COST OF CYCLING
AND
DAMAGE CONTROL
– NTPC PERSPECTIVE


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Presentation Outline

- Introduction to Cycling
- Damage Mechanism in Cycling
- Manifestation of cycling effects
- NTPC Perspective
- Cost of Cycling
- Suggested Solution
- Conclusions
• Introduction to Cycling
• Damage Mechanism in Cycling
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• Conclusions
Introduction to Cycling

- Cycling – Deviation from base load operation
  - Unit startup/shutdown operations
  - On-load cycling - high frequency MW changes (Manual or RGMO) Or MW changes due to equipment problems Or less schedule Or fuel/water shortages
- Cycling can be very damaging to the generation equipment designed for base load operation
- The Damage - Boiler, steam lines, turbine and auxiliary components go through large thermal and pressure stresses resulting in long term irreparable structural damages
• Introduction to Cycling
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Damage Mechanism in Cycling

- Base load units design
  - to operate predominantly under creep conditions
  - The design codes assume that the effects of fatigue were contained within the design stresses.

- Creep and Thermal Fatigue
  - Creep is both time and temperature dependent hence cycling has no direct effect on long-term creep
  - But cumulative effects of repeated overheating (cycling) may result in accumulation of creep damage
  - Major problem experienced due to cycling is thermal fatigue damage. – cracking of metal
  - Severe thermal gradients arise from excessive steam to metal and through-wall temperature differences
Damage Mechanism in Cycling (Contd..)

- Creep-Fatigue Interaction
  - Materials behave in a complex way when both creep and fatigue mechanisms are present
  - Creep strains will reduce fatigue life, and fatigue strains will reduce creep life

Source: EPRI
Damage Mechanism in Cycling (Contd..)

- Increased failure rates due to cycling may not be noted immediately
- Critical components will eventually start to fail.
- Shorter component life / higher plant forced outage / longer scheduled outages
• Introduction to Cycling
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Manifestation of cycling effects

The effects of Cycling damages could result in the following which may not be totally attributed to cycling:

- Lower availability as a result of increased failure rate and outage time
- Increased routine O&M cost from higher wear and tear
- Increased capital spending for component replacement
- Increased fuel cost from reduced efficiency and non-optimum heat rates
  - Efficiency is lower under startup, shutdown, and low-load
  - And general wear and tear (eg worn out seals, etc) also affects efficiency
Manifestation of cycling effects (Contd..)

• The interruptions to operation caused by cycling will also result in higher amounts of oxygen and other ionic species to be present in the boiler leading to corrosion and fouling issues

• Cost of chemicals will increase to maintain the required quality

And the degree to which each of these factors is applicable depends on plant-specific factors like design of the plant, the way plant is operated, the quality of water chemistry, etc.
• Introduction to Cycling
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• Conclusions
NTPC – Are we Cycling?

- Major event of Cycling – Unit start ups / shutdowns
  - Hot / Warm / Cold Starts
- On-load Cycling
  - Shortage of fuel / water
  - less schedule and high Grid Frequency
  - Equipment problems
  - Increasing share of RE

Cycling is only expected to increase in the wake of Fuel shortages, increasing green power and increasing gap between peak & off-peak demand.
NTPC – Are the effects felt?

The effects of Cycling damages result in the following which may not be totally attributed to cycling:

- Lower availability
- Increased capital spending
- Increased routine O&M cost
- Increased fuel cost from reduced efficiency and non-optimum heat rate
- Increased Risk of Personnel Errors during Cycling operation
- Introduction to Cycling
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Cost of Cycling

• Non-Availability cost
  • Loss of Fixed Charges due to loss of Declared capability
  • Loss of incentive above target availability
  • Profit loss (Marginal contribution)

• Life Cost of Component
  • Repair and Maintenance Cost
  • Capital Spending for component replacement
  • Capital Cost Impacts for Renovation & Modernisation

• Heat Rate Impacts
• Startup Auxiliary Power and Chemicals
• Startup Fuel and Manpower
# Cost of Cycling – typical values for start up cycling

