PRESENTATION ON
"IMPROVING POWER PLANT EFFICIENCY
OPERATOR PERSPECTIVE"

by

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1. Overview Of NTPC

2. Objectives & Approach
   • Indian Scenario & Potentials Of Heat Rate Improvement In India
   • Power Plant Heat Rate: Salient Features & Concepts
   • Methodology For Heat Rate Improvement
     ➢ Strategies Adopted
       1. Summary Of Observations
       2. Techniques & Systems Demonstrated To Recover Losses

3. What Is To Be Done For Indian Power Sector?
NTPC WAS FORMED ON 7TH NOVEMBER 1975

NTPC - VISION

To be a world class integrated power major, powering India’s growth, with increasing global presence
NTPC contributes more than one-fourth of India’s total power generation with less than one-fifth capacity.
OVERVIEW OF NTPC INSTALLED CAPACITY

<table>
<thead>
<tr>
<th>Projects</th>
<th>No. of Projects</th>
<th>Commissioned Capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NTPC OWNED</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COAL</td>
<td>14</td>
<td>21,395</td>
</tr>
<tr>
<td>GAS/ LIQ. FUEL</td>
<td>07</td>
<td>3,955</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>21</td>
<td>25,350</td>
</tr>
<tr>
<td><strong>OWNED BY JVCs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COAL</td>
<td>3</td>
<td>314</td>
</tr>
<tr>
<td>GAS/ LIQ. FUEL</td>
<td>1</td>
<td>740</td>
</tr>
<tr>
<td><strong>GRAND TOTAL</strong></td>
<td>25</td>
<td>26404</td>
</tr>
</tbody>
</table>
Capacity expansion programme

Present Installed Capacity

Commissioned

Planned

“Plant Performance Improvement”

Operator perspective
What it Means to the Operator

- Maintaining the operating parameters at or better to the design value
- Take measures to Improve upon the performance of various systems
  - strategy to reduce accounted loss and
  - strategy to reduce Un-accounted loss
Benefits

- Ease of Operation
- Low breakdown
- Low cost of Maintenance
- Life cycle Improvement
- Lower Heat rate

Lower cost of Generation
Indian Thermal Power Sector
Some of the Reasons for Low Generation Efficiency

- Emphasis on plant load factor instead of ‘efficient generation’
- Degradation of equipment resulting in loss of capacity
- Delayed overhauls (Seasonal Constraints)
- Financial constraints in adequate maintenance
- Lack of awareness on efficiency related issues:
  - Inadequate MIS systems (analysis of financial impact of various operating parameters)
  - Inadequate monitoring system for parameters
  - Non availability of performance measuring instruments at Stations
  - No dedicated group to target efficiency improvement
- Maintenance management & Operation management systems
Why Efficiency is Important?

An average increase of 1% in the Efficiency would result in:

- Coal savings of approx. 11 million tons per annum
- Rupees savings worth Rs.13,000 Million
- 3% CO₂ reduction per annum (approx. 13.5 million tons per annum)
- Higher productivity from the same resources is equivalent to capacity addition
- Lower generation cost per kWh
## INDIAN SCENARIO: DESIGN HEAT RATE TRENDS

<table>
<thead>
<tr>
<th>PERIOD</th>
<th>STEAM PRESSURE</th>
<th>UNIT SIZE (MW)</th>
<th>Turbine HR (kcal/kwh)</th>
<th>Calculated Unit HR (kcal/kwh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1951-60</td>
<td>60 Kg/cm², 482 deg C</td>
<td>30 - 57.5</td>
<td>2470</td>
<td></td>
</tr>
<tr>
<td>1961-75</td>
<td>70 Kg/cm², 496 deg C to 90 ata 538 deg C</td>
<td>60 -100</td>
<td>2370</td>
<td></td>
</tr>
<tr>
<td>1961-75</td>
<td>130 ata 535/535 deg C</td>
<td>110 - 120</td>
<td>2170 -2060</td>
<td>2552-2423</td>
</tr>
<tr>
<td>1977-82</td>
<td>130 ata 535/535 deg C</td>
<td>210/Russian)</td>
<td>2060</td>
<td>2423</td>
</tr>
<tr>
<td>1983 +</td>
<td>150 ata 535/535 deg C</td>
<td>210 (Siemens)</td>
<td>1985</td>
<td>2335</td>
</tr>
<tr>
<td>1984 +</td>
<td>170 ata 535/535 deg C</td>
<td>500</td>
<td>1950 (TDBFP)</td>
<td>2294</td>
</tr>
<tr>
<td>1990 +</td>
<td>150 ata 535/535 deg C</td>
<td>210 / 250</td>
<td>1950 (MDBFP)</td>
<td>2294</td>
</tr>
<tr>
<td>1990 +</td>
<td>170 ata 538/538 deg C</td>
<td>250 / 500</td>
<td>1950 (TDBFP)</td>
<td>2294</td>
</tr>
</tbody>
</table>

