temperature range. This allows subsequent start-ups to be performed as a warm start instead of a cold start.

The developed solution can be applied to both new build and service applications covering both reaction- and impulse technology steam turbines.

Utility Steam Turbine Valve Servicing – Siemens Energy (KWU) Experiences and Latest Developments with Service Innovations

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The reliability and efficiency of old steam turbine components including Steam Turbine (ST) valves, decreases with time because of aging, wear & tear, solid particle erosion (SPE), erosion-corrosion, deposits, foreign object damage, etc.

Furthermore, modern energy mix demands the changing power grid requirements, like increased number of fast starts, flexible load changes or low load operation. This results in, requirements for the steam turbine inlet admission valves to follow…to align/adapt such changes.

Because of such probable changes in operational pattern, highly stressed major ST components like inlet valves are likely to be exposed/vulnerable to the risk of findings/failures and may require long time for component repair or replacement, if a pre-planned “Turbine Maintenance & Service (TMS) Plan/Strategy” is not in place either from bidding or after commissioning of the ST Units.

The aim of this paper is to briefly summarize the Siemens Energy (SE) best practices during periodic ST valves services, developed by ST Service Engineering, to increase the turbine valves availability, reliability & performance and further its evolvements i.e. the on-going developments in this regard.

This paper provides a general short overview of SE best practices for servicing of ST inlet valve parts based on Service Engineering operational experiences worldwide and considering the available refurbishment methods/technologies & innovations including nondestructive testing (NDT), in-situ weld repair & unit specific operational risk assessment (High/Medium/Low).

Case Studies on Generation Losses in Solar Power Plants: An O&M Perspective

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Maintaining solar assets throughout their operational life is essential to achieve the designed generation targets and ensure a favorable return on investment. While the quality of installed equipment plays a significant role, the overall performance of a solar plant largely depends on the quality and precision of erection and commissioning, and more importantly, on how effectively the plant is operated and maintained from the start of commercial operations.

This paper highlights select examples from this extensive experience—showing how systematic diagnostics and targeted interventions restore generation and reduced CUF deviation. To mitigate the risk of failures and to avoid wastage of unutilized solar power, the paper advocates for the adoption of AI-powered diagnostic tools to analyze real-time SCADA and other sensors data to detect deviations and predict component failures, predictive cleaning systems utilizing environmental sensors and machine learning to optimize cleaning schedules. A 10 MW ground-mounted plant demonstrated severe performance collapse, with output falling from 15.8 MU (2014) to 7.73 MU (2025), and CUF declining from 18.05% to 8.84%. Root cause analysis identified DC capacity degradation caused by module cracks, hotspots, and defective cell connections, accounting for a 2.65 MW capacity loss. Furthermore, inverter issues such as high leakage currents delayed auto wake-up times, exacerbating soiling losses by disrupting cleaning cycles. A major fire incident further reduced capacity by 2.2 MW due to delayed emergency response caused by poor road access. The study outlines a recovery plan to restore CUF to 14–15%, projecting an annual revenue gain of ₹1.3–1.6 Cr.

Floating solar projects presented unique infrastructure challenges. A 56 MW plant recorded significant CUF deviations when compared to actual versus GHI corrected targets, which were mitigated through root cause analysis and efforts put in by the team, resulting in generation gains from subsequent period. Conversely, cable failures plagued other floating installations. A 25 MW project lost 7.87 MU due to 74 instances of underground cable failure in a single year; implemented solutions successfully eliminated subsequent tripping.

Renewable Energy & BESS: Li-ion thermal runaway – the critical challenge

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The accelerated deployment of Battery Energy Storage Systems (BESS) to support renewable energy integration has heightened concern over thermal runaway in lithium-ion (Li-ion) batteries, a failure mode capable of producing high-temperature fires, toxic off-gases, and propagation across modules. This paper presents results from the FirePro R&D program involving controlled full-scale BESS and modular tests across multiple Li-ion chemistries and formats. FirePro's condensed aerosol fire suppression technology has consistently demonstrated its effectiveness to knock down the flames, significantly reduce heat, control and interrupt the propagation of thermal runaway to nearby Lithium-ion batteries and neutralize flammable and explosive gases. The findings confirm the applicability of condensed aerosol technology as a mitigation strategy for thermal runaway events in Li-ion energy storage systems.

Designed to Test: Integrating Performance Verification into Modern PV Project Design and Operation

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Utility-scale PV plants continue to grow in size, scale, and system complexity, increasing the difficulty of verifying performance under real operating conditions. Curtailment, variable albedo, tracker control behavior, hybrid PV-storage dispatch, heterogeneous module technologies, inconsistent inverter programming, and unreliable data architectures all interfere with clean, repeatable testing. Common contributors include SCADA systems that are not configured for transparent data access, insufficient or poorly located meteorological stations, and incomplete capture of key guaranteed parameters such as module temperature, soiling, and electrical losses, amongst others. Together, these factors drive uncertainty in both technical conclusions and commercial outcomes.

The forthcoming revision to ASME PTC 46 includes, for the first time, a mandatory appendix dedicated to utility-scale solar photovoltaic plant testing, providing standardized methods for plant-level capacity and energy performance verification. This paper applies the “designed to test” philosophy from ASME performance testing practice to modern utility PV systems, demonstrating how testability must be embedded into project development, contracting, and design rather than addressed reactively during commissioning. Field cases illustrate strategies to manage uncertainty, align test and commercial boundaries, and maintain traceable measurement quality. The paper concludes with a practical framework and checklist for designing PV assets that are truly ready to test, defend, and operate with confidence.

Hydropower Flexibility as a Key Enabler of Energy Transition: Challenges and Opportunities

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India's rapid expansion of renewable energy, particularly solar and wind, has fundamentally changed the operational landscape of thermal and hydro generation. The increasing variability and intermittency of RE have elevated the importance of flexibility, making hydro and gas-based power plants pivotal in ensuring grid reliability, inertia, and fast-ramping capability.

Hydropower, with its unmatched response time, storage potential, and ability to provide primary, secondary, and tertiary reserves, is emerging as a central resource in India's evolving low-carbon system. Gas-based plants, despite limited utilization in recent years, offer complementary fast-start characteristics essential for managing sudden fluctuations.

This paper presents an integrated perspective on hydro and gas flexibility, drawing on operational data, IEGC-2023 requirements, AGC performance, the 9PM-9MIN grid event, and future projections. It examines challenges and modernization needs and highlights pathways to unlock the full potential of flexible hydro and gas assets in India's future grid.

Toward a National CO_2 Pipeline Network in India: Techno-Economic Insights, Safety Risks, and Policy Guidelines

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Carbon Capture, Utilization, and Storage (CCUS) is increasingly recognized as a critical technology for achieving deep decarbonization in hard-to-abate industrial sectors, particularly in emerging economies such as India. While notable progress has been achieved in CO_2 capture technologies and in the assessment of geological storage potential, the availability of safe, efficient, and cost-effective CO_2 transportation infrastructure remains a key enabling challenge for large-scale CCUS deployment. Among available transport options, pipelines are considered the most viable solution for continuous, high-volume CO_2 transfer; however, pipeline design and operational performance are strongly influenced by the thermodynamic phase of CO_2 during transport. This study presents a comparative techno-economic and safety assessment of gaseous-phase and supercritical-phase CO_2 pipeline transportation under Indian industrial and regulatory conditions. A representative case study involving the transport of 1.0 million tons per annum of CO_2 over a 25 km onshore pipeline is analyzed using consistent design assumptions, including compression configuration, pressure-drop constraints, and material specifications. Hydraulic performance, compression energy demand, capital and operating costs, and safety risk characteristics are evaluated for both transport modes. The results show that gaseous CO_2 transport requires larger pipeline diameters but offers lower compression energy demand and reduced operating expenditure. In contrast, supercritical CO_2 transport enables smaller pipeline sizes and lower initial capital investment, while incurring higher energy consumption and more complex safety risks associated with high-pressure operation. The study highlights key trade-offs between capital cost, operating efficiency, and safety, and provides quantitative insights to support informed decision-making and the development of CO_2-specific pipeline guidelines essential for India's CCUS roadmap.

Wet FGD performance considerations and alternative technologies

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As power producers continue to operate their plants under reduced load conditions for extended time periods or under high and low load demand, operators must adjust their systems to continue reliable and safe operation. EPRI reviewed past studies for coal-fired plants equipped with wet FGD and that operated at extended low-load or under flexible load demand. In general, three categories of FGD performance variables are those that can be directly controlled, such as absorber pH, slurry density, and number of pumps in-service; those that operators have limited control such as reagent properties, solution chemistry, mechanical factors, and water management; and those that operators have little to no control over such as, absorber inlet flue gas temperature, flue gas flow rate, incoming species concentrations from coal quality changes, and finally boiler operation mode. This paper provides an overview of the primary issues identified from the study and discusses potential workarounds or solutions.

Transforming plastic waste into CO_2 capture material- An Innovative solution for efficient carbon capture

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Changes in atmospheric carbon dioxide levels could substantially alter the surface temperature through the greenhouse effect. Carbon dioxide increases in Earth's atmosphere contribute to global warming. Carbon emission Trading, which involves the buying and selling of carbon credits, represents a quantified reduction in carbon dioxide or other greenhouse gas emissions.

We propose an innovative solution for efficient carbon capture by using plastic waste. This method addresses two major environmental problems simultaneously: Plastic Pollution and CO_2 emissions, offering a potential pathway toward net negative emissions.

An in-house idea devised for the reduction of CO_2 emissions by chemical absorption method and thereby has potential for accumulating carbon credits and a huge monetary benefit. A chemical upcycling of PET waste into useful materials for CO_2 capture via ammonolysis. The ammonolysis reaction producesa bis-aminoamide (BAETA) and oligomers—exhibit high CO_2 capture capacity up to 3.4 moles per kilogram as a stand-alone organic solid material. BAETA shows strong chemisorption featuring high selectivity for CO_2 capture from flue gas (5 to 20% CO_2) and ambient air (~400 parts per million CO_2) under humid conditions. BAFTA is a thermally stable material (>250°C).

Basic plan is to pass flue-gas through a chemical absorption tank filled with solid CO_2 sorbent called BAETA. The CO_2 present in the flue-gas was captured by this BAETA molecule. The CO_2 stored Blocks can be supplied to vendors for manufacturing products like Biofuel, Methanol, formic acid & urea. It has proven reusability, retains performance after >100 capture–release cycles. The project is in line with NTPC's brighter plan – 2032 where the target for decarbonization is 713.74 gm/kwh by 2032 and thereby contributing towards India's target for net zero emissions by 2070.