<table>
<thead>
<tr>
<th>Type of cycling</th>
<th>Cost category</th>
<th>Expected</th>
<th>Low</th>
<th>High</th>
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<td>Maintenance and capital</td>
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<td>15.2</td>
<td>22.8</td>
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<td>Startup fuel</td>
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<td>17</td>
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<td></td>
<td>Auxiliary power</td>
<td>2.2</td>
<td>1.75</td>
<td>2.75</td>
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<td>Efficiency loss from low &amp; variable - load operation</td>
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<td>0.85</td>
<td>1.7</td>
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<td>Water chemistry cost &amp; support</td>
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<td>0.4</td>
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<td></td>
<td><strong>Total cycling cost</strong></td>
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<td><strong>57.3</strong></td>
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<td>Startup fuel</td>
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<td>Efficiency loss from low &amp; variable - load operation</td>
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<td>1.05</td>
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<td>Water chemistry cost &amp; support</td>
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<td>2.1</td>
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<tr>
<td></td>
<td><strong>Total cycling cost</strong></td>
<td><strong>223.9</strong></td>
<td><strong>247.8</strong></td>
<td><strong>319.95</strong></td>
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</table>

Some of the costs are calculated from Best estimates for cycling cost from EPRI paper on “Damage to Power Plant due to Cycling”
• Introduction to Cycling
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• Suggested Solution
• Conclusions
Suggested Solution

- Current practices towards reducing / avoiding cycling damages

- What is required?
  - For New Units - Design changes for present & expected cycling
  - For Existing Fleet – Active Asset Management
Active Asset Management

• Better plant management systems including systems for monitoring of plant operation, behavior of critical components, premonition & problem analysis

• Adoption of practices to reduce cycling damage like slower ramp rates

• Strategy of component inspection and replacement to address Cycling damage and to introduce flexible equipment

• And the most important is a Comprehensive Real time cycling cost monitoring & life monitoring Software available to the Operator

• Also to alert operators when the plant is using a damaging ramp rate or operating mode

• Development of Fleet-wide monitoring to take advantage of number of similar units and for better expertise
Active Asset Management (Contd..)

Active Asset Management
the practice of using resources to create maximum value

- Fleet-wide monitoring
- Monitoring of plant operation
- Component inspection and replacement
- Action plan for partial loading reduction
- Real time cycling cost monitoring & life monitoring
- Zero Forced Outage action plan
- Plant management systems
- Real time cycling cost
- Operational Practices
- System Modifications
• Introduction to Cycling
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Conclusions

• Now the time has come to address Cycling in the wake of increasing age of the Fleet and changing Market scenario

• Also cycling damages are evident in component inspections & failures

• Active Asset Management is the solution
Any Questions, Please
Thank you
NO. OF OUTAGES PER UNIT PER YEAR UPTO JAN'13

Source: NTPC OS Reports
Cycling of Unit Starts

LL1: Lowest load at which design MS/HRH temperatures can be maintained

LL2: Normal low load during start ups

LL3: Lowest load on which the unit can be online
Cycling due to Fuel Shortage

Generation Loss Coal Shortage – NTPC Stns

Source: NTPC SAP Data
Cycling due to Grid Conditions

Less Schedule Trend – NTPC Coal Stns

Source: NTPC SAP Data
Cycling due to Grid Conditions (Contd..)

Intraday load fluctuations – due to less schedule

In a 3 days period, for Unit-4,5&6 of NTPC-Ramagundam station, 4 times Schedule was reduced to technical minimum
Cycling due to Grid Conditions (Contd..)

Gen Loss due to No demand & Hi Freq – NTPC Stns

Source: NTPC SAP Data
Projected Energy Mix by 2020

Source: GlobalData
Grid Frequency Vs Wind Generation

\[ FVI = \frac{\sum (F-50)^2}{24 \times 50} \]
Cost of Cycling and Damage Control – NTPC Perspective
13-15th Feb’13 – International O&M Conference, New Delhi

NTPC COAL STATIONS: NO. OF OUTAGES AND TRIPS

<table>
<thead>
<tr>
<th>Year</th>
<th>Outages</th>
<th>Trips</th>
<th>No of Units</th>
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<tr>
<td>06-07</td>
<td>593</td>
<td>244</td>
<td>71</td>
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<tr>
<td>07-08</td>
<td>584</td>
<td>256</td>
<td>74</td>
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<tr>
<td>08-09</td>
<td>631</td>
<td>280</td>
<td>75</td>
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<tr>
<td>09-10</td>
<td>643</td>
<td>259</td>
<td>79</td>
</tr>
<tr>
<td>10-11</td>
<td>713</td>
<td>303</td>
<td>81</td>
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<tr>
<td>11-12</td>
<td>759</td>
<td>357</td>
<td>83</td>
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<tr>
<td>12-13 UPTO NOV</td>
<td>403</td>
<td>90</td>
<td></td>
</tr>
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</table>

Note: Every desynchronisation of the unit is considered as an outage.