* Above are best design values/ design heat rates of individual unit varies based on reference ambient, coal quality, design and supply dates.
What is Heat Rate?

• Heat rate is the amount of chemical energy that must be supplied to produce one unit of electrical energy.
• Heat rate is a measure of how efficiently it converts the chemical energy contained in fuel into electrical energy.
• Since, coal chemical energy is measured in kilocalories (kCal) and electrical energy is measured in ‘unit’ i.e. kilowatt-hours (kWh), the units of heat rate are kilocalories per kilowatt-hours (kCal/ kWh).
• Empirically, 1% improvement in efficiency is equal to 3% improvement in heat rate.
Minimizing Unaccountable
(e.g. valve leakage, high accuracy measurements, etc.)

Mills & Combustion Optimization
(5 to 15 kCal/kWh)

Reducing Auxiliary Power Consumption
(e.g. BFP, CW system & ESP power consumption)

Condenser
(25 to 100 kCal/kWh)

‘What can not be measured can not be saved’
Method: Periodic Measurement of Deterioration (simplified tests)
Heat Rate Deviations in Power Plants

Heat Rate Deviations:
- Losses-A = Expected – Design
- Losses B = Actual - Expected
### Actual-Expected: Segregation of Losses

<table>
<thead>
<tr>
<th>ACCOUNTABLE</th>
<th>UNACCOUNTABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Deviations in critical parameters from design or expected</td>
<td></td>
</tr>
<tr>
<td>• Deterioration in equipment performance</td>
<td></td>
</tr>
<tr>
<td>• Fuel characteristics</td>
<td></td>
</tr>
<tr>
<td>• Auxiliaries power consumption</td>
<td></td>
</tr>
<tr>
<td>• Operation practice</td>
<td></td>
</tr>
<tr>
<td>• Passing of valves</td>
<td></td>
</tr>
<tr>
<td>• Equipments where performance assessment difficult e.g. LP turbine</td>
<td></td>
</tr>
<tr>
<td>• Radiation losses</td>
<td></td>
</tr>
<tr>
<td>• Uncertainties of Instruments</td>
<td></td>
</tr>
</tbody>
</table>

Accountable are categorized into Controllable (Recoverable) & Non-controllable
## EFFECT OF CRITICAL PARAMETERS ON HEAT RATE

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Variation</th>
<th>Impact (kCal/kWh)</th>
<th>200 MW Unit</th>
<th>500 MW Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>SH Spray</td>
<td>20 T/hr</td>
<td>0.30</td>
<td>0.81</td>
<td></td>
</tr>
<tr>
<td>RH Spray</td>
<td>20 T/hr</td>
<td>12.00</td>
<td>4.76</td>
<td></td>
</tr>
<tr>
<td>MS Pr</td>
<td>10 kg</td>
<td>12.00</td>
<td>7.30</td>
<td></td>
</tr>
<tr>
<td>MS Temp</td>
<td>10 degC</td>
<td>6.00</td>
<td>6.20</td>
<td></td>
</tr>
<tr>
<td>RH Steam</td>
<td>10 degC</td>
<td>6.00</td>
<td>5.55</td>
<td></td>
</tr>
<tr>
<td>LOAD</td>
<td>10 MW</td>
<td>12.00</td>
<td>4.36</td>
<td></td>
</tr>
<tr>
<td>Cond Back Pr</td>
<td>5 mm Hg</td>
<td>8.00</td>
<td>6.70</td>
<td></td>
</tr>
<tr>
<td>FW Temp</td>
<td>10 degC</td>
<td>8.00</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>
HP/IP Turbine Efficiency

Effect of Turbine Efficiency on Heat Rate

2% change in HP or IP Turbine Efficiency in a 210 MW unit leads to change in HR by about 8 kcal/kWh
Efforts for Improvement in Turbine Efficiency

- Alumina Blasting of Turbine Components
- Refinining of Inter-stage sealing fins and balance drum / gland sealing fins.
Alumina Blasting of Turbine Components

• Alumina Blasting of HP turbine Rotor and Casing being done to remove the Silica deposit from the bladding surface. The deposits on the blades & turbine steam path increases flow path surface roughness and decrease the flow area of the cascade. This results in reduced efficiency of turbine cylinder.