From Viability Gap Fundings (VGFs) to Profits: How MSW based Green Charcoal can Fix the Economics of India's Waste Sector

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India confronts a dual strategic challenge: managing an urban waste crisis where 160 million tonnes of MSW are generated annually (with 73% landfilled and metro sites saturating in 2–5 years), while simultaneously steering its massive coal based thermal fleet toward Net Zero targets and reducing a imported coal dependency.

Despite aggressive policy support for Waste to Energy (WTE) sector, including ₹5 Cr/MW subsidies and preferential tariffs of ₹7.5–9.75/kWh, WTE sector has failed to deliver financial viability. Historically, only 10 out of 78 planned plants have sustained operations, with critical failures like the Okhla plant (emitting dioxins 890% over limits) and the Mandur plant (₹73 Cr losses) proving mass incineration unsuitable for wet Indian waste.

This paper evaluates WTE against MSW-green charcoal co-firing, and the analysis demonstrates that if a plant like NTPC Dadri (1,820 MW) adopts a conservative 0.5% co-firing blend, it effectively processes ~220 tonnes of raw MSW per day (via 55 MT of Green Charcoal) without degrading boiler efficiency. This model slashes CAPEX by 33% compared to WTE (₹247 Cr vs. ₹370 Cr for 600 TPD capacity) and results in a minimal generation cost increase of ~₹0.14/kWh, yielding a competitive blended tariff of ~₹4.59/kWh. The findings argue that unlocking co-firing scale (potential for 6–8M tonnes/year processed) is the optimal path to de-risk Urban Local Bodies (ULBs) and accelerate the power sector's green transition ahead of 2026 policy deadlines.

Carbon Accounting in Green Belt - A Study in Mejia Thermal Station, DVC

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For combating twin objectives of environmental issues mainly in NCR region due to stubble/biomass burning and reducing greenhouse gas emissions for achieving target of Net Zero by 2070, National Biomass Mission promotes biomass co-firing with coal in coal based thermal power plants in India. Torrefaction of biomass improves the milling/combustion properties and in turn higher biomass coal co-firing ratio can be achieved. The technology of torrefaction in India is in nascent stage and various technologies are being used in small scale to produce torrefied biomass. To meet the requirement of thermal power plants for achieving higher co-firing ratio, development and standardization of technologies is required. Torrefaction of agri-waste as well as torrefaction of municipal solid waste leading to solid biofuel resembling coal and can be co-fired in TPPs with higher percentage as compared to non-torrefied biomass co-firing. One screw conveyor-based torrefaction plant integrated with densification and palettization unit has been installed to demonstrate the technology and carry-on further research to see the impact of feedstock, temperature of torrefaction and retention period on the characteristics of Torrefied Biomass.

State-of-the-Art-Sustainability Automation and Intelligence for NTPC Using AI and ML

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Global sustainability disclosures are entering a phase where information must be accurate, consistent across regions, and increasingly forward-looking. For a large power producer such as NTPC, this is challenging because reporting expectations vary across countries, and the climate requirements now demand greater visibility into emissions, risks, and long-term environmental impacts. This project develops an AI-based system that automatically reads sustainability information and estimates emissions at three levels: those directly related to power generation (Scope 1), those associated with purchased energy (Scope 2), and broader ecosystem effects, including fuel extraction and transportation (Scope 3). The solution connects these insights with major reporting frameworks such as BRSR, GRI, CSRD and SBTi, and generates structured outputs suitable for disclosures across India, Europe, and other regions using a single automated platform. A key contribution is predictive modelling that provides early indications of future emissions and environmental performance trends. This helps NTPC shift from retrospective reporting to planning based on forward-looking insights. Early internal testing shows potential to reduce manual reporting effort by 30–40%, improve consistency of disclosures, and significantly shorten document preparation time, especially when multiple frameworks are involved. Overall, the initiative enables NTPC to move from manual document compilation toward digital sustainability intelligence—making information easier to access, communicate and apply for everyday decision-making. In the long term, this supports responsible planning and builds greater confidence in NTPC's transition journey.

Session-16

Flexibilization in Thermal Power Plants

Flexible Operation Implementation, Challenges & Opportunity in Coal based thermal power plant

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In today's rapidly evolving energy landscape, thermal power plants are no longer operated solely as base-load units. With the large-scale integration of renewable energy sources, the operational paradigm of coal-based power plants has shifted towards flexibility, responsiveness, and grid support. As a key contributor to India's power sector, JSW Mahanadi Power Company Limited (JMPCL) recognizes the growing need for flexible operation of thermal power plants. With an installed capacity of 1800 MW, JMPCL is proactively adapting its generating units to operate across a wider load range, respond to rapid grid fluctuations, support renewable integration, and minimize environmental impact—while maintaining safety, reliability, and asset life.

Flexible operation may be visualized as enabling thermal power plants to adjust generation quickly and safely in response to variable demand and renewable intermittency, thereby strengthening grid stability and sustainability.

Need for Flexibilization.

India, under its Intended Nationally Determined Contribution (INDC) submitted to the UNFCCC in 2015, committed to achieving 40% of cumulative installed electric power capacity from non-fossil fuel sources by 2030.Estimated renewable potential: ~1050 GW, Present installed renewable capacity: ~114 GW, Solar: ~62 GW, Wind: ~42 GW i.e. Target by 2030: ~450 GW.

Role of Thermal Power Plants

Given the intermittency of renewables, flexible operation of coal-based generating units is essential to ensure:

• Grid security and reliability

• Frequency control and balancing services

• Reliable power supply during renewable variability.

Flexible Operations Challenges and Opportunities in Coal-Based Power Plant of 660 MW Supercritical Units of JPVL

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Renewables, with a share of almost 50 % percent of the installed capacity of India till Nov. 2025, have already surpassed the thermal plant capacity, are now fast catching up to be the major share power generation source. India's primary renewable energy goal is achieving 500 GW of non-fossil fuel capacity by 2030, a target it's actively progressing towards, having already hit 50% non-fossil power capacity ahead of schedule. Key strategies include massive solar expansion (aiming for 280 GW solar by 2030), promoting green hydrogen via the National Green Hydrogen Mission, boosting battery storage, and supporting wind power, all while working towards a Net Zero goal by2070.

Central Electricity Authority of India (CEA) has released the Gazette notification dated: 30 Jan 2023, all coal fired thermal power plant need to be operated with flexible operation with increase in Renewable Energy Sources (RES). The RES has environmental advantage over the coal fired thermal power plant. This notification is applicable for all new upcoming thermal power plants and already operating thermal power plants in India. As per the Gazette notification, all coal based thermal power generating units shall be capable of providing flexible operation as per the grid requirements. The new operations standard has set the ramp rates requirements as well as minimum operating level with exclusive coal for all new upcoming units and already operating units.

This paper covers the issues being faced by the various Utilities of Indian power sector due to flexibilization which were originally designed for base load operation, premature failures of the equipment, either already taken place or are expected to happen if the units are continued to be operated in this new regime. The flexible operation was carried out at Nigrie Power Plant of JPVL, which is a Supercritical plant of 2*660 MW and tested for ramp rates of 1 %, 2 % and 3 %. The paper brings out the issues faced during the implementation of the study. The present scenario is the harsh reality of Indian Power Sector, though had already been in vogue in the countries of US and Europe. The paper also discusses the cautious approach the sector should take to ensure grid stability, security as well as uninterrupted power supply to the customers ensuring minimal forced outages of Power Plants on the account of flexibilization.

India's Energy Transition, Flexibilization Challenges & Opportunity at Mundra UMPP, Tata Power

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The integration of solar and wind energy has introduced significant variability in the daily load curve. During midday, solar generation peaks, reducing the demand for thermal power. Conversely, in the evening, thermal plants must ramp up quickly to compensate for the drop in solar output. This operational challenge necessitates flexible coal plant operation, including faster ramp rates and lower minimum load capability, to maintain grid stability. Since renewable energy is considered "must-run" or free power, the resulting load reduction for thermal plants is inevitable.

Complete Cycle Optimization and Flexibility for Combined Cycle Power Plants

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The ARNOLD advanced Steam Turbine Shell warming System electrically maintains the Steam Turbine in Hot start condition during shutdown which significantly reduces Plant Startup time, safes fuel and emissions on the Gas Turbine due to decreased pre-warming run time. It monitors and controls the rotor elongation, eliminates the top to bottom casing differential, significantly reduces fatigue and thermal stress of the turbine components as well as casing and valve cracks. Due to improved single layer Insulation which is part of the System also the turbine compartment temperature drops up to 50%. With our latest case study of an installed warming system, we could show the improvements and savings in concrete numbers.

AI-enhanced Flexibility Health Monitoring Framework for a 660mw Solapur Supercritical Unit Using Multi-Index Stress Modelling and Machine Learning

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Coal-fired supercritical units originally designed for base load operation are increasingly required to support renewable-rich grids by performing rapid load ramps, deep turndown, and frequent cycling. These flexible operating modes impose complex thermal–mechanical stresses across boiler, turbine, combustion and auxiliary subsystems. Conventional DCS trends and threshold-based alarms cannot represent the multi-dimensional nature of these stresses, nor anticipate when they will escalate during dynamic operation.

This paper presents an AI-assisted Flexibility Health Monitoring Framework developed using one month of 1-minute PI data from the 660 MW Unit-1 of NTPC Solapur. A suite of physics-based indicators—Ramp Stress Index (RSI), Thermal Gradient Index (TGI), Spray Stress Index (SSI), Valve Activity Index (VAI), Mill Cycling Index (MCI), Draft Stability Index (DSI), O□ variance, Air–Fuel Ratio (AFR) deviation, fan loading per MW, and vacuum deviation—were engineered and combined through robust statistical scaling into a unified Flexibility Health Index (FHI). A supervised machine-learning model was trained to predict high-stress windows 5 minutes ahead, achieving an AUC of 0.92, precision of 0.81, and high interpretability through feature importance analysis. The model reveals that stress primarily emerges from the interaction of ramp intensity, spray modulation, steam temperature gradients, combustion variability, draft fluctuations, valve activity and cycle-side disturbances. A real-time dashboard architecture is proposed that integrates FHI, stress indicators, predictive alerts, and operator guidance. The framework provides a scalable digital O&M tool for reducing fatigue damage, improving operational reliability, and enabling safer flexible operation across the NTPC fleet.

