Presented By:
Group 17

OPERATIONAL EFFICIENCY ANALYSIS OF NTPC POWER STATIONS SUBTITLE

Designing for Sector Energy

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Sector Context

Thermal plants are India's grid backbone, where efficiency (PLF) drives profitability, but aging assets and fuel volatility challenge operations.

Problem Statement

To identify the root causes of the 11.8% efficiency gap in low-performing units and quantify the 607,137 MW cumulative capacity lost to outages.

Objective

Recover ₹582 Crores in lost revenue by optimizing the 7 Core KPIs, targeting underperforming assets, and aligning maintenance with seasonal demand.

Data Engineering

Source

- Government of India / NTPC Daily Generation Reports (https://ndap.niti.gov.in/dataset/7686)

Cleaning

Key Columns

- Missing Values Handling: 2,042 missing coal stock entries were set to 0 or marked unavailable, and 7 null outage records were filled with 0 to maintain calculation integrity.
- Outlier Treatment: Daily_Capacity_Factor values above 100% or near 0% were flagged using Zero_Gen_Flag for anomaly review.
- Transformations: Dates were standardized into a uniform format, and station names were cleaned into "Station_Clean" by removing underscores and normalizing spacing.
- Feature Engineering: Created Daily_Capacity_Factor for normalized performance comparison, Capacity_Category to segment high vs low performers, and Zero_Gen_Flag to quickly detect zero-generation days.

- Name of the power station: Name of the specific unit.
- Monitored capacity: Installed capacity of the unit (MW).
- Available capacity: Capacity actually available for generation (MW).
- Power generation under todays actual: Actual energy generated on the date (MU – Million Units).
- Capacity under outage: Capacity unavailable due to forced or planned maintenance (MW).
- Coal Stock: Days of coal stock available (critical for thermal plants).
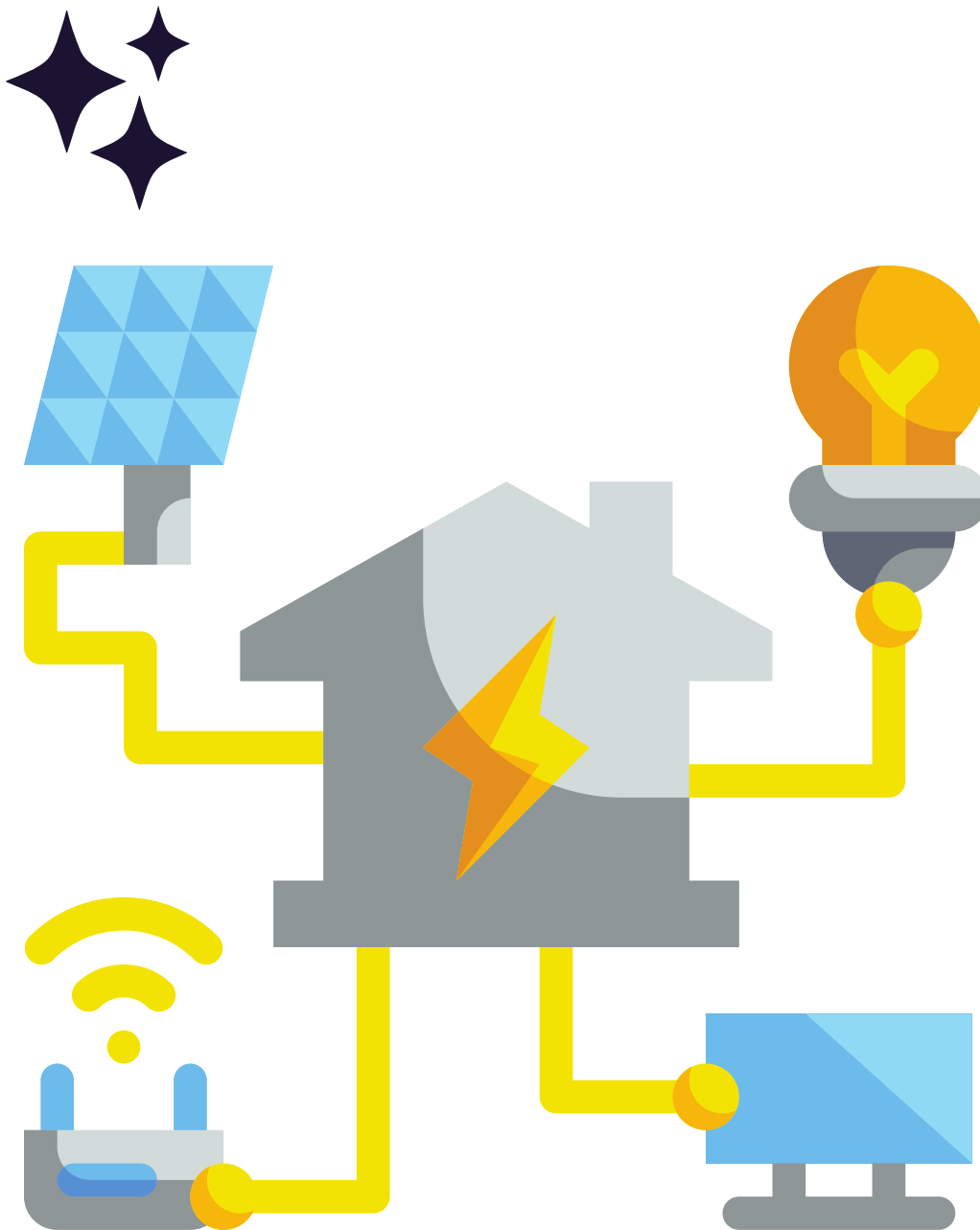
KPI & Metric Framework

