BEST PRACTICES IN THERMAL POWER PLANT

Confederation of Indian Industry
CII – Godrej Green Business Centre, Hyderabad, India
Agenda

- Indian Scenario – Power Plant
- Factors affecting Power Plant Performance
- Case studies
All India Installed Capacity (MW)

Total Installed Capacity: 3,19,287 MW

Source: As on 31-07-2015, CEA Website
## APC % - Thermal Power Plant Scenario

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Operating Capacity, MW</th>
<th>APC %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant A</td>
<td>250</td>
<td>8.20</td>
</tr>
<tr>
<td>Plant B</td>
<td>135</td>
<td>9.63</td>
</tr>
<tr>
<td>Plant C</td>
<td>60</td>
<td>8.19</td>
</tr>
<tr>
<td>Plant D</td>
<td>250</td>
<td>9.20</td>
</tr>
<tr>
<td>Plant E</td>
<td>130</td>
<td>6.99</td>
</tr>
<tr>
<td>Plant F</td>
<td>300</td>
<td>7.92</td>
</tr>
<tr>
<td>Plant G</td>
<td>150</td>
<td>8.23</td>
</tr>
<tr>
<td>Plant H</td>
<td>300</td>
<td>9.36</td>
</tr>
<tr>
<td>Plant I</td>
<td>125</td>
<td>13.10</td>
</tr>
</tbody>
</table>
### APC % - Captive Power Plant Scenario

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Operating Capacity, MW</th>
<th>APC %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant A</td>
<td>06</td>
<td>13.5</td>
</tr>
<tr>
<td>Plant B</td>
<td>15</td>
<td>9.82</td>
</tr>
<tr>
<td>Plant C</td>
<td>15</td>
<td>7.73</td>
</tr>
<tr>
<td>Plant D</td>
<td>15</td>
<td>7.57</td>
</tr>
<tr>
<td>Plant E</td>
<td>18</td>
<td>7.80</td>
</tr>
<tr>
<td>Plant F</td>
<td>25</td>
<td>8.15</td>
</tr>
<tr>
<td>Plant G</td>
<td>25</td>
<td>10.95</td>
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<tr>
<td>Plant H</td>
<td>27</td>
<td>7.69</td>
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<tr>
<td>Plant I</td>
<td>30</td>
<td>6.96</td>
</tr>
<tr>
<td>Plant J</td>
<td>33</td>
<td>11.0</td>
</tr>
</tbody>
</table>
Thermal power plants

- APC % ranges: 8 – 12.5%
  - Large Bandwidth

Example:
- Installed capacity: 163304 MW
- Operating Capacity: 130643 MW @ 80% PLF
- APC power: 11104.6 MW @ 8.5% APC (average)

At least 0.5% reduction in APC%
- Huge increase in the Net Power Generation
  - Approx. 653 MW
Captive power plants

- APC % ranges: 5 – 12.5%
  - Large Bandwidth

Example:

- Installed capacity: 34444.12 MW
- Operating Capacity: 27555.3 MW @ 80% PLF
- APC power: 2342.2 MW @ 8.5% APC (average)

At least 1% reduction in APC%

- Huge increase in the Net Power Generation
  - Approx. 275 MW
# APC% Benchmarking - AFBC boilers

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Auxiliary Name</th>
<th>Specific Power Consumption, kW/MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fans (PA, SA, ID &amp; ACC fans)</td>
<td>17.9</td>
</tr>
<tr>
<td>2</td>
<td>Pumps (BFP, CEP, &amp; ACWP)</td>
<td>24.6</td>
</tr>
<tr>
<td>3</td>
<td>BOP (WTP, CHP, ESP, Lighting, AC, CHP, Compressors &amp; Misc.)</td>
<td>11.1</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>53.6 (APC – 5.36%)</strong></td>
</tr>
</tbody>
</table>
## APC% Benchmarking - CFBC boilers