Session-17

BoP (Balance of plant)

Experience, Learning and Strategies to achieve Eco Friendly Generation with Dry Bottom Ash System

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In alignment with India's evolving environmental regulations and NTPC's commitment to sustainable and eco-friendly power generation, Dry Bottom Ash (DBA) technology has been adopted as an alternative to conventional wet bottom ash handling systems. The first-of-its-kind implementation of DBA system at Patratu Vidyut Utpadan Nigam Limited, Patratu, marked a significant transition toward water-efficient and environmentally responsible ash management. This paper presents operational experiences, key learnings, and strategic interventions undertaken during the commissioning and stabilization of the DBA system under Indian operating conditions. Initial challenges were encountered in mechanical components such as Plummer blocks, rollers, and chain, primarily due to high ash temperatures causing clinkering and continuous heavy-duty operation. Issues related to Plummer failures, roller wear, and chain elongation highlighted the need for design optimization and adaptive maintenance practices.

Based on root-cause analysis, several corrective and preventive strategies were implemented, including the adoption of higher temperature-rated grease and optimized tensioning mechanisms. Operational strategies were revised, SOP prepared, and training of O&M personnel by OEM. Improved coordination between main plant and AHP operation also contributed to stabilizing DBA and reducing mechanical stress. Environment friendly bottom ash evacuation contingent arrangement fabricated to run the unit at full load prior to failure of 2nd stage DRYCON system, generation loss worth many crores avoided.

The learning-driven improvements resulted in enhanced system reliability, reduced unplanned outages, and sustained dry ash generation suitable for beneficial utilization. The experiences from NTPC's DBA implementation demonstrate that proactive learning, and robust operational strategies are critical to achieving eco-friendly power generation. The study provides valuable insights and a practical roadmap for future NTPC and Indian thermal power projects adopting dry bottom ash technology.

Novel approaches for CW Pumps failure in NTPC Telangana

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Telangana Ph-I CW Pumps have been in a spot of bother since August-2024 as many breakdowns occurred rendering the station without a standby pump. CW Pump No-2 broke down twice, indicating an unsolved mystery, propelling a detailed study to find out potential cause of failure.

After the first breakdown, it was interpreted that the void created in the shaft while drilling a grub screw mounting hole led to the failure of shaft and then leading to sheering of column pipe bolts. However, after the second breakdown, the cause of failure is predicted to be entirely opposite to the initial understanding, indicating that the failure was occurring from bolts sheering happening in the first place, and then leading to sheering of shaft due to an additional load on one direction. Necessary actions have been taken in the third time assembly of the pump to avoid further breakdown.

Underground CW Hot Water Duct Leakage Repair

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Attending underground CW hot water duct leakage is a non-routine maintenance activity involving significant safety risks, limited accessibility, and complex confined space challenges. This paper presents a case study of underground CW hot water duct leakage rectification executed during Unit-2 overhauling at, APCPL, Jhajjar. Due to the underground location, continuous water presence, and single entry–exit access, conventional repair approaches alone were inadequate, necessitating the adoption of multiple innovative repair techniques.

A combination of underwater welding, fast-setting sealant cementing, online sealing through inner surface injection of leaked/cracked duct sections, and traditional welding was employed to arrest the leakage and restore duct integrity. Underwater welding enabled repair of submerged sections without complete dewatering, while fast-setting sealant cementing provided immediate control of active leaks. Online sealing, conventionally applied on external pipe surfaces, was uniquely implemented on the internal surface of the CW hot water duct, demonstrating its effectiveness under confined conditions.

The activity involved critical confined space work, including welding inside the CW hot water duct with only a single entry and exit point. Detailed planning, stringent safety preparedness, continuous atmospheric monitoring, and rescue readiness were integral to successful execution. This paper outlines the triggering factors, qualification requirements, repair procedures, and safety measures adopted, along with a comparative assessment of these techniques against conventional methods. The learnings from this case study provide valuable insights and demonstrate the potential applicability of these repair methodologies across thermal power plants facing similar underground duct leakage challenges.

Evidence from Robotic Sludge Cleaning Deployment

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Sludge accumulation in thermal power plant water bodies can hinder reliability, maintenance, and safety. Traditional removal methods require manual work, exposing staff to risks and causing downtime. Robotic cleaning systems offer a safer, more efficient alternative, reducing hazardous man-hours and improving maintenance predictability. This paper reviews field deployments of robotic systems, evaluating their impact on safety, reliability, and efficiency. Results show improved safety and operational outcomes, suggesting robotics can optimize maintenance strategies and procurement for large power utilities.

Thermal power plants depend on the reliable flow of water, but sludge and silt build-up in reservoirs and channels can hinder performance, increase equipment wear, and raise safety risks. Traditional sludge removal methods manual cleaning and mechanical dredging involve operational disruptions and put workers at risk. As safety standards advance, automation is increasingly adopted in the power sector. Robotic sludge cleaning reduces human exposure and minimises downtime, making it a promising solution for sediment management. This paper shares findings from field deployments of robotic cleaning systems in thermal power plants, focusing on their effects on safety, reliability, and efficiency to guide future maintenance decisions. In summary, while traditional cleaning creates risks and interruptions, robotic cleaning offers a safer and more efficient alternative, as supported by real-world results.

Throughput Enhancement in Existing Ash Handling Systems in Thermal Power Plants with Optimized Ash Feed Control

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The importance of proper ash feeding, such as from "blow tank" or "air lock vessel" in pressure conveying system and ESP/APH hoppers in vacuum conveying system, is just as much as appropriately sizing air movers (compressors and vacuum pumps). It is critical to emphasize that the compressor or vacuum can only do justice to their selection if there is appropriate/matching amount of ash available in the ash transport pipes. This paper results from an experimental program including the pneumatic conveying of 23 ash samples from five power stations of NTPC (Dadri, Mauda, Kaniha, Sipat, Rihand) tested in the pressure and vacuum conveying pilot plants at the institute laboratory. The results show pressure conveying, an optimum selection of pre-pressurization, fluidizing and distribution of top air and conveying air in the blow tank, can increase ash discharge rate by 20 to 40% depending on the types of ash (coarse or fine) and aeration methods. For vacuum system, results show that an optimum combination of operating vacuum, hopper aeration and air intake valve settings can not only improve the ash conveying rate by as much as 30% but also can remove rat-hole formation in case of fine ash, on the other hand prevents blockage in case of highly flooding ash. A guideline will be presented for achieving significant increase in ash flow rate without any capital investment in existing thermal power plants for different types of ash (coarse and fine) by optimizing the operational procedures.

Minimum Technical Load Limit for Gas Turbines: Combined Cycle Operations—Strategies and Challenges

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The ability of gas turbine power plants to operate at minimum technical load while maintaining compliance with emissions regulations, combustion stability, and component integrity has become increasingly critical in modern electricity grids with high renewable penetration. This technical paper presents a comprehensive analysis of minimum technical load (MTL) limitations for combined-cycle gas turbines (CCGT), examining the fundamental constraints, operational strategies, and engineering challenges that govern the lower bounds of stable operation. Combined-cycle plants offer superior part-load performance through steam bottoming cycles but encounter complex interactions between gas turbine exhaust temperature profiles, heat recovery steam generator (HRSG) component stress, attemperator flow limitations, and emissions constraints. This paper synthesizes findings from EPRI case studies and field operational experience to establish practical MTL boundaries and adaption of up-rates to existing MHI 701D machine of NTPC Auraiya by changes in IGV operation logic to bring down CCGT minimum load.

Solar Thermal Integration for Steam Turbine Revival in Gas-Based Power Plants

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Gas-based combined cycle power plants in India are experiencing sustained underutilization due to high natural gas prices, limited domestic gas availability, and increasing penetration of variable renewable energy sources. This has resulted in partial or idle operation of steam turbines (STs) in stations such as Kawas, Jhanor-Gandhar, and Anta, leading to higher station heat rates and elevated energy charge rates (ECR).

This study investigates the feasibility of integrating Concentrated Solar Linear Fresnel Reflector (SLFR) technology with the low-pressure (LP) steam circuit of existing gas-based power plants to revive steam turbine operation, reduce fuel consumption, and improve overall plant efficiency.

The proposed configuration employs direct steam generation (DSG) using SLFR technology, wherein solar-generated steam at suitable LP parameters is injected into the steam turbine system. Plant operational data and heat rate analysis are used to evaluate performance improvement and fuel savings.

Integration of a 5 MW SLFR system demonstrates an increase in steam turbine output by 3–5 MW during solar hours. Analysis indicates a heat rate reduction of 20–30 kcal/kWh, resulting in measurable gas savings, reduced ECR, and improved operational economics without compromising grid dispatch requirements.

The study further highlights the potential of molten salt thermal energy storage, enabling storage of solar thermal energy during daytime and controlling steam generation during evening peak hours. This enhances dispatchability and further reduces reliance on gas-fired generation during peak demand periods.

SLFR-based solar thermal integration offers a technically feasible, economically viable, and environmentally sustainable pathway for revitalizing steam turbine operation in existing gas-based power plants, while supporting grid flexibility and India's clean energy transition.

Technical Paper on Gas Turbine Performance Improvements

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India's power generation matrix has rapidly diversified, exceeding 505 GW of installed capacity by 2025 with over 50% from non-fossil sources meeting COP26 commitments ahead of schedule. However, increasing renewable penetration introduces intermittency and grid-balancing challenges that demand flexible, fast-ramping thermal assets. Gas turbine–based power plants, though currently underutilized due to fuel constraints, offer a critical solution with their superior operational flexibility, rapid start capabilities, and high part-load efficiency.

This paper examines the various environmental and operational factors influencing gas turbine performance including ambient temperature, turbine inlet temperature, altitude, humidity, fuel characteristics, and degradation and quantify their impact on output and efficiency. Practical improvement measures such as compressor washing (online/offline), inlet air cooling (evaporative and chiller systems), and fuel gas heating are discussed, supported by comparative analyses of technologies including vapor absorption and electric chillers. Additionally, enhancements through metallurgical uprates, advanced cooling and sealing designs, and fuel flexibility including hydrogen and bio-fuels are presented as pathways to align existing gas turbine fleets with future decarbonized grids.

Overall, the paper emphasizes that gas turbine performance improvement must be treated as a continuous lifecycle strategy, integrating operational optimization, hardware upgrades, and emerging fuel technologies to ensure reliability, efficiency, and grid support in India's renewable-rich energy future.