Why These KPIs? Each KPI maps directly to a lever the operations team can act on. PLF and Capacity Utilisation tell you the outcome. Outage Rate and Coal Stock tell you the cause. The Composite Score enables prioritisation — which station deserves attention first.

KPIs Measured:

- **High Cap Share (26.97%)**
- **Total Gen (49,620.6)**
- **Avg DCF (65.9%)**
- **Outage (607k)**
- **Available Cap (2.4M)**
- **Monitored Cap (3.0M)**
- **Zero Gen (70)**

Visualizations

- **Year-wise Trend Analysis: Line chart showing generation growth over time (Pivot 3).**
- **Month-wise Seasonality: Column chart highlighting the August dip (Pivot 6).**
- **State-wise Performance: Stacked Bar Chart comparing Monitored vs. Available Capacity per state (Pivot 2).**
- **Capacity Category Analysis: Donut/Pie chart showing the 26.97% High Capacity share (Pivot 4).**
- **Zero Generation & Outage Analysis: Chart tracking the breakdown of the 70 critical failure events (Pivot 5).**
- **Station Performance Summary: Bar chart/Table highlighting top and bottom performing stations (Pivot 1).**

Advanced Analysis

Segmentation

- We segmented stations into "High Capacity" and "Low Capacity".
- Insight: The "High Capacity" segment operates at 79.3% DCF with minimal outages. The "Low Capacity" segment operates at 67.5% DCF but accounts for the vast majority of the recorded outage MW (~98% of outage volume comes from this segment).
- Conclusion: The problem is not systemic across all NTPC stations but concentrated in specific "problem assets."

Anomaly Detection

- 70 events were flagged where generation was exactly 0.
- These are not random; they cluster in specific stations (e.g., Faridabad CCPP, Dadri CCPP). This suggests specific units have chronic starting/technical issues.

Key Finding: The problem is not fleet-wide. It is concentrated in specific low-capacity assets and chronic failure stations.