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Auxiliary Name</th>
<th>Specific Power Consumption, kW/MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fans (PA, SA, ID &amp; ACC fans)</td>
<td>29.79</td>
</tr>
<tr>
<td>2</td>
<td>Pumps (BFP, CEP, &amp; ACWP)</td>
<td>25.74</td>
</tr>
<tr>
<td>3</td>
<td>BOP (WTP, CHP, ESP, Lighting, AC, CHP, Compressors &amp; Misc.)</td>
<td>9.83</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>65.36 (APC – 6.53%)</strong></td>
</tr>
</tbody>
</table>
Factors affecting Power Plant Performance

- Overall Plant Heat Rate
  - Plant Load Factor
  - Operational efficiency of the equipments
  - Startup & shutdown
  - Age of the plant
  - Fluctuation load
  - Coal quality
Typical APC % Breakup

- Net Generation, %, 91.15
- APC, 8.85
- Compressors, 0.51
- ACC fans, 1.42
- ID Fan, 0.30
- PA Fan, 0.21
- WTP, 0.07
- CHP, 0.12
- ACWP, 0.35
- CEP, 0.28
- ESP, 0.12
- Lighting, 0.08
- AC & Vent, 0.10
- BFP, 3.64
- Misc., 0.35
Energy Conservation at macro level...

Capacity utilization

Three-pronged approach

Fine-tuning

Technology up gradation

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Best Practices
Optimise the operation of CEP

- Condensate extraction pump
- Operating with the valve controlling
  - Deareator level is controlled with the control valve
    - Pressure drop across the control valve is 5 – 8 kg/cm$^2$
- Recirculation valve is 90% closed
  - But 12.8 m$^3$/hr is passing through recirculation line
- Good potential to optimise the CEP operation
Optimise the operation of CEP

- Recommendation

- Option 1:
  - One stage blinding

- Option 2:
  - Install VFD
  - Interlock the VFD with the condenser level and operate it in closed loop
  - Open the control valve fully
  - Maintain “ZERO” recirculation
  - Atleast 3.0 kg/cm² reduction in the discharge pressure
Optimise the operation of CEP

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Annual Saving</strong></td>
<td><strong>Rs 40.0 Lakhs</strong></td>
</tr>
<tr>
<td><strong>Investment</strong></td>
<td><strong>Rs 15.0 Lakhs</strong></td>
</tr>
<tr>
<td><strong>Investment</strong></td>
<td><strong>5 months</strong></td>
</tr>
</tbody>
</table>
Operate condenser vacuum at design vacuum level

- What is the effect of vacuum on turbine performance?
  - Turbine capacity: 250 MW
  - Present operating Load: 115 MW
- Load less than 50% of the capacity
- During normal operating condition very low vacuum has been achieved
  - Achieved vacuum: 0.04 kg/cm² (a)
  - Design vacuum: 0.1 kg/cm² (a)
Operate condenser vacuum at design vacuum level

- Effect of lower vacuum compared to the design
- Life of turbine
  - Reduction in dryness fraction of exhaust steam
    - Turbines normally design for 0.88 dryness fraction
  - Increased pitting on LP turbine blades
- Increase in energy consumption
  - Velocity of steam flow increases
  - Exhaust loss increases
**Operate condenser vacuum at design vacuum level**

<table>
<thead>
<tr>
<th>Pressure (kg/cm²)</th>
<th>Velocity (m/sec)</th>
<th>Exhaust loss kCal/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>85</td>
<td>2.8</td>
</tr>
<tr>
<td>0.09</td>
<td>93.8</td>
<td>2.5</td>
</tr>
<tr>
<td>0.08</td>
<td>104.8</td>
<td>2.4</td>
</tr>
<tr>
<td>0.06</td>
<td>137.5</td>
<td>3.0</td>
</tr>
<tr>
<td>0.05</td>
<td>163</td>
<td>3.8</td>
</tr>
<tr>
<td>0.04</td>
<td>201</td>
<td>6.5</td>
</tr>
</tbody>
</table>
 Operate condenser vacuum at design vacuum level