Low cost-efficient operation in shifted paradigm for Gas Turbines with Grid Security for India

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India's target of 500 GW of non-fossil fuel capacity by 2030 emphasizes the critical need for efficient renewable energy (RE) integration. However, the variability and intermittency of RE sources pose significant challenges for grid stability. Gas turbines, with their fast start-up and ramping abilities, can play an important role in energy transition and support expanded RE deployment. Despite this potential, India's 25 GW of gas-based power capacity remains under-utilized due to high costs and limited availability of conventional fuels, such as gas and naphtha.

To overcome these issues, alternative fuels such as hydrogen, methanol, ammonia, and syngas present potential solutions for efficient utilization of gas assets while enabling large-scale RE integration. NTPC's initiatives in carbon capture from flue gases to synthesize methanol highlight its potential as a fuel for gas turbines. Methanol firing can promote a circular carbon economy while advancing decarbonization efforts. Compared to conventional fuels, methanol offers advantages such as lower CO_2, NO_x, and particulate emissions, along with absence of SO_2.

Hydro & Gas Power plant: Challenges and opportunities in flexible operations

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The increasing penetration of variable renewable energy sources (VRES) like solar and wind into power systems requires the flexible operation of conventional power plants to maintain grid stability and reliability. Hydropower plants, known for their rapid response capabilities, play a critical role, but fast ramping to meet grid fluctuations presents a major challenge in the form of hydraulic transients and threatens equipment integrity. Solutions with advanced controls significantly enhance flexibility, achieving faster, smoother power changes, and reducing mechanical stress. Furthermore, hydro-generators provide essential rotational inertia due to their large spinning masses, which instantly resist sudden frequency drops.

In contrast, India's gas power sector, despite challenges like fuel constraints and aging assets, is strategically positioned to support grid flexibility and peak power needs. While gas units offer moderate inertia, their typical ramp rate makes them ideal for medium-term needs. The CERC Ancillary Services Regulations (2022) formalize the monetization paths for flexibility. Hydro plants are best suited for the fastest services, PRAS (Primary) and SRAS (Secondary, via AGC), and provide strong reactive/voltage support. Gas plants excel in providing TRAS (Tertiary), leveraging their quick-start capability, making them ideal for sustained deficits and real-time peaking.

Ultimately, enhancing the flexible operation of both plant types is critical, requiring a unified real-time model that integrates the hydraulic dynamics of hydro units with the electrical dynamics of the grid. Modelling them separately is insufficient to capture the true every -second interaction and flexibility potential required in a renewable-heavy power system.

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Innovative O&M Practices

Flexibilization of thermal power plants begins not in the boiler, but in the mill

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Balancing energy transition with flexible thermal generation requires that coal power plants must enhance efficiency and operational flexibility without large investment. This paper presents first comprehensive, India-focused & field-validated study project on ‘Improving mill performance’ through retrofitting dynamic classifiers in existing mills coupled with strategic monitoring & control through AI enabled Mill Performance window, as a low-capex & high-impact intervention. It simultaneously addresses efficiency, emissions, flexibility, and economics and provides actionable insights. Integrating these with payback and environmental impact, it becomes evidence-based decision enabler.

The complete project was carried out in-house highlighting benefits for various unit-clusters separately. Project specialties include site visits (08 nos.), interaction with plant personnel, including technical consultations with four vendors, supplemented by retrofit studies at two plants (Bandel & JSW). Analysis establishes that dynamic classifier retrofit leads to marked improvement in coal fineness, reduction in unburnt carbon, improved NOx management, and increased mill capacity, thereby enabling sustained and stable part-load operation—an essential requirement for thermal plant flexibilization under contemporary grid conditions. Project-uniqueness lies in evaluation-based segmentation of units at 1-10 scale w.r.t retrofit ease, feasibility & economics. A detailed techno-economic assessment for 500–800 MW units indicate payback from 2 to 8 years, with 500 MW units demonstrating superior economics due to higher improvement and shorter payback.

In the end, coal’s renewed role may not be permanent, but it underscores sector’s resilience and reinvention-call by way of smart retrofits towards meeting today’s challenges for balanced energy future. It enables flexibilization without major boiler modification.

Design Changes in SWAS Packages to adapt Flexible Operation in Coal Based Power Plants

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Flexible Operation in Coal based Thermal Power plant is need because of changing cyclic load patterns. Frequent Start-stop, Changing Pressure and Flows in Steam and Water Cycle Imposing new challenges in Water and Steam (WS) Cycle Chemistry.

Flexible Operation going to impose new challenges compare to constant load operation of thermal power plants like:
(1) Higher oxidation Corrosion rates.
(2) Preservation of Boilers and Feed Water Systems during shutdowns
(3) More chances of Carryovers in Steam

Thus, Flexible operation is going to impose multiple challenge on Operation Chemistry and Instrumentation Teams to monitor water chemistry parameters using Steam and Water Analysis System (SWAS).

This Paper is going to concentrate more on "Design changes" required to implement in "Steam and Water Analysis System (SWAS)" to ensure reliable measurement of Water Chemistry Parameters during Flexible Operation in Coal Based Power Plants.

This paper discusses on following two points:
(1) New Online Measurements required in SWAS
(2) Changes required in sampling system design.

Continuous Heat Transfer Mapping for Boiler Performance Optimization and its Integration with Intelligent Soot Blowing

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Effective and continuous monitoring of heat transfer across all the different zones of the boiler is essential for ensuring reliable operation, maintaining thermal efficiency and minimizing fuel consumption. This study provides a comprehensive and effective approach for continuous heat transfer mapping in furnace, radiative, convective and heat recovery sections of a coal fired utility boiler using real time process data and comparison of the same with the original design heat absorption profiles provided. Deviation of actual parameters from the design are used to analyse and identify localised fouling, sub-optimal operating conditions and mal distribution of heat flux. The mapped data is made available to the operation engineers on a continuous basis and is further utilised to optimise key operational parameters including burner tilt, mill loading, secondary air distribution in the furnace and optimization of excess air. Additionally, by pinpointing specific zones with significant deterioration and deviation of heat transfer, this model enables intelligent soot blowing operations thereby minimising excessive steam loss and tube erosion. The proposed methodology demonstrates reduced Gross Heat Rate, enhanced boiler efficiency and increased reliability while providing a predictive diagnostic tool for proactive operation and maintenance.

Biomass Blended Coal Flow-Ability in Storage Bunker in Biomass Co-Fired Thermal Power Plants

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Open burning of Biomass is a major contributor to the air pollution. To minimize this, Ministry of Power is promoting biomass co-firing in coal-based power plants through comprehensive policy under the umbrella of the SAMARTH Mission.
The policy covers both torrefied and non-torrefied biomass pellets to be used as fuel in power stations. It applies to all (existing and new) coal based thermal power plants with the appropriate type of coal-mill (bowl mills, ball & race mills, ball & tube mills). Responsibility of implementation of this policy in power plant lies with the power sector stakeholders. This Technical Paper focuses on the flow-ability of biomass blended coal in storage bunker.

In thermal power plant, the coal is fed to mills through bunkers. The coal flowability study has traditionally been used as a measure to find out various parameters impacting coal flow and consequently to ensure uninterrupted coal discharge to the mills. However, in case of blending of biomass with coal, the flowability of blend through the bunker is expected to get impacted due to lower bulk density, higher compressibility and fibrous nature of biomass which increases the probability of arching and bridging issues in bunker, especially for non-torrefied pellets with fines. This paper analyses critical flow characteristics like mass flow, shape of bunker, long term storage effects, critical bunker outlet diameter, slope angle, liners, segregation of particles, adhesion/cohesion of materials. The paper also presents various practices being used for improvement in material flow across industries for suitable adoption.

Integrated Non-Invasive Diagnostics for Thermal Power Plants

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Thermal power plants require accurate monitoring, preventive maintenance, and integrated control systems to ensure safety and efficiency. Traditional methods (manual inventory, scaffold inspection, pipe removal) are time-consuming, risky, and expensive. To address these issues, power plants can take an integrated approach that combines:

• Drone diagnostics to measure coal reserves, detect thermal anomalies and check structure performance without stopping.

• Gamma scale checker non-invasively assesses pipeline contamination, reducing downtime and improving process efficiency.

• Engineering solution services (measurement, control and automation) as the foundation for reliability and digital transformation. Includes:

• Software and Systems: CMCS/DCS/PLC upgrades, CEEMS dashboards, automated reporting.

• Hardware and Panels: Design, manufacture, and modernization of control panels and instrumentation.

• Testing and commissioning: Actual load conditioning in hydropower plants, chemical power plants, steel power plants, power plants.

• Analytical equipment and services: Water and gas quality analytical equipment with structured test programs.

Together, these solutions create a closed loop from discovery to action, improving safety, reducing downtime, and enabling predictive maintenance and digital twin integration.

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Energy Transition-Integrating Renewables, GridFlexibility & Clean Technology

Nuclear coupled Hydrogen: Pathway to Energy Transition to Net Zero for DVC

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India's electricity system is at an inflection point. Marking a significant shift in the country's energy landscape. As of end of 2025, India's total installed electricity generation capacity has risen to 505.023 GW, non-fossil capacity stands at about 259 GW, with 31.2 GW added in the current financial year according to the Ministry of New and Renewable Energy (MNRE).Thus fulfilling the NDC target five years ahead. An impressive 250.6 GW comes from renewable energy alone. Of 505.023 GW generation capacity, 245.6 GW comes from fossil-fuel-based sources. This milestone arrives at a crucial moment in India's pursuit of its long-term climate commitments, particularly the goal of achieving 500 GW of non-fossil energy capacity by 2030. Non fossil sources now contribute 50% of installed capacity, with renewables at 250 GW and nuclear at 8.8 GW. But in present scenario thermal power will continue to play a central role in reliability and resource adequacy for years to come. Yet, aging coal fleets face mounting compliance costs (ESP augmentation, SO_x/NO_x control), cycling stress for renewable integration, and capital allocation tradeoffs relative to low carbon investments. Renewable energy integration, grid stability and scaling storage is the challenge India needs to overcome. Under the Green Energy Corridor scheme India's transmission infrastructure is undergoing a major upgrade as well for evacuation of renewable energy.

This paper proposes a strategic pathway centered on nuclear–hydrogen hybridsco locating advanced reactors (SMRs/HTGRs) with high temperature electrolysis (HTE) and sector coupling applications (steel, fertilizers, transport). The approach provides baseload decarbonization and flexible, dispatchable capacity, absorbing surplus VRE via hydrogen production and delivering seasonal storage and industrial feedstock. We focus on DVC's Eastern Grid context (e.g., Chandrapura, Mejia) and NTPC pilots (Dadri AEM, Vindhyachal PEM + CCU methanol, Ladakh mobility) to illustrate operational feasibility, market fit, and regulatory alignment (CEA advisories, NGHM, SHANTI).