Source: NTPC OS Report
Cost of Cycling and Damage Control – NTPC Perspective

13-15th Feb’13 – International O&M Conference, New Delhi

COAL STATIONS: OUTAGES PER 1000 HOURS PER UNIT

Outages per 1000 Hour per unit

Trips per 1000 Hour per unit

Only trips due to Station Equipment Problems considered.

Source: NTPC OS Report

EEMG - Ramagundam
Increase in Maintenance Expenditure

Source: NTPC SAP Data
Design Turbine Cycle Heatrate Vs Load

TURBINE CYCLE HEATRATE Vs UNIT LOAD - STAGE-2 (500 MW) UNITS

Turbine Heatrate at any load: $1801.425 + 92947.5/MW$

EEMG - Ramagundam
NTPC – Current practices

- Real time Monitoring of plant operation and behavior of critical components
  - Start up Monitoring
  - Monitoring for Optimum Efficiency
  - Combustion monitoring
  - Condition Monitoring
Unit Start up Monitoring
**Monitoring for Boiler Cleanliness**

<table>
<thead>
<tr>
<th>Plot 1</th>
<th>Plot 2</th>
<th>Plot 3</th>
<th>Plot 4</th>
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<td>350</td>
<td>350</td>
</tr>
<tr>
<td>310</td>
<td>360</td>
<td>320</td>
<td>330</td>
</tr>
<tr>
<td>1002/2020 00:00:00</td>
<td>1102/2020 00:00:00</td>
<td>1002/2020 16:08:16</td>
<td>1002/2020 16:08:16</td>
</tr>
</tbody>
</table>

**FG temp at APH inlet - Today**

**FG temp at Individual APHs inlet - Today**

Flue Gas temperature at Economiser outlet helps in understanding:
- a) Cleanliness of Heat transfer surfaces
- b) Miling System performance
- c) Effectiveness of Wall Blowing/LRSE Opn / SADC / PAD / Burner Tilt Opn

**EEMG - Ramagundam**
Boiler Tube Metal Temperature – RH Panel
NTPC – Current practices (Contd..)

- plant management systems including systems for premonition, problem analysis, etc
PEPSE – Thermodynamic Modeling tool
## PADO – Diagnostic and Optimization tool

**BHEL Ramagundam 70**

**Overview Degradation**

<table>
<thead>
<tr>
<th>Component</th>
<th>operating time [h]</th>
<th>life time consumption [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>monitored</td>
<td>downtime</td>
</tr>
<tr>
<td>1. Drum 1, upper side 70hAD01</td>
<td>23245.2 h</td>
<td>6183.3 h</td>
</tr>
<tr>
<td>2. Drum 1, lower side 70hAD01</td>
<td>23245.2 h</td>
<td>6183.3 h</td>
</tr>
<tr>
<td>3. HRH1, outled header, tee, upper side 70LB01</td>
<td>23245.2 h</td>
<td>6893.3 h</td>
</tr>
<tr>
<td>4. HRH1, outled header, tee, lower side 70LB02</td>
<td>23245.2 h</td>
<td>6893.3 h</td>
</tr>
<tr>
<td>5. HRH1, outled header, middle, lower side 70LE01</td>
<td>23245.2 h</td>
<td>6893.3 h</td>
</tr>
<tr>
<td>6. HRH1, outled header, left, upper side 70LB01</td>
<td>23245.2 h</td>
<td>6893.3 h</td>
</tr>
<tr>
<td>7. HRH1, outled header, left, lower side 70LE01</td>
<td>23245.2 h</td>
<td>6893.3 h</td>
</tr>
<tr>
<td>8. MS1, outled header, tee, upper side 70LBA01</td>
<td>23245.2 h</td>
<td>6194.3 h</td>
</tr>
<tr>
<td>9. MS1, outled header, tee, lower side 70LBA01</td>
<td>23245.2 h</td>
<td>6194.3 h</td>
</tr>
<tr>
<td>10. MS1, outled header, left, upper side 70LBA01</td>
<td>23245.2 h</td>
<td>6194.3 h</td>
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<tr>
<td>11. MS1, outled header, left, lower side 70LBA01</td>
<td>23245.2 h</td>
<td>6194.3 h</td>
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<tr>
<td>12. YP 1, 70LEB01</td>
<td>23245.2 h</td>
<td>6794.6 h</td>
</tr>
<tr>
<td>13. YP 1, 70LBA01</td>
<td>23245.2 h</td>
<td>6194.3 h</td>
</tr>
<tr>
<td>14. MS1, outlet header, tee, lower side 70LBA01</td>
<td>23245.2 h</td>
<td>6194.3 h</td>
</tr>
</tbody>
</table>
Incipient Parameter Deviation Detection

