Flexible Operations in a Changing World

Session 8A
Coal Power Plants

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For stable operation of the grid, supply and demand must be in perfect balance at all times.
Flexible Operations: Impact on Boiler Reliability

Creep, Fatigue, Corrosion & Erosion Impacts for Flexible Operation

Minimum or Reduced Load Operations
- Circulation Issues and overheat (DNB)
- SH and RH Overheat
- High Spray Flow rates & Attemperator Damage
- Economizer Steaming
- Flow Accelerated Corrosion

Two Shifting
- Increased thermal fatigue damage
- Operator error or injuries
- Increased wear on valves motors
- Longer operation time with chemistry out of specification

Weekend Shutdown
- Operator Error
- Same as two shifting with increase in
  - Corrosion fatigue
  - Pitting corrosion
  - Potential for increase in oxide exfoliation
  - Overheating of tubing if startups are rushed

Extended Shutdown
- Same as two shifting with increase in Corrosion fatigue
- Pitting corrosion
- Potential for increase in oxide exfoliation
- Overheating of tubing if startups are rushed
Flexible Operations: Impact on Steam Turbines

Challenges:
- Increased operator training to improve temperature matching and reduce over-temperature operation
- Increased wear on valve components
- Casing humping due to base-to-cover temperature differentials
- Rotor differential expansion limitations
- Water induction risk increases with more unit starts
- Increased in SPE rate on valves and blading due to increased starts
- Increased risk of blade flutter with low exhaust volumetric flow rates
- Upstream movement of phase transition zone; SCC risk increases; higher exhaust wetness; solubility changes
- Steam seal pressure control issue
- Excessive use of hood sprays as exhaust temperature increases results in LSB erosion, especially with flow recirculation
- Control valves throttling at very low loads; increase heat rates; wear on plug/seat
- BFP turbine steam supply issues
- Impact of reduced minimum loads on shaft rotor dynamics (bearing unloading under partial-arc)
- Trade-off between low load and ramping rate
- Increased air in-leakage
Flexible Operations: Impact on Main Generators

Cycling Main Generators

- Determination of generator maintenance intervals under cycling duty
- Generator winding insulation system
- Copper dusting – differential expansion
- Rotor coil ratcheting
- Core tightness changes due to thermal cycles
- End winding blocking and tie failure
- Fatigue in bore, tooth-tops, rings
- Wedge fretting

Main Generators Extended Shutdown

- Safe operation of generator hydrogen system
- Generator stator cooling water system protection
- Generator protection against moisture-related damage
- Collector ring pitting of generator and exciter field

3002013652
Outage Intervals for Generators in Flexible Operation
## Major Challenges: 0 – 30% MCR

### Flexibility Challenges: Boiler, Turbine, BOP, Environmental

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Cycling On/Off</th>
<th>Turn Down</th>
<th>Fast Ramping</th>
<th>Load Cycling</th>
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<tbody>
<tr>
<td>Equipment Turndown</td>
<td>R</td>
<td>O</td>
<td>F</td>
<td>C</td>
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<td>Burners/Combustion Stability</td>
<td>R</td>
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<td>C</td>
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<tr>
<td>Boiler Circulation</td>
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<td>Pressure Part Damage</td>
<td>R</td>
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<td>C</td>
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<tr>
<td>Fans/Motor Reliability</td>
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<td>F</td>
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<tr>
<td>Ramp Rate</td>
<td>R</td>
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<td>C</td>
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<td>Steam Temperature Control</td>
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<td>Air Heater Issues</td>
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<td>R</td>
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<td>Environmental Control Systems</td>
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<td>Turbine Thermal Stresses</td>
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<td>O</td>
<td>F</td>
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<td>Condenser Issues</td>
<td>R</td>
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<td>F</td>
<td>C</td>
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<tr>
<td>Water/Steam Cycle Chemistry</td>
<td>R</td>
<td>O</td>
<td>F</td>
<td>C</td>
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<tr>
<td>FW Pumps &amp; Motors</td>
<td>R</td>
<td>O</td>
<td>F</td>
<td>C</td>
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</table>

### Managing FLEXIBLE OPERATIONS

- **Understand where training & awareness is needed**
- **Flexible Operations**
  - Identify areas needing systematic program management
  - Identify needs for defense strategy

**Managing FLEXIBLE OPERATIONS**

- **Start-up time** (upward flexibility)
- **Ramp Rate** (response time)

**Valley of the Shadow of Death**
Adapting to change demands enhanced plant defense strategies that utilize systematic processes. Flexibility is complex and strategic countermeasures to protect assets undergoing the new operating regimes.

Managing fleet flexibility requires the inclusion of both quantitative and qualitative actions that drive awareness, apply best practices, encourages benchmarking and most importantly, integrates modifications and defense strategies to protect assets:
Operational Flexibility: Impacts People and Processes

- Varying Operating Modes
- Procedures
- Operations, Monitoring & Diagnostics

- Operations & Maintenance Activities
- Layup Requirements

FLEXIBLE OPERATIONS

- People
- Process
- Technology

Process Optimization
Mission Profile

Digital Transformation & Optimization

Aware Managed Proactive Predictive
Expanding the Flex Ops Tool Box - People, Process, Technology

Flexible Operation Tools
Click one of the buttons below to access the appropriate site.