- The exhaust loss is the lowest at 0.08 kg/cm² (a) vacuum

- How to maintain the design vacuum
  - Reduce the quantity of water supply
  - Optimise the operation of cooling tower fan

- Equivalent reduction in steam consumption – 300 kg/hr

Annual Saving - Rs 27.00 Lakhs
Heater performance Improvement

- HP & LP heaters – improves overall efficiency of the plant

- HP heater performance
  - More important compared to LP heaters
  - Marginal reduction in performance – significantly increases the heat rate
  - During normal operating condition – Difficult to identify the deterioration
HP Heater performance Improvement

- Key parameters indicating performance of the heaters
  - Economizer inlet feed water temperature
  - Terminal temperature difference (TTD)
  - Drain cooler approach (DCA)
  - Steam flow through HP heater – to be estimated based on heat balance
Definition of key parameters

- **Terminal temperature difference**
  - Temperature difference between heater outlet feed water temperature and the saturation temperature of steam
  \[ \text{TDD} = \text{Tsat} - \text{Ttwo} \]

- **Drain cooler approach**
  - Temperature difference between drain temperature and inlet feed water temperature
  \[ \text{DCA} = \text{Tdrain} - \text{Tfwi} \]
Heater performance improvement – Case study

- **Saturation Temp of steam**: 358.2°C
- **Feed water from HPH5**: 210°C
- **Feed water to Economizer**: 248°C
- **DCA**: 18.2°C
- **TTD**: 3.36°C
- **Drain to HPH5**: 228.2°C
## Heater performance improvement

<table>
<thead>
<tr>
<th>UNIT</th>
<th>HEATER</th>
<th>OPERATING</th>
<th>DESIGN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>DCA</td>
<td>TTD</td>
</tr>
<tr>
<td>1</td>
<td>HPH6</td>
<td>11.6</td>
<td>3.37</td>
</tr>
<tr>
<td></td>
<td>HPH5</td>
<td>2.4</td>
<td>7.00</td>
</tr>
<tr>
<td>2</td>
<td>HPH6</td>
<td>18.2</td>
<td>3.36</td>
</tr>
<tr>
<td></td>
<td>HPH5</td>
<td>5</td>
<td>7.21</td>
</tr>
</tbody>
</table>
Heater performance improvement

- Observations
  - Quantity of steam flow is also high compared to design in HPH – 6
  - Drain cooler approach is very high compared to design
  - Marginal increase in TTD

- Possible reasons
  - Performance of HP heater
  - Passing of drain valve
Heater performance improvement

- Drain valve to deaerator leaking
- Replace the existing drain valve preferably with multi-stage pressure reduction drag valve
  - Avoid passing
Guide line for heater performance improvement

1. Increase in steam flow

2. Did TTD increase?
   - Yes: Check drain valve passing
   - NO: Did DCA increase?

3. Did DCA increase?
   - Yes: Check for lower heater level
   - NO: High heater level?

4. High heater level?
   - Yes: Reduce heater level
   - NO: Did DCA increase?

5. Did DCA increase?
   - Yes: Increase heater level & reduce DCA
   - NO: Check for heater tube leakage & increased drain flow

6. Partition plate may be leaking
Optimise the pressure drop in flue gas circuit

- Static pressure measurement in the flue gas circuit
  - Pressure drop across APH, Economiser & ESP
    - 120 – 135 mmwc across each section
  - Calculated flue gas velocity
    - 6 – 18 m/sec
- Possible reasons are
  - Due to duct bends (90°)
  - Due to improper distribution of the flue gas
  - Turbulence in flue gas path
- Standard Norm (Pressure drop):
  - APH & Economiser – 60 – 80 mmwc
  - ESP – 15 - 25 mmwc
CFD Model

AS IS

Design Modification

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Turbulence is observed in the rectangular sections.
No Turbulence is observed in the new design.
CFD Application