Towards an Indigenous Biomimetic CO_2 Capture Technology: Enzyme-MOF-Biopolymer Contactors for India's Thermal Power Sector

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India's coal-fired thermal power sector, with an installed capacity of about 210 GW as of 2023, emits nearly 1 gigatonne (Gt) of CO_2 annually, a figure projected to rise to around 1.2 Gt by 2030. Although carbon capture, utilization and storage (CCUS) technologies such as amine-based post-combustion capture, oxy-fuel combustion, membranes and calcium looping are technically mature, their large-scale deployment in India remains limited. High energy penalties, substantial operating costs, solvent degradation, and challenges posed by flue-gas impurities (SO_x, NO_x and ash) constrain adoption. In addition, the absence of well-developed CO_2 transport and storage infrastructure means CCUS implementation in Indian thermal power plants is still at an early stage, with only pilot-scale initiatives such as the NTPC Vindhyachal project.

To address these limitations, the article presents an indigenous, low-energy and thermally stable biocatalytic platform for CO_2 capture tailored to Indian coal-based power plants. High-efficiency biomimetic contactors have been developed using cellulose and chitosan combined with metal–organic frameworks (MOFs), offering an alternative to conventional homogeneous catalysts. These materials function as active sites or host matrices that immobilize carbonic anhydrase or orient reactant molecules to enhance CO_2 sequestration and catalytic conversion to cyclic carbonates.

Two novel nitrogen-rich MOFs, ZS-2 and ZS-3, synthesized via a solvothermal route, exhibit rare architectures and unique Stimulated Raman Scattering (SRS) topology. Their robust crystalline frameworks are designed to withstand harsh CO_2 scrubbing environments, allow straightforward scale-up, and serve as "drop-in" components for existing chemical absorption systems, with potential applications in direct air capture. Currently assessed at Technology Readiness Level 2–3, the technology represents a promising indigenous pathway. Further validation under realistic Indian flue-gas conditions, supported by academia–industry collaboration, is essential for advancing toward commercial deployment.

Integration Of Battery Energy Storage Systems (BESS) For Flexible and Efficient Thermal Power Plant Operation

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India's power system is expanding renewable generation rapidly, yet dispatchable thermal capacity remains essential for meeting demand during non-renewable hours and for providing frequency control, inertia, and ramping capability. This paper evaluates the integration of Battery Energy Storage Systems (BESS) as an operational retrofit for existing thermal power plants, rather than as an extension of renewable capacity. BESS is assessed as an internal load-buffer that stabilizes unit operation by absorbing short-duration variability and limiting inefficient low-load and cycling operation. Using a representative 500 MW coal-fired power plant integrated with a 100 MW/100MWh BESS, the analysis demonstrates that improved operating stability can materially reduce start–stop events, ramp-induced mechanical stress, and deviation settlement penalties, while enabling participation in fast-response ancillary service markets. These operational improvements translate into measurable economic benefits and heat-rate gains corresponding to a 2–6% reduction in CO_2 intensity. The results indicate that BESS integration enables thermal plants to shift from high-stress load-following toward stable, efficiency-optimized dispatch, enhancing reliability and reducing emissions intensity without displacing firm generation in a high-renewable grid.

From Stability to Flexibility- Thermal Power Plant Adaptations for Renewable Integration

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India's Nationally Determined Contributions target a substantial RE capacity of 500 GW by 2030, constituting 45% of the total installed capacity. The same is projected to increase to 596 GW by 2032 dominating the installation of 304 GW from fossil-based sources. Although, this accelerated growth of RE is pivotal to India's energy transition, it poses operational challenges to thermal power plants. The intermittency & variability of RE generation calls for enhanced flexibility in TPP operations to ensure grid stability.

In FY 2023–24, India's thermal power plants average PLF remained at 69%, which is further expected to decrease with rising RE penetration. Moreover, advancements in technologies, like pumped storage and battery energy storage systems, are anticipated to further reduce PLFs, especially during night time.

In India, most of the plants are traditionally designed for a 55% MTL considering the base load operation but same must be lowered to 40% MTL to accommodate the growing generation from RE sources. Additionally, it is also required to have steeper ramp rates of up to 3% per minute and shortened startup / shutdown cycles for addressing variability & intermittency of RE. These adaptations strain equipment reliability and efficiency, escalating operational costs.

This paper includes outcomes from flexibility trials conducted at Indian TPPs, detailing key operational challenges and highlighting mitigation strategies. It further explores innovative solutions that can help enhance efficiency and reduce APC during part-load operations. Finally, a brief roadmap is presented to enable TPPs to adapt to India's dynamic energy ecosystem while maintaining grid stability and economic viability.

Case Studies of Misoperation of Restricted Earth Fault and Differential Protection of Transformers

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This paper presents 6(Six) cases of mal-operation of Transformer Restricted Earth Fault Protection[64R] and Transformer Differential Protection [87T] at various powerhouses of Damodar Valley Corporation. It shares the experiences gained while analysing these mis-operations of protection system with the objective of reducing mal-tripping due to commissioning errors, setting errors, scheme errors etc. Each case study starts with a brief history of the event, system SLD with operated relay targets, in depth study of relay disturbance records [DR] & event records [ER] picked up, root cause analysis of the event, lessons learnt & remedial actions taken.

Event-1 teaches us to use the maximum of 1LG and 3LG fault current as the through fault current for calculation of Stabilizing Resistance for High Impedance REF Schemes.

Event-2 teaches us the considerations for choosing correct lead length of CT cable during stabilizing resistance calculations during 3LG and 1LG faults.

A general saturation voltage calculation methodology has been included for varying fault currents (for 1LG / 3LG fault type), varying distances of NCT and PCT secondary to REF shorting point and varying CT resistances of NCT & PCTs.

Event-3 teaches us that motor back feeding onto a fault, however minor it might be may also be a reason of unwanted relay operations.

Event-4 & 5 is about mal-operation of 87GT due to wrong NCT polarity causing incorrect Zero sequence correction one during an external fault and the other during desynchronization of the unit due to Breaker Pole scattering.

Event-6 deals with mal-operation of 87T due to opened neutral return path in CT secondary.

The lessons learnt can act as O & M strategies to eliminate such mal-tripping at the root level.

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Asset Life Extension through Digitalization

Asset Management for Enhanced Reliability in Thermal Power Plants

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Thermal power plants (TPPs) are undergoing a structural transition to flexible operations, exposing assets to higher thermal and mechanical cycling, which elevates failure risk and forced outage rates. Effective asset management—integrating reliability engineering, risk-based inspection (RBI), and optimized spare parts strategies—provides a systematic approach to sustain availability, reduce lifecycle cost, and improve safety and performance. This paper presents a pragmatic framework tailored for coal-based TPPs to quantify reliability via MTBF/MTTR and availability indices, prioritize inspection and maintenance based on risk, and right-size critical spares using data-driven methods. Implementation guidance, calculation examples, KPIs, and a roadmap are provided to support reliability teams in achieving measurable improvements in plant reliability under flexible operations.

An Artificial Intelligence Framework for Ash Dyke Safety and Data-Driven R&M Planning in Thermal Power Plants

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Large thermal power stations increasingly depend on intelligent monitoring and predictive analytics to ensure structural safety and optimize long-term asset planning. This paper presents an integrated dual-framework built around artificial intelligence (AI) and machine learning (ML), developed through two ongoing NTPC pilot initiatives: (i) an AI-driven decision support system developed jointly with IIIT–Naya Raipur for automated identification and prioritization of Renovation & Modernization (R&M) schemes/equipment, and (ii) an AI/ML-based early warning and predictive monitoring system for ash dyke health assessment at NTPC Simhadri.

The R&M planning project shall employ multi-feature extraction, Large Language Models (LLMs), ML algorithms, and optimization techniques to evaluate operational records, diagnostic reports, degradation patterns, historical profit-loss and Permit to Work (PTW) reports. Mathematical formulations/biasing to prioritize the equipment/scheme shall also be provided.

The ash dyke project shall incorporate deployment of web-based cameras for imaging, electronic pore-pressure sensing with electronic piezometers, long range Wide Area Network (LoRaWAN) system and GSM redundancy. Suitable Artificial neural network models shall be integrated with the system for real time safety surveillance, anomaly detection in the ash dyke.

The combined effect of these concepts will lead to data driven R&M scheme identification within the budget availability and 24*7 monitoring of dyke conditions thus ensuring dyke safety all the way leading to safe and better environmental conditions. Together, these systems will act as a blueprint for AI-integrated safety and asset-management transformation across NTPC.

Digital Transformation in Unit Startups Using AI Enhanced Web-Based Comprehensive Start-Up Dashboard for Subcritical Units

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Thermal power plants (TPPs) are undergoing a structural transition to flexible operations, exposing assets to higher thermal and mechanical cycling, which elevates failure risk and forced outage rates. Effective asset management—integrating reliability engineering, risk-based inspection (RBI), and optimized spare parts strategies—provides a systematic approach to sustain availability, reduce lifecycle cost, and improve safety and performance. This paper presents a pragmatic framework tailored for coal-based TPPs to quantify reliability via MTBF/MTTR and availability indices, prioritize inspection and maintenance based on risk, and right-size critical spares using data-driven methods. Implementation guidance, calculation examples, KPIs, and a roadmap are provided to support reliability teams in achieving measurable improvements in plant reliability under flexible operations.

ML driven decision support for Flexible Operation of Thermal Power Plants in Energy Transition era

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Energy is a foundational enabler of economic growth and national development, and for NTPC targeting 149 GW capacity by 2032, timely station-level visibility is critical to improving performance and reliability. With the rapid rise of energy data from sensors, digital control systems, wireless transmission, and cloud platforms, the central challenge is no longer data availability but integrating heterogeneous sources into a single source of truth and translating them into actionable KPIs that surface exceptions in near real time. This paper proposes a machine learning–driven smart decision support system for NTPC by establishing a scalable data lake to acquire, cleanse, and unify operational and market data from SAP, RLDC feeds, Merit India, Delhi SLDC, PI servers, and other relevant sources. The integrated insights are delivered through an innovative mobile application, "Power Track", designed with an intuitive dashboard that enables real-time tracking of key performance indicators such as the gap between normative and actual APC, DC vs. SG vs. AG, equipment losses, real-time URS availability, and the market sale potential of surplus power, alongside outage and market trend views via dynamic reports and graphs.