- Parameter deviation detection Screen developed using VB and PI data to capture Parameter deviation at the incipient stage
- Around 800 parameters of the Unit are included
- Variation over last 3 days maximum Or below last 3 days minimum are captured
- UCE can detect all the parameter deviations before alarm value enhancing time available for action
- TG vibrations changes, TDBFP vibration changes, Gen casing pressure, MOT level change are some of the recent examples.
- In another case Mill PA flow addition problem also could be identified
Manifestation of cycling effects (Contd..)

Increase in Forced Outage:

- One of the major impacts of cycling
- Expected to be more predominant with increasing age of the plant
- Also depends on design of the plant

Relationship Between Cycling and FO rate
(result of a study of Aptech, United States)

Source: EPRI
Manifestation of cycling effects (Contd..)

Increase in Forced Outage (Contd..):

- Data of a UK Utility shows single largest reason for equipment failure is cycling

### Breakdown of Cycling-Related Failures

<table>
<thead>
<tr>
<th>Component</th>
<th>Total Number of Failures</th>
<th>Percentage of Failures Due to Cycling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler tubes</td>
<td>33</td>
<td>33</td>
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<tr>
<td>Headers</td>
<td>6</td>
<td>83</td>
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<tr>
<td>Superheater tubes</td>
<td>47</td>
<td>19</td>
</tr>
<tr>
<td>Reheater tubes</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>Condenser</td>
<td>27</td>
<td>38</td>
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<tr>
<td>HP heater</td>
<td>17</td>
<td>70</td>
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<tr>
<td>LP heater</td>
<td>3</td>
<td>33</td>
</tr>
</tbody>
</table>

Source: EPRI
Real Time Creep Fatigue Damage Monitoring System

- Finite element based on-line damage monitoring system
- Calculates real time creep fatigue damage in the material
- It is interfaced with a real-time data acquisition system that acquires data of plant transients
- Thermal module evaluates the temperature distribution in the actual 3D component geometry
- Structural module evaluates the stress distribution in the component 3D geometry
Real Time Creep Fatigue Damage Monitoring System
Real Time Creep Fatigue Damage Monitoring System

- Centralized data handling
- Simultaneous assessment of Creep & Fatigue damage

- Monitors 20 components

**UNIT 1**
**UNIT 2**
**UNIT 3**
**UNIT 4**

**REAL-TIME MONITORING SYSTEM**

**COMPONENTS**
- SHOH
- RHIH
- RHOH
- HRHL
- HRHR

**DAMAGE ASSESSMENT**
- Process history
- CF Damage
- Stress intensity
- Residual life

**EEMG - Ramagundam**
Extra slides
World

Worldwide State of the Power Generation Industry - A number of forces have contributed to the increase in the number of fossil-fueled units needing to move to varying load operation of min load to two-shifting, including the following:

- Privatization, particularly when the end result is a fragmentation of the industry
- The fact that nuclear, hydroelectric, and “green” power plants have priority over fossil-fueled units
- The rise of low-cost, gas-fired combined-cycle plants that have displaced older, more expensive fossil-fired units
- The increased availability of low sulfur and chlorine coal that has allowed coal-fired units to continue to operate without the necessity for flue gas cleanup
<table>
<thead>
<tr>
<th>Year</th>
<th>Hydro</th>
<th>Wind</th>
<th>Solar PV</th>
<th>Solar Thermal</th>
<th>Biogas</th>
<th>Biomass</th>
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<tr>
<td>CAGR 2009-2020</td>
<td>5.1%</td>
<td>10.3%</td>
<td>52.7%</td>
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<td>10.4%</td>
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