Key Insights

1. **Efficiency Gap:** High Capacity units run at 79.3% DCF versus 67.5% for Low Capacity units, creating an 11.8% performance gap.
2. **Massive Capacity Loss:** Outages caused a cumulative daily loss of 607,137.78 MW, significantly reducing available capacity from the 3,033,314 MW monitored.
3. **Regional Disparity:** Uttar Pradesh accounts for ~23% of outage volume among the five worst-performing states, with outages heavily outweighing generation.
4. **Operational Benchmark:** Talcher (Old) Thermal Power Station operates near 100% DCF, proving high efficiency is achievable even with aging assets.
5. **Asset Reliance Risk:** Although more efficient, High Capacity units supply only 26.97% of total generation, leaving most production dependent on lower-efficiency units.
6. **Seasonal Vulnerability:** Generation falls about 12% in August compared to March, indicating an underused window for planned maintenance.
7. **Chronic Failures:** 70 zero-generation events cluster in specific units like Faridabad Thermal Power Station and Dadri Thermal Power Plant, signaling persistent technical issues.
8. **Coal Availability:** Despite 27% missing data, recorded zero coal stock periods clearly align with sharp generation drops, confirming fuel logistics as a secondary constraint.
9. **Maintenance Misalignment:** Maintenance outages are poorly timed with seasonal demand patterns, causing avoidable generation losses during peak months.
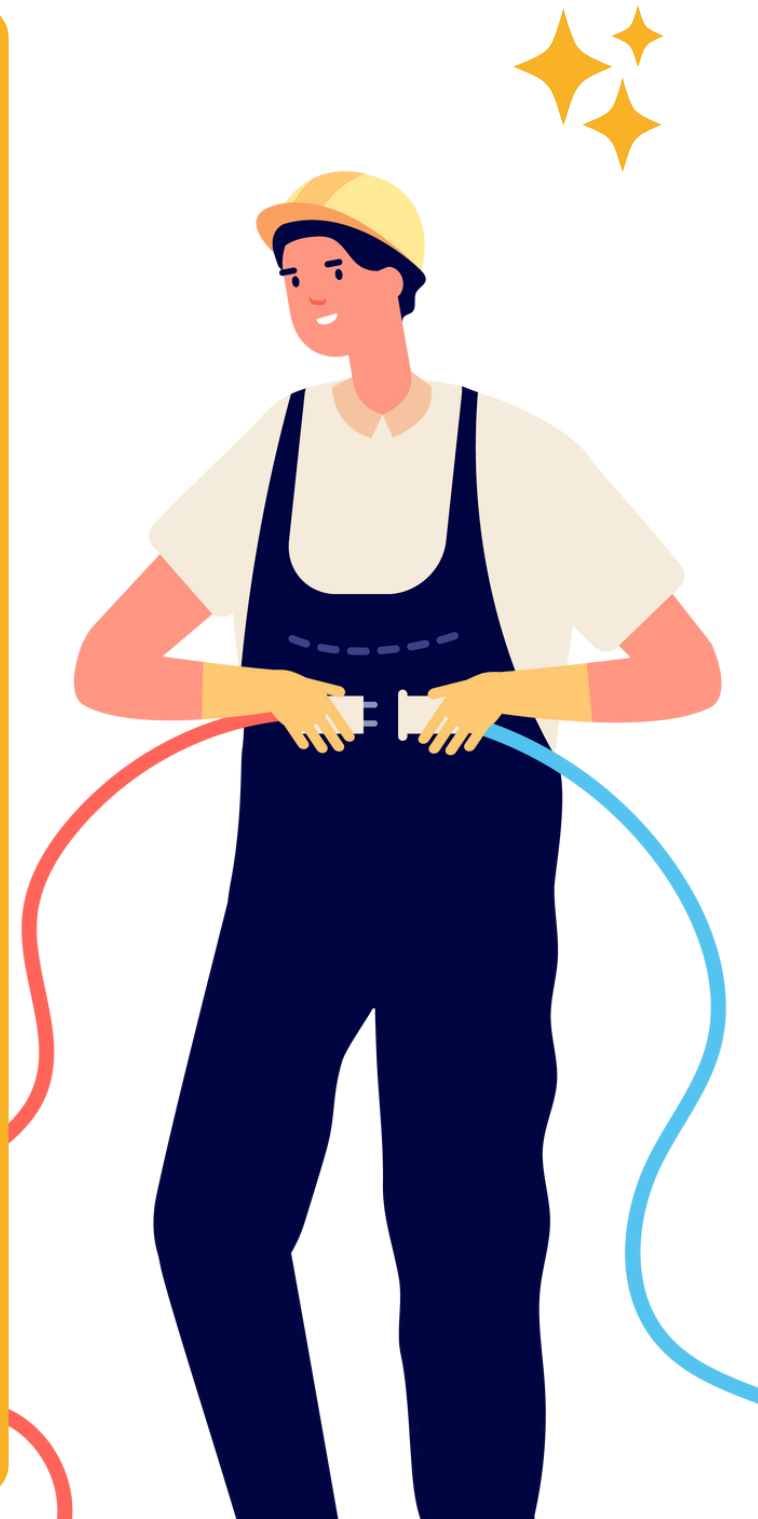
Recommendations

Recommendation 3: Automated "Zero-Gen" Protocol
Implement an automated "Zero-Gen Alert" system that flags any unit reporting 0 generation and requires a mandatory Root Cause Analysis (RCA) report within 24 hours of occurrence.

Recommendation 1: Performance Turnaround Program
Initiate a targeted operational review for the bottom 25% of stations (specifically the "Low Capacity" category). Focus on bringing their Daily Capacity Factor (DCF) from the current average of 67.5% up to a target of 75%.

Recommendation 4: Strategic Maintenance Scheduling
Align planned annual maintenance (overhauls) strictly with the August low-generation window (observed ~12% dip) to ensure maximum availability during peak demand months (March/April).

Recommendation 2: Technical Task Force for UP
Deploy a specialized technical audit team to Uttar Pradesh stations (the highest outage contributor) to diagnose specific equipment failure patterns (e.g., Boiler tube leaks vs. Turbine vibrations).