• Cleaning of deposits from Turbine components results in increase in turbine efficiency.
Refining of Inter-stage sealing fins

- Inter-stage sealing fins are provided at each stages to seal the gap between moving & stationary parts i.e. Rotor blades & casing / guide blades & rotor.
- 5 fins are provided at each stage (18 x 5 = 90 fins) to create labyrinth effect and hence sealing.
- Radial clearances at these fins play vital role in turbine efficiency.
- Clearances of these sealing fins tends to increase over a period of time due to wear / tear / warping of fins.
- Increase in sealing fin clearances result in short circuiting of steam and increase in steam quantity and first stage pressure requirement for generating same load in turn.
- Increased first stage pressure results in increase in Heat rate and deterioration of turbine efficiency.
HP Turbine Casing Fins Arrangement
HP Turbine Casing after Refinishing

Inter-stage Fins
<table>
<thead>
<tr>
<th>S.No</th>
<th>Parameters</th>
<th>Design</th>
<th>Before</th>
<th>After Refinining</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HP Cylinder efficiency</td>
<td>89 %</td>
<td>83.49%</td>
<td>88.65 %</td>
</tr>
<tr>
<td>2</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; Stage Pressure</td>
<td>162 Ksc (max)</td>
<td>164 Ksc at 498 MW</td>
<td>156.4 Ksc at 502 MW</td>
</tr>
<tr>
<td>3</td>
<td>IP Cylinder efficiency</td>
<td>91.7 %</td>
<td>86.67 %</td>
<td>88.35 %</td>
</tr>
<tr>
<td>4</td>
<td>Heat Rate</td>
<td>2094</td>
<td>2027</td>
<td></td>
</tr>
</tbody>
</table>
Major Other losses in turbine cycle

- Loss due to high back pressure
- Loss due to RH attemperation
- Loss due to low HRH temperature
- Loss due to passing of high energy drain valves
Condenser Performance

Condenser performance deterioration leads to about 20 to 30 mm Hg deviation in vacuum. Main reason for deterioration is due to

- tube fouling
- air ingress
- high heat load
- CW Flow
- CW inlet temp
Example

**Fouling V/s Cleaning Effects On Heat Transfer In Condenser**

![Graph showing decrease in heat transfer rate with and without tube cleaning over time.](image)
Condenser Performance

Action to reduce losses

• Decision for condenser cleaning
  1. Cleaning of tubes at Part load / during opportunity shut down
  2. Fixing limit for deterioration in vacuum 10-15 mm

• Cleaning at part load / Opportunity S/D
  1. Butterfly Valve - Effective isolation
  2. Bullet/HP jet cleaning - Availability of cleaning
Condenser Performance

Condenser Air - Ingress

- Monitoring/Checking
  - air flow measurement
  - air-steam mixture depression
  - dissolved O2

- Online Sealing of air ingress point
  - use of sealing compounds

- Identification of Air ingress point
  - Steam pressurization during Overhaulings

Others:
  - offline flood test during O/H
  - online Helium leak detection
Condenser Performance

Other Factors

- High heat load due to
  - poor Turbine performance
  - passing of high energy drains
  - poor condenser upkeep
  - low inlet steam parameters

- Low CW flow
  - poor pump performance
  - low intake level
  - Tube choking

- CW inlet temperature
  - Higher CW inlet temperature due to poor CT performance
Condenser Performance

Performance Assessment

- Use of absolute pressure transmitter for Condenser back pressure measurement.
- Grid measurement for back pressure & CW outlet temperature
- Air flow measurement for vacuum pump/ejector
- Temperature measurement for air-steam mixture
- CW flow validation
- Calibration of instruments
Major Boiler losses

- Dry flue gas loss (controllable)
- Loss due to moisture and H\textsubscript{2} in fuel
- Combustible loss with BA and FA (controllable)
- Heat loss due to bad insulations & other unaccounted losses
Measures to reduce dry flue gas loss