In addition to real-time monitoring, the solution extends into predictive decision support by incorporating solar generation forecasting, down-reserves forecasting, and All-India demand forecasting. These forecasting layers strengthen grid- and market-aligned operations by helping solar stations proactively manage schedule adherence and reduce DSM (Deviation Settlement Mechanism) losses through improved generation commitment. Further, down-reserves and demand forecasts support operational choices such as taking thermal units under shutdown by providing forward-looking signals on demand levels, reserve requirements, and likely grid conditions thereby minimizing over injection loss due to schedule below technical minimum. Overall, the proposed approach promotes a culture of data-driven decision-making and enhances reliability.

Intelligent Methods for Assessing and Maintaining the Integrity of Steel Structures in Power Plants

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Power plants are critical infrastructures that support economic growth and industrial development, relying heavily on extensive steel structures associated with turbine–generator units, boilers, and auxiliary systems. Ensuring the structural integrity of these steel structures is essential for safe, reliable, and uninterrupted plant operation. However, steel structures in power plants are often exposed to harsh environmental and operational conditions, making them susceptible to deterioration mechanisms such as corrosion, fatigue, overloading, and connection failures. Recent incidents, including structural collapses and excessive deformations in power plant facilities, highlight the limitations of conventional inspection practices and the need for proactive monitoring approaches.

This paper presents an intelligent methodology for assessing and maintaining the integrity of steel structures in power plants through advanced structural health monitoring techniques. The proposed approach integrates sensor-based monitoring, non-destructive evaluation, data-driven analysis, and real-time condition assessment to detect early signs of structural distress. By enabling continuous performance evaluation and predictive maintenance, the methodology aims to mitigate potential risks, prevent unforeseen structural failures, and enhance overall plant safety and operational reliability. The adoption of intelligent monitoring systems is shown to offer significant benefits in extending service life, reducing maintenance costs, and improving decision-making for infrastructure management.

Performance Optimization of Dry Sorbent Injection System: A Case Study of NTPC Dadri Stage-I

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Dry Sorbent Injection (DSI) technology is widely adopted as a cost-effective and rapidly deployable solution for controlling sulphur oxide (SO_x) emissions from coal-based thermal power plants, particularly where space, water availability, and remaining plant life constrain the installation of wet Flue Gas Desulfurization (FGD) systems.This paper presents a detailed case study on performance optimization of the DSI system installed at NTPC Dadri Stage-I (4 × 210 MW), highlighting design assumptions, operational challenges, corrective actions, and achieved outcomes.

The DSI system at Dadri Stage-I was commissioned as a judicious measure for compliance of statutory environmental emission norms based on assumptions of lower plant load factor (PLF) and a limited remaining operational life. DSI system was designed with certain operational parameters, however, actual operating conditions significantly deviated from design values. These deviations in the input parameters which were beyond our control resulted in elevated baseline SO_2 concentrations, excessive sodium bicarbonate (SBC) consumption, frequent system choking, and difficulties in meeting the statutory emission limit of 600 mg/Nm³.

Comprehensive performance evaluation, including Performance Guarantee (PG) tests, identified key limitations such as inadequate injection blower capacity, uneven SBC distribution between ducts, sub-optimal mill fineness, high moisture ingress due to poor instrument air & Injection/Unloading blower air dew-point control, and mechanical issues in RVF/RAL, Viper Mills and conveying systems. Based on joint learnings & observations from DSI Task force, OEM, Operation Services, and Engineering teams, a series of targeted mechanical, process, instrumentation, control, and electrical modifications were implemented.Post-optimization results demonstrate a marked improvement in system stability and SO_2 removal performance, with consistent compliance below statutory limits. Although DSI remains a high-OPEX solution under high-load operation, this study establishes that systematic optimization and proactive maintenance can significantly extend the effectiveness and reliability of DSI systems under off-design conditions.

Performance Bottlenecks in FGD Systems: A Study of O&M Challenges in Thermal Power Plants: Insights from NTPC Lara

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Flue Gas Desulphurization (FGD) systems are essential for controlling SO_2 emissions in coal-based thermal power plants, ensuring compliance with stringent environmental norms. However, their operational performance is often compromised by multiple technical and maintenance challenges. This paper focuses on identifying and analysing major operational, material and maintenance-related issues commonly encountered in FGD systems. Key observations were collected from field operations, equipment performance data, and maintenance records. This study highlights recurring challenges such as free falling of duct isolation gates, erosion–corrosion in absorber and duct materials, scaling and choking in spray nozzles, vacuum belt filter failures and reliability concerns in Wet Ball Mills, slurry (Limestone Slurry and Gypsum Slurry) circulation pumps and mist eliminator effectiveness. This paper also includes the frequent leakages observed in the FRP pipeline and damage to Ceramic Ball valves.

Root cause analysis indicates that inadequate material selection, suboptimal operating practices, and lack of predictive maintenance strategies are major contributors to these failures. The paper emphasizes the need for advanced corrosion-resistant materials, improved monitoring techniques, and proactive maintenance planning for enhancing reliability and extending equipment life for sustained operation. These findings provide actionable insights for the Indian power sector to optimize FGD performance and achieve sustainable environmental compliance.

Ash Utilization: Challenges and Sustainable Strategies for Pithead Stations: Case Study of NTPC Vindhyachal

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India's thermal power sector generates a substantial volume of fly ash due to its continued reliance on coal-based electricity generation. Recognizing the environmental, ecological, and land-use implications of unmanaged ash disposal, the Government of India has progressively strengthened the regulatory framework for ash utilization through successive amendments to the Fly Ash Utilization Notification issued by the MoEFCC. These regulations now mandate 100% utilization of fly ash by thermal power plants, aligning with national goals of sustainability and the circular economy.

Despite significant regulatory progress, achieving complete ash utilization remains a challenge for several thermal power stations, particularly pithead plants located in regions with limited industrial demand, inadequate infrastructure, and logistical constraints. NTPC Vindhyachal, with an installed capacity of 4,760 MW, is the largest pithead thermal power plant in India and generates approximately 20,000 MT of fly ash per day. Managing this large volume of ash poses substantial operational and environmental challenges, especially with Geographical location, limited local avenues and underdeveloped transportation infrastructure.

This paper examines the specific challenges associated with fly ash management at pithead thermal power stations such as NTPC Vindhyachal and explores practical and scalable strategies to overcome these challenges. Emphasis is placed on enhancing ash utilization pathways, improving logistics and infrastructure, and adopting innovative, sustainable approaches to ensure regulatory compliance while minimizing environmental impact.

Probabilistic Wind Forecasting for Thermal Flexibility. A Multi-Model Ensemble and Operational Case Study for All-India 7-Day Wind Generation Forecast

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India's power system is undergoing a structural transition in which rapidly increasing renewable energy penetration must be balanced by a thermal fleet that is simultaneously shrinking in relative share and expanding in operational responsibility.

This paper demonstrates that wind-induced variability, rather than absolute renewable penetration, is now the dominant driver of operational stress on thermal generation. Using operational data, regulatory context, and a detailed machine learning (ML) forecasting framework, the study shows that large wind generation reversals—ranging from 200 MU over two days to more than 400 MU over five days—are frequent, seasonal, and structurally embedded in the Indian power system. These events impose measurable physical degradation, economic penalties, and reliability risks on thermal assets.

To address this challenge, the paper presents a national-scale, probabilistic wind forecasting framework explicitly designed for thermal dispatch, reserve planning, and flexibility management. A stacked ensemble of gradient-boosted decision trees, quantile regression models, and autoregressive correction is developed using multi-corridor meteorological data and historical All India wind generation. Operational validation demonstrates that accurate and probabilistic wind forecasts materially reduce start–stop cycles, ramping stress, reserve procurement costs, and incremental coal consumption.

The paper concludes that wind forecasting is a first-order enabler of thermal flexibility, more consequential than solar forecasting, and should be institutionally embedded into SCUC/ SCED, AGC bandwidth allocation, reserve sizing, and maintenance planning frameworks.

FGD Operation -Challenges and Stabilization

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FGD system retrofitted at Simhadri Power Station (4*500MW), at present all units of FGD System running under COD. Ultimate benefit from FGD system is SOX reduction from thermal power plants emissions and observed SPM reduction from FGD system in service. As per NEW guidelines, All Category A thermal stations should comply with SOX norms by installing FGD systems.

FGD system improving ESG score to the company. Challenges faced during commissioning and required modifications carried out for stabilization of FGD system at SIMHADRI. Challenges also faced in maintaining Limestone stock and gypsum offtake. CEMS analysers maintenance and other equipment Spares availability also challenge due to foreign vendors. Modifications and SOPs followed at SIMHADRI for stabilization of FGD system, due to this initiatives FGD system availability at SIMHADRI improved from 20% in FY24-25 to 80% plus in FY25-26.

Challenges in Flexible unit operation across multiple units of same make due to HP Turbine control valve abnormalities

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Telangana 800MW unit reported high deviations of HP control valve position during load variation along with high vibration at valve coupling. Load fluctuations upto 130MW due to mismatch in HPCV position vs demand also observed during daily ramp up/down leading to unit instability and missing CERC ramp obligations thereby hindering flexible unit load operations. Considering the urgency to enable the units to run as per CERC norms, RCA and rectification works in consultation with OEM, NTPC CC-OS and Engineering followed. Routine actuator and coupling inspection work like pre-pilot (MOOG) setting, coupling physical inspection, coupling stroke calibration, calibration of feedback transmitters and logic interventions carried out. Valve internal inspection carried out, and HPCV valve spindle found sheared/ separated from valve body. Complete HPCV body servicing and replacement of spindle, other correlated valve internals done to find out RCA of spindle shear. Similar cases also reported in other Non-NTPC plants having same OEM of HPCV wherein units had to be shut down to replace the damaged parts of HPCV. This warranted engineering rectifications to be done in valve internals in addition to routine valve actuator checks. Consequently, these taken up like replacement of spindle assembly including valve spindle, bell valve, weld-in ring and valve seat to address component wear out and clearance issues, dummy box up for addressing coupling gap issues, installation of coupling check nut as per dummy box up corrections and corrections of actuator operating curve to ensure gap free operation of valve internals. On completion of works, successful unit flexible operation demonstrated, and all corrective actions recorded for future overhauling and servicing works.