- Pressure drop reduced by 50%
- Excellent potential for energy saving
  - Low investment & downtime
- Further areas for CFD Application
  - Ducts, ESP, Cyclones – return dust loss & ΔP
  - Optimization of separators & Bag House - cement
Optimise the pressure drop in flue gas circuit

- **Recommendation**
  - Potential area to do CFD analysis and reduce pressure drop
  - At least 15 – 20 mmwc reduction in pressure drop possible
  - Successfully implemented in many cement plants & Utility power plants

**Annual Saving** - Rs 4.0 Lakhs
**Investment** - Rs 5.0 Lakhs
**Payback period** - 12 Months
Optimizing operation of Cooling water pump

- **Background**
  - **4 x 135 MW IPP:**
    - 4 Cooling water pumps for condenser cooling and auxiliary cooling water requirements
    - Common for all 4 units
  - **Operating condition**
    - CW operate at discharge pressure of 0.21-0.23 Mpa
    - Range across the condenser – 7.5 Deg C
Optimizing operation of Cooling water pump

Cooling Tower

Units 1 & 2

Units 3 & 4

Forebay

Unit 1

Unit 2

Unit 3

Unit 4

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Optimizing operation of Cooling water pump

- **Observation by the plant team**
  - The team observed that by increasing the range across condenser, the cooling water requirement could be met with 3 CWPs alone.

- **Action taken**
  - Initially the flow through one of the CWP was throttled and when the valve position reached 70%, the pump was stopped.
Optimizing operation of Cooling water pump

- **Existing System**
  - The 3 pumps operate with
    - Discharge pressure – 0.18 to 0.19 Mpa
  - Range across condenser
    - Increased from 7.5 to 9.5 Deg C

- **Benefits**
  - Reduction of power by stopping one pump
  - Loading of cooling tower reduced with reduction in total water flow quantity
Optimizing operation of Cooling water pump

- **Savings**
  - The overall savings achieved from this project by stopping one pump was
    - 2350 kw
  - **Investment - NIL**
Installation of Multistage Pressure Reduction Drag Valve

- Difference in drum flow and total pump flow
  - Passing of recirculation line

- Quantity of recirculation
  - BFP – 1 = 14 m³/hr
  - % of passing : 7%

- Possible reason for passing of recirculation line
  - Higher dp across the valve

- Good potential exists by avoiding recirculation
Installation of Multistage Pressure Reduction Drag Valve
Installation of Multistage Pressure Reduction Drag Valve
Installation of Multistage Pressure Reduction Drag Valve

- Difference in drum flow and total pump flow
  - Passing of recirculation line

- Recommendation
  - Replace the exist valves with multi stage pressure reduction drag valve
  - Reduces recirculation flow
# Installation of Multistage Pressure Reduction Drag Valve

<table>
<thead>
<tr>
<th>Description</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Saving</td>
<td>Rs 30.00 Lakhs</td>
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<tr>
<td>Investment</td>
<td>Rs 45.00 Lakhs</td>
</tr>
<tr>
<td>Payback</td>
<td>18 Months</td>
</tr>
</tbody>
</table>

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Speed Optimisation of unit -1 & 2 BFP
hydraulic coupling

Unit-1 & 2 Boiler Feed Pump Pump Specification

- 2 X 100 % per unit
- Single stage Booster pump, make Weir (UK)
- Three stage Pressure stage pump, make Weir (UK)
- Motor rating 8800 KW, make Peebles Electric Ltd (UK)
- Geared variable speed Turbo-coupling for Pressure stage pump, make Voith (Germany)
Speed Optimisation of unit -1 & 2 BFP