Impact & Value

Generation Recovery

- **Current State:** The analysis recorded a cumulative daily outage volume of ~607,137 MW.
- **Target:** A conservative reduction of 10% in outage volume through improved maintenance planning and RCA.
- **Recovered Capacity:** 607,137 MW * 10% = 60,714 MW (cumulative daily).

Energy Gain

Converting this recovered capacity into actual energy units (Million Units - MU): Energy = 60,714 MW * 24 hours * 0.001 = 1,457 MU

Financial Impact

Assuming an average revenue realization (tariff) of Rs 4.00 per unit: Revenue Recovered = 1,457 MU * Rs 0.4 Crores/MU = Rs 582.8 Crores

Efficiency Lift

Recovering this lost generation would improve the overall fleet Daily Capacity Factor (DCF) by approximately 1.5%, shifting the fleet average from 65.9% to ~67.4%.

Limitations & Next Steps

Limitations

- Coal Stock column had 27% missing data — limits ability to correlate fuel shortages with outages definitively
- Outage nulls assumed to mean "Zero Outage" — if data was simply not reported, outages may be under-reported
- Data tells us an outage occurred but not why — no specific reason codes available to distinguish boiler failure vs coal shortage
- Partial data for 2026 — limits conclusions for the most recent year
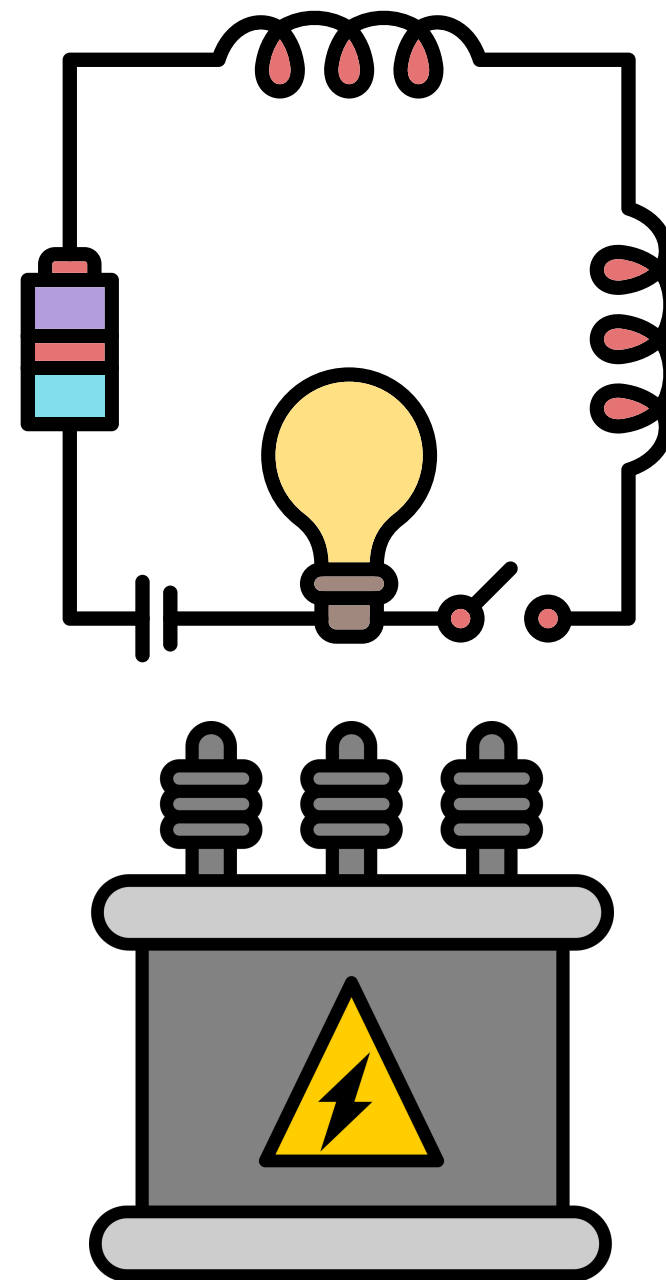
Next Steps

- Predictive Maintenance (PbM): Integrate IoT sensor data (vibration, temperature) with Machine Learning to predict equipment failures before they cause "Zero Generation" events.
- Coal Logistics Optimization: Incorporate external railway and supply chain data to model "Days of Stock" accurately, overcoming the current 27% data gap.
- Financial Dashboarding: Add real-time "Cost of Generation" and revenue data to the dashboard, transforming operational metrics into financial actionable insights.