FGD System Stabilization: Issues, Interventions, and Indigenization Efforts at NTPC Telangana

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Flue Gas Desulphurization (FGD) is a relatively new system in India, currently in the erection and commissioning phase at most sites, with only a few projects having entered the O&M stage. NTPC Telangana is one such project with an integrated Wet FGD system. The wet FGD process utilizes limestone slurry as a reagent in absorber tanks to remove SO_2 from flue gas through a series of chemical reactions, producing Gypsum as a byproduct.

This paper discusses the practical and cost effective solutions implemented at NTPC Telangana for challenges faced during stabilization of FGD system like Replacing the use of expensive grease in pump mechanical seals with water quenching arrangement, Replacing rubber-lined spools with CPVC and wear resistant (Linatex) hoses for easier maintenance and reduced downtime, Addressing wet gypsum issues by adding an extra cloth wash header with changed water source, installing an additional roller in the vacuum belt filter(VBF) to prevent cloth folding and installation of a connection from filtrate water to waste water to control the fine particles and chlorides causing VBF cloth blinding, installation of chute vibrators at VBF discharge to prevent frequent choking, Strengthening valves supports and prompt replacement of damaged or passing valves to prevent line choking or slurry dilution and damaged mist eliminator modules in every opportunity, Addressing the frequent failures of FGD sump pumps bearings, Indigenization of costly imported spares like pH control ceramic ball valve, agitators mechanical seals and vacuum pump parts etc.

Proactive maintenance and continual improvement efforts aim to ensure smooth, sustainable, and cost effective FGD system operation.

Energy Intelligence as an Enabler of NTPC's Digital Transformation and Research Development & Innovation (RD&I)

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India's power sector is undergoing a fundamental transition driven by rapid demand growth, large-scale renewable energy integration, increasing grid complexity, and national commitments towards sustainability and net-zero emissions. As India's largest power generation utility and a Maharatna PSU, NTPC plays a pivotal role in ensuring energy security while simultaneously leading the transition towards cleaner and smarter energy systems. This paper presents Energy Intelligence as a unifying and enabling framework that integrates NTPC's Digital Transformation initiatives with its Research, Development & Innovation (RD&I) ecosystem. It demonstrates how Energy Intelligence converts digital infrastructure, operational data, and research outputs into actionable insights, resulting in enhanced operational efficiency, grid reliability, commercial optimization, and a credible, data-backed energy transition. The paper also highlights strategic outcomes aligned with national priorities such as Viksit Bharat @2047 and India's net-zero ambitions.

Transition From LDOto Natural Gas During Start-Up of Coal-Fired Boilers

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Modern coal-fired power plants face increasing pressure to improve operational flexibility and reduce start-up costs. Traditionally, Light Diesel Oil (LDO) is used for boiler start-up and flame stabilization. This paper evaluates the technical and economic transition to Natural Gas (NG) for these processes at NTPC Dadri. By analysing combustion characteristics, required burner modifications, and economic ROI, this study demonstrates that switching to NG can reduce start-up costs significantly while lowering the environmental footprint.

Digital Transformation of Protection Bypass Management System (PBMS)

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Protections and permissive are vital for the safe operation of any equipment/system including those used in power plants. Temporary bypass of protections becomes unavoidable during maintenance, testing and troubleshooting activities. However, such bypasses introduce operational risks if not managed in a structured and time-bound manner. Traditionally, protection bypass activities at NTPC Vindhyachal were handled through offline registers and manual approvals, as per LMI, which had limitations such as lack of real-time monitoring, process delay, data management, weak audit trails and absence of automatic alerts.

To overcome these challenges, an Online Protection/Permissive Bypass Management System (PBMS) was developed jointly by the Operation and IT Departments. The system digitizes the complete bypass workflow including initiation, acceptance, approval, execution, supervision, restoration and closure. With built-in checklists, role-based access, conditional approvals, automated SMS/email alerts and real-time dashboards, PBMS ensures transparency, accountability and strict compliance with LMI instructions. The implementation of PBMS has significantly enhanced process standardization, agility, digital monitoring, analysis, audit readiness and overall plant safety.

AI Enabled surveillance system for Safety in Fly Ash Silo area at NTPC Mouda

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Ensuring safety within power plant areas is of paramount importance due to the high-risk environment characterized by heavy machinery, hazardous materials, and complex operational processes. This paper proposes an AI-enabled surveillance system to address safety challenges and enhance operational efficiency in such critical zones.

One particularly critical area is the Fly Ash Silo zone. The ambitious goal of achieving 100% ash utilization has made this area a hub of continuous activity, with trucks and bulkers transporting fly ash round the clock to destinations such as cement factories, National Highway Authority of India (NHAI) road construction projects, ash brick manufacturing units, and mine-filling sites. The transportation process involves moving ash in covered trucks and closed bulkers, following proper cleaning and handling protocols at the silo.

Handling fly ash presents significant safety risks due to its hazardous nature, potential exposure to harmful dust, and the operational complexities of loading, covering, and cleaning. These activities, if not managed effectively, can lead to accidents, health issues, and operational inefficiencies.

The proposed AI solutions aim to mitigate these risks by optimizing truck movement, predicting safety hazards, identifying blind spots, and issuing real-time alerts for compliance with Personal Protective Equipment (PPE) and safety protocols. Key focus areas include ensuring the use of safety belts during fly ash loading, monitoring the proper covering of ash-filled trucks, and overseeing cleaning activities to prevent exposure to harmful materials.

Learning Boiler Operational Latent Space Using CNN1D Autoencoders for Anomaly Detection: A Pilot on Unit-5 (490 MW), NTPC Dadri

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This work presents a live, data-driven anomaly detection system for a large utility boiler, designed to identify abnormal operational behaviour from multivariate sensor data and deployed on Unit-5 (490 MW) at NTPC Dadri. The objective is to develop an early warning framework that learns normal boiler behaviour from historical plant data and validates detected deviations against documented operational events.

The system uses one-minute resolution plant historian data spanning 2023–2025 and includes 18 critical boiler process variables representing load, flow, pressure, temperature, air–gas, and furnace conditions.

A one-dimensional convolutional auto-encoder (1D-CNN-AE) was trained exclusively on validated normal-operation data of 2023 and 2024, with startup, shutdown, communication failures, and sensor-unavailable periods explicitly excluded. Each 64-minute window was compressed into a 16-dimensional latent representation characterizing the boiler's operational state. Stable convergence of training and validation loss indicates that the auto-encoder learns consistent normal-operation dynamics without over-fitting.

The Deviation Index is defined as the mean squared reconstruction error between each 64-minute sensor window and its auto-encoder reconstruction. Lower values are consistently observed during stable operation, while elevated values coincide with disturbed periods documented in unit shift logbooks. In several cases, the Deviation Index exhibits a gradual and sustained rise prior to recorded disturbances, suggesting early warning capability for developing abnormal operating conditions.

For operational use, a real-time dashboard was developed that ingests live plant sensor data and continuously computes the Deviation Index. The dashboard visualizes recent trends, highlights top deviation contributing sensors, and provides directional guidance toward affected subsystems.

Implementation of Augmented Reality in NTPC: Enhancing O&M Reliability, Training Effectiveness and Operational Quality

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Thermal power plants operate in highly complex and safety-critical environments where even minor deviations in operational procedures or maintenance practices can significantly impact unit reliability, availability, and safety. Increasing equipment complexity, ageing assets, frequent cycling of thermal units, and continuous workforce transition have exposed limitations of conventional knowledge dissemination methods such as two-dimensional manuals, classroom training, and verbal instructions. In this context, NTPC undertook a pilot-based implementation of Augmented Reality (AR) as a digital enabler to strengthen quality, reliability, and safety in Operations and Maintenance (O&M).

This paper presents NTPC's experience in implementing AR with primary emphasis on O&M applications, supported by selective use cases in Stores and Training. The AR solutions provide contextual, on-site visualisation of Standard Operating Procedures (SOPs), interactive Job Safety Analysis and Toolbox Talks (JSA/TBT), three-dimensional visualisation of complex and inaccessible equipment components, and real-time remote expert guidance using AR annotations. The implementation followed a frugal, largely in-house development approach, ensuring minimal capital expenditure and scalability across thermal power stations.

Observations from the pilot implementation indicate improved procedural clarity, enhanced operator confidence, better hazard perception during maintenance activities, and improved communication between field personnel and subject matter experts. Users reported faster learning curves, reduced dependence on physical manuals, and improved situational awareness during critical tasks. The paper discusses the implementation architecture, operational use cases, qualitative benefits, challenges encountered, and scalability potential of AR within NTPC, establishing it as a practical workforce-centric digital solution aligned with the IPS-2026 theme, "Optimising Thermal Generation with Quality & Reliability."

Effect of Flexibilization on Boiler Forced Outage

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With the progressive capacity addition and increase in Renewable Energy generation in India, there is continuous decline in contribution of power generation by coal power plants. This has resulted in backing down of coal power plants to significant level. The frequent backing down of coal units to 55% Minimum technical load have affected equipment reliability thereby increasing forced outage and generation loss of the flexing units. This problem will further get aggravated in coming days with the further addition of Solar, wind and battery storage capacity which may lead to further backing down of coal plants to even 40% MTL.

The harmful effect of flexible operation of Unit is seen in Boiler with increase in boiler startup, shutdown, low load ramping, chemistry upsets thereby increasing boiler tube failures. The boiler tube failures have increased with the significant increase in unit flexibilization from 2019 onwards. Further, units installed in initial years of 1980s are designed for base load operation. Older base load plants were designed to operate predominantly under creep conditions. Flexible operations were taken into account for unit installed in later years, however all units are bought under significant load following as per grid requirement.

Transforming Waste to Resource (Bottom Ash as substitute of natural sand)

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In ash-dykes, controlling seepage and preventing the build-up of excess pore pressure have always posed challenges. Conventionally, natural sand is used as filter in dyke, however, with natural resources rapidly depleting and sand mining causing considerable environmental impacts, the need for sustainable alternative has become increasingly important.

In response, an innovative system is developed to process bottom-ash and convert it into suitable filter material capable of effectively replacing conventional sand. Initially, several tests were conducted on bottom-ash to predict its behaviour. As bottom-ash possess the geotechnical properties like sand, therefore it can be used as alternate filter material in dyke-embankment. However, in some cases it is observed that bottom-ash does not meet some of filter-criteria with respect to base material. Based on preliminary investigation indicating very high percentage of fines, conventional dry sieving was carried out through 100μ sieve to limit fines content in bottom-ash, however dry sieving results does not meet the filter criteria.