hydraulic coupling
# Speed Optimisation of unit -1 & 2 BFP hydraulic coupling

<table>
<thead>
<tr>
<th></th>
<th>Before Modification</th>
<th>After Modification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input Motor Speed</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design (47.5 Hz)</td>
<td>1406 RPM</td>
<td>1470 RPM</td>
</tr>
<tr>
<td>Operating (50 Hz)</td>
<td>1470 RPM</td>
<td>1470 RPM</td>
</tr>
<tr>
<td><strong>Max Output Pump Speed</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design (50 Hz)</td>
<td>1470 RPM</td>
<td>1470 RPM</td>
</tr>
<tr>
<td>Operating (50 Hz)</td>
<td>1470 RPM</td>
<td>1470 RPM</td>
</tr>
<tr>
<td><strong>Gear Ratio</strong></td>
<td>143/34</td>
<td>113/30</td>
</tr>
<tr>
<td><strong>Total Loss in Coupling</strong></td>
<td>1148 KW</td>
<td>430 KW</td>
</tr>
</tbody>
</table>
Speed Optimisation of unit -1 & 2 BFP hydraulic coupling

- Intangible benefits:
  - Reduction of Hydraulic oil temperature by 30°C which in turn reduced the cooling water demand for the pump

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Annual Saving</td>
<td>Rs. 140 Lakhs</td>
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<tr>
<td>Investment</td>
<td>Rs. 80 Lakhs</td>
</tr>
<tr>
<td>Payback period</td>
<td>7 Months</td>
</tr>
</tbody>
</table>
Installation of Magna Drive

- Magnetic coupling
  - Principle of operation
    - It has a magnetic rotor surrounded by a conductor rotor.
    - Both the rotors are never in contact with each other
    - Torque is transmitted through an air gap in the coupling by the relative motion between the conductor rotor and extremely powerful permanent magnets contained in the magnetic rotor.
    - This relative motion creates a magnetic field in the conductor thereby transmitting torque
Installation of Magna Drive

Magnetic coupling:

- Advantages
  - The signal could be given directly from the DCS (4-20 mA)
  - No direct coupling hence lesser stress on the motor
  - No harmonics
  - No separate unit/ space required unlike VFD panel
  - Tolerates misalignment, thermal expansion and vibration issues
  - Operates with any kind of motor
  - Slip of 2-3%

Magnetic Adjustable Speed Drive for 190 KW ID Fan
Installation of Magna Drive

- Can operate with Angular Misalignment
- Can operate with Parallel Misalignment
- Can operate with Axial Misalignment
Install Intermediate controller in compressed air system

- Reciprocating compressors 3 no's in operation for compressed air supply
  - Instrumentation & Service air supply
  - Total Capacity : 1250 cfm
- Operating pressure variation significant
  - Load pressure : 6.0 kg/cm²
  - Unload pressure : 7.0 kg/cm²
- Total compressor load : 450 kW
Typical Compressed Air Pressure
Real Time Data

PSIG

Time

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Effect of pressure fluctuation due to artificial demand

- Artificial demand: compressor tries to maintain higher set pressure in the entire system

- Consumption increases at:
  - User equipment
  - Open end users such as cleaning
  - Increase in leakage

- Increased compressor power consumption
Pressure graph with & without controller
Benefits of Installing Controller

- Energy savings from 7 – 20%
- Reduction in air generating pressure
- Constant air pressure
  - +/- 0.1 kg/cm²
- Reduction in artificial demand
- Reduction in compressed air leakages

<p>| | |</p>
<table>
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<tbody>
<tr>
<td>Annual Saving</td>
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<tr>
<td>Investment</td>
<td>Rs. 15.00 Lakhs</td>
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<tr>
<td>Payback period</td>
<td>13 Months</td>
</tr>
</tbody>
</table>

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Further Energy conservation measures
Energy conservation measures

- Installation of Combustion Optimisation system
- Variable frequency drive (VFD) for - BFP, CEP, CWP, ACWP, DM transfer pumps, FD, PA/ SA Fan & ID fan etc..
- Monitor the efficiency of the boiler
- Monitor the flue gas exit temperature
- Calculate the heat loss from the hot surface
- Transfer makeup water from CST to condenser hot-well with the help of gravity
To Sum up...

- Tremendous potential to reduce the present operating heat rate
- Become a World Class Energy Efficient unit
  - Implement the latest technologies
  - Learning the best practices from the other sector / industries
Thank you

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