- High excess air and high exit FG temp attribute to increased DFG
- FG O$_2$ at APH inlet is a feedback to adjust excess air, which is sometimes misleading.
- Excess air optimization through monitoring of CO in exit FG will be more effective
- Reduction in FG quantity at APH inlet will reduce FG exit temp.
- Reduction of tempering air will reduce exit FG temp
  - Arresting air ingress in flue path
  - Ensuring steady coal quality through blending
- Maintaining cleaned heat transfer surfaces through timely soot blowing
Control combustible loss with ash

- Firing of coal from multiple sources attribute to wide variation in combustible loss with ash
- Ensure proper PF fineness
  - Retrofitting of online LOI monitoring instrument
  - Retrofitting of remote operable classifiers
- Ensure proper excess air and PA to SA ratio
Steps involved in Boiler Performance Optimization

• Balancing of coal and air flow in coal pipes of each mill using ASME dirty pitot kit & rotary probe
• Air heater performance testing
• Combustion regime evaluation to ascertain level of combustion completion
• Evolving an optimum boiler operating regime by testing boiler under different conditions.

Feedback from these tests is also used to cross-check the ‘on line’ station instruments and to plan the work to be undertaken during next overhaul.
High Energy Drains

Passing of High Energy drain valve affects in 3 ways

1. Loss of High Energy steam
2. Deterioration in Condenser Vacuum
3. Damage to the valve

(Typical example)

Loss (Energy loss & vacuum) due to High Energy drain valve passing is about 7-9 kcal / kWh
(Taking about nominal passing of 4 valves out of 20 valves)

Remedial Measures

• Installation of thermocouples on down stream of High Energy drains along with display facility at control room.

• Progressive replacement of High energy drain valves by superior quality valves.
Reduction of Unaccountable Losses

Strategy: Application of new technologies to identify & measure losses to prioritize repair

Example: Cycle Isolation problems: Valve Leakage (Passing), Radiation Losses

• Valves have considerable potential to reduce unaccountable losses
• Applicable to:
  ➢ Reheater & Super heater spray valves
  ➢ High energy drains
  ➢ HP heater alternate drains
  ➢ Boiler feed-pump & condensate pump re-circulation lines

Use of multiple technologies like acoustics & IR - Thermography (IRT) to identify ‘passing’ and estimate extent of passing to prioritize maintenance
Summary of Observations

- **Combustion optimization**: Reduction in Air leakages
- **Air-fuel ratio optimization**: periodic adjustments in mills & installing appropriate orifices periodically.
- **Air-preheater performance**: deterioration in condition of baskets & seals with time
- **Furnace parameter profile**: Optimization of operational parameters & calibration/validation of on-line instruments for day to day operation
- **Performance Optimization of ESPs**: Flue gas conditioning techniques like water fogging & sodium conditioning have demonstrated savings of auxiliary power consumption.
Measures Adopted

1. Formalization of ‘Efficiency Management System (EMS)’

2. Three step process:
   - No cost or low cost options for initiating a Program
   - Medium cost options
   - Long term actions for sustainability
Step 1: No cost or low cost items

1. Organizing efficiency awareness programs.
2. Involvement of higher management is essential
3. Establishing a ‘Efficiency group’ by relocating two or three suitable engineers at each Station.
4. Focus on critical parameter monitoring, calculation of deviations, segregation into ‘controllable parameters’, action plan identification.
5. Daily MIS to Station / utility management on financial impacts.
7. Identification of high potential areas (to start with it could be condenser, valves, mills & combustion optimization).
**Step: 2 - Strengthening Efficiency Group**

1. Strengthening of analysis & testing related functions:
   i. Periodic calibration of on-line instruments
   ii. Evaluation of performance based on on-line measurements

2. Benchmarking of performance after overhaul, periodic evaluation to assess degradation for actions.


Technologies are fascinating but they are only tools
Step-3: Steps for sustainability

1. Acquisition of medium cost equipment at station level & high cost equipment at utility level
2. Periodic testing of equipment / systems
3. Evaluation of deviations to assess degradation (loss areas)
4. Validation of on-line instruments
5. Identification of items for maintenance / replacement based on degradation & financial implications
6. Testing after repair / overhauling, to evaluate effectiveness of actions
Thank You