To overcome these shortcomings, an innovative Hydro-cyclone-based processing arrangement for bottom-ash is introduced. A hydro-cyclone is a gravity separation device that segregates slurry particles based on their weight. Ash-slurry is fed tangentially at high velocity, generating a spiralling motion inside the cylindrical chamber. As it descends into the conical section, increased centrifugal forces separate coarse bottom-ash particles from finer fractions. The bottom-ash processed through this system successfully met all filter criteria. The adoption of this processed bottom-ash in dyke construction reduces dependency on natural-sand, shortens construction time, and offers a more economical and environmentally sustainable solution.

A case study on "In house RCM of Hydraulic Drive Motors for its extended and reliable usages in Wagon Tippler System at NTPC Kudgi"

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Station NTPC Kudgi, a rail feed load centre plant, has 3 x 800 MW coal units that get coal from diversified sources ranging from minimum of 800 KMs to 2200 KMs from the coal mining source. Coal comes in different sizes up to 100mm and above. The receivable coal through Indian Railways is being unloaded at wagon tipplers, the only available unloading infrastructure. Being a non-pit head plant, the coal unloading system's healthiness is very critical.
The only available unloading system of NTPC Kudgi, i.e. Wagon Tippler, is asking for high reliability to meet flawless coal unloading received through Indian Railways wagons i.e. BOXC, BOXN, BOXHL, BOXNHS etc. with a tippling capacity of 25 wagons/hour.

Any tripping or failure to the 1st unloading point, like Wagon Tippler, Apron Feeder, Side Arm Charger, etc. leads to complete stoppage of unloading of loaded rakes and further leads to bunching as well as spikes in demurrage charges. This further also cascaded into a poor rake receiving pattern, depletion in fuel stock, as well as a poor image of station in front of external bodies like Indian Railways, Coal Companies etc.

There were outages seen with the Wagon Tippler System, but with some proactive maintenance initiatives of the most critical part of the Wagon Tippler system, i.e. Hydraulic Drive Motors of the system are a case study for us to prevent great time-saving by avoiding outages of WT system, avoiding monetary losses, enhancing self-confidence to working team, team building to face new challenges etc.

Normally, many issues pertaining to the Wagon Tippler are resolved at the site level itself, but outages of the most critical and one of the costliest equipment of the WT system, i.e. Hydraulic motors demand longer outages, monetary inputs, many other additional activities like hydraulic line pickling, flushing, hydraulic pumps testing etc along with OEM's M/s Hagglunds Motors. With some proactive maintenance activities at NTPC Kudgi, at many times' failure of Hydro Motor has been avoided.

This paper deals with identifying the pre-indications of Hydro Motors' internal abnormalities and the actions taken to correct those abnormalities with minimal spare replacement and the procedures adopted for having enhanced life of Hydraulic Drive Motors.

In-House Development of Tracker Roller Assembly and Pulley Crowning method for Belt Sway Control

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This paper depicts in detail the work done to develop our own belt tracker roller assembly and pulley crowing lagging method to eliminate the belt sway problem in CHP. Belt misalignment or sway is one of the most critical problems in CHP. When belts drift off-centre, it leads to multiple operational challenges including belt edge damage, coal spillage, frequent housekeeping & unscheduled outage.

We were facing persistent belt sway in conveyors & pulleys. To address this, we developed our in-house tracker roller assembly with two significant design improvements as compared to our conventional trainer idler. First improvement is the use of conical rollers with rubber sheet lagging. This design significantly enhanced the coefficient of friction between rollers and conveyor belt, thereby generating higher frictional force, leading to more effective belt deflection and improved tracking performance.

The second improvement is in the pivot assembly. We have provided a stronger pivot shaft along with a more robust bearing & housing arrangement, which improved the mechanical stability and responsiveness of the tracker roller assembly under higher operating loads.

Additionally, based on the principle that conveyor belts tend to move toward the side with higher tension or greater friction, we implemented pulley crowning as a corrective measure in locations where belt sway was prominent. Crowning the pulleys at the centre using 12 mm or 20 mm thick lagging sheets, covering approximately 60–70% of the pulley face width from the centre, yielded excellent results in controlling and correcting belt sway.

Reliability improvement of CW pump

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Thermal Power Plant unit with water cooled condenser, requires high flow and low heat pumps which is generally vertical, mixed flow type. These pumps are necessary for efficient operation and plays critical role in maintaining heat rate of the generating units.
MUNPL-Meja with an installed capacity 2x660MW operates with CW for cooling the condensers of both units. Total 5 No (4W+1S) CW pumps are installed for catering circulating water requirement of both units.

Abnormal sound and high vibration were persisting in CW pumps. During dismantling of the CW pump, bowl assembly was found damaged. Vortex breaker was found damaged and dislocated in the CW sump bed. Severe pitting was observed on the failed components which was clear sign of cavitation, which occur due to improperly designed CW channel and formation of vortices, which tend to result in energy loss, reduced flow rate, vibration, structural damage, cavitation.

Modification in the MOC of impeller casing and suction bell with higher strength material in consultation with OEM for future, inhouse repairing of CW impeller along with proper anchoring of the vortex breaker for further improving the reliability of CW pumps.

Mechanized Hydro-Jetting for Safe and Efficient Cleaning of Condenser and APH in Thermal Power Plants

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Condenser and air preheater (APH) performance significantly influence the heat rate and overall efficiency of thermal power plants. During overhauls, maintenance of these components is critical but traditionally involves time-consuming, labour-intensive, and high-risk manual cleaning activities. This paper presents the implementation and performance evaluation of mechanized high-pressure hydro-jetting for condenser and in-situ APH basket cleaning. For the first time in NTPC, condenser cleaning was carried out using mechanized hydro-jetting at a pressure of 800 kg/cm², and for the first time in India, mechanized in-situ APH basket cleaning was successfully executed in a power plant. The mechanized approach enabled remote operation, minimized manual intervention, and significantly improved safety.

The results demonstrated a reduction in cleaning duration of approximately 30% for the condenser and 50% for the APH, along with superior cleaning effectiveness compared to conventional methods. In-situ APH cleaning eliminated the need for basket removal, thereby avoiding high-risk lifting and handling operations. Pre- and post-maintenance performance tests indicated substantial performance recovery, achieving near-design parameters.

The study establishes mechanized hydro-jetting as a safe, efficient, and time-effective solution for condenser and APH maintenance, with strong potential for large-scale adoption in thermal power plants.

Optimum Use of Hot Water Siphon during Lean Season at NTPC Farakka

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Thermal power plant efficiency is significantly governed by the condenser performance. Condenser effectiveness is controlled by several geometrical, metallurgical and thermo-fluid parameters. NTPC Farakka (3x200 MW, 2x500MW,1x500MW) has three stages, where St-I and St-II operate on open cycle and St-3 operates on closed cycle cooling water system. Circulating cooling water inlet temperature and flow depends on the climate due to raw water flow from the river Ganges. NTPC Farakka faces challenges during the period of March to May due to lack of water from feeder canal as well as main river. It leads to implementation of some mitigation systems during this lean water period, like barge pumping arrangement, hot water use for raw water, ash water, fire water etc. and hot water siphon to CW forebay to maintain minimum submergence of CW pumps. The last option i.e. taking siphon into service is to raise the forebay water level to operate CW pumps at minimum MSL but it causes mixing of hot water with CW cooling water and results in increase of cooling water temperature at condenser inlet. Subsequently, it affects the performance of condenser and causes loss in heat rate. In the present paper an attempt has been made to derive a correlation between numbers of siphon & condenser back pressure to optimize the use of siphon with minimize heat rate loss through minimum condenser vacuum loss.

Dry bottom ash system - NTPC Experience

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Ash handling systems have undergone continuous upgradation driven by changed environmental norms & increased emphasis on water conservation and by more thrust on ash utilization (Ash is Cash).

For the first time in NTPC, Dry-type Bottom Ash Handling (DBA) System along with a Dry Evacuation System for economizer ash has been implemented at Patratu Phase-I (3 × 800 MW). The system installed at Patratu is the largest DBA system in the world. Operating such a large-capacity plant with harsh ash characteristics posed significant challenges, even for experienced system suppliers. DBA systems have also been envisaged in upcoming NTPC projects due to their advantages over conventional wet systems.

Presently, NTPC has experience with two DBA technologies, namely chain-driven metallic conveyors implemented at Patratu, and steel-mesh belt conveyors installed at BIFCL (2 × 660 MW). This paper is an attempt to share the major learnings of operating thermal power plants of such a big scale with complete dry-type handling of bottom ash and economizer ash.

The challenges encountered are broadly design-related and O&M-related. Initial operation at Patratu revealed several unforeseen design and operational issues in the sprocket and chain system, while the steel-mesh belt system is yet to be fully evaluated for such capacity. Learning provides valuable inputs for addressing these challenges at the design stage, benefiting NTPC and offering useful insights to the global thermal power sector.

Evaluation of Integrated Agri-Waste Torrefaction and Pelletization (iAWTP) Plant: Torrefaction for Higher Biomass Co-Firing in Thermal Power Plant

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For combating twin objectives of environmental issues mainly in NCR region due to stubble/biomass burning and reducing greenhouse gas emissions for achieving target of Net Zero by 2070, National Biomass Mission promotes biomass co-firing with coal in coal based thermal power plants in India. Torrefaction of biomass improves the milling/combustion properties and in turn higher biomass coal co-firing ratio can be achieved. The technology of torrefaction in India is in nascent stage and various technologies are being used in small scale to produce torrefied biomass. To meet the requirement of thermal power plants for achieving higher co-firing ratio, development and standardization of technologies is required. Torrefaction of agri-waste as well as torrefaction of municipal solid waste leading to solid biofuel resembling coal and can be co-fired in TPPs with higher percentage as compared to non-torrefied biomass co-firing. One screw conveyor-based torrefaction plant integrated with densification and palletization unit has been installed to demonstrate the technology and carry-on further research to see the impact of feedstock, temperature of torrefaction and retention period on the characteristics of Torrefied Biomass.

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GEM

Girl Empowerment Mission

Giving Wings To Their Dreams

Korba

Lara

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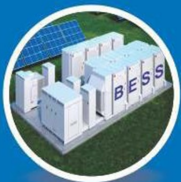

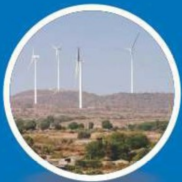
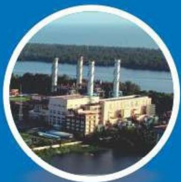
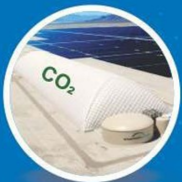

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