- Flexible Operation Database (FlexOps)
- Minimum Load Reduction Web Tool (MinLoad)
- Resource Database for Flexible Operation (RDFlex)

20/20 and Beyond - Visions for the Future
Flexible Operations

1) Training workshops / Awareness
2) Operational Readiness Guideline
3) Systematic Assessments / Studies
4) Minimum Load Tool
5) Modeling of Grid Requirements
6) Mission Profile Working Group Database
7) Ramp Rate Guidelines
8) Controls Optimization
9) Benchmarking
10) Ongoing Flexibility Assessments
11) Digital Dashboards
12) Optimization
Reducing Minimum Load (Turndown)

Common Turn-down Challenges:
- Fuel Loading / Heat Input Management
- Controlling steam temperatures.
- Flame Stability
- Feedwater control
- Environmental Controls
- Excessive cooling of steam turbine due to control valve throttling
- Feedwater heater cascade drain function
- FD and ID fan vibrations
- Damage to back end of LP turbine
Fast Load Ramping

Limitations
- Temperature control
- Pressure Control
- Level Control
- Instability due to imbalances in mass flows from various plant systems and energy flows between the boiler and turbine.

Solution
- Control loop tubing
- Improved coordination of boiler and turbine masters
Steam Plant Controls: Not Designed for Turndown

- Many units were designed and tuned to operate best at full load, or close to it.
  - When sliding pressure, the boiler pressure response to changes in firing rate becomes more sluggish.
  - Operating with the upper level burners in service, reduces heat input to the water walls, thereby dulling pressure response to changes in firing rate.

- All of these factors combined often create a situation where the boiler controls respond very poorly when in automatic, as the existing level of proportional response is insufficient to prevent large lazy swings in boiler pressure.

- Steam temperature and drum level controls are also often likely to be poorly tuned for extreme low load operation.
Managing Precursors to Boiler Damage

**Material**
Shape, dimension, properties, flaws, surface scales, oxides and deposits

**Flue Gas**
- Temperature, Velocity
- Heat Transfer, Fuels, O₂, Boiler Cleaning System Process, etc.

**Boiler Component Damage Influencers**

**Fluid Side Environment**
Temperature, Pressure, Flow, Quality, Chemistry, Scale

**Air Side Environment**
Atmospheric conditions, temperature, chemistry, insulation characteristics and condition

**Effect of Flexible Operation on Boiler Components**
Volume 1: Fundamentals, 3002001180
Volume 2: Water-Touched Components 3002005871
Volume 3: Steam-Touched Components 3002010385
Managing Fossil Generation as a Tool for Grid Flexibility and Stability

“You can’t wipe out society and make a whole new society. You have to deal with the society that exists. But you have to figure out how you’re going to change it to something that’s better.”

Chauncey Starr, EPRI Founder
Qualitative Operational Assessment

<table>
<thead>
<tr>
<th>Issue</th>
<th>Area of Concern</th>
<th>Best Practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Clear and concise communications by operations personnel at shift turnover.</td>
<td>Communications during shift turnover are a critical part of facility operations and should provide oncoming operators with an accurate picture of facility status. Flexible operations will create new areas of focus for operators.</td>
</tr>
<tr>
<td>1.2</td>
<td>Baseload operations often do not provide enough hands-on experience with startups, shutdowns, and transient operations. Flexible operations often require this to be done regularly, quickly, and efficiently.</td>
<td>As personnel experience more transient operations, shutdowns, and startups, the opportunities for personnel injury, equipment damage, and higher operating costs are greater. Startups and shutdowns might not occur in a way that gives all personnel the same opportunity to gain experience. Personnel need to understand the functional requirements of flexible operations, the commercial aspects of plant running costs and efficiency, and the long-term effects on the life expectancy of the plant.</td>
</tr>
<tr>
<td>1.3</td>
<td>Reducing startup times.</td>
<td>Utilities prefer the fastest safe and efficient startup times. Each plant will have its own characteristics and constraints. The main constraint will be matching steam and turbine metal temperatures.</td>
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<thead>
<tr>
<th>Benchmark</th>
<th>Probability</th>
<th>Implication</th>
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</thead>
<tbody>
<tr>
<td>Red (1)</td>
<td>1 = Very low</td>
<td>1 = Minimal</td>
</tr>
<tr>
<td>Yellow (2)</td>
<td>2 = Low</td>
<td>2 = Moderate</td>
</tr>
<tr>
<td>Green (3)</td>
<td>3 = Moderate</td>
<td>3 = Significant</td>
</tr>
<tr>
<td></td>
<td>4 = High</td>
<td>4 = Severe</td>
</tr>
<tr>
<td></td>
<td>5 = Very high</td>
<td>5 = Critical</td>
</tr>
</tbody>
</table>

Item: **Issue** | **Area of Concern** | **Recommendation** |
---|---|---|
1 | --- | --- |

Item: **Probability** | **Impact** | **Risk Rating** |
---|---|---|
1 | 4 | 4 | ✓ |
Quantitative Benchmarking Assessment

High Level Assessment (HLA)

a) Subcritical Conventional (Coal)
b) Supercritical Conventional (Coal)
c) CC/HRSG (Gas)

1. Equipment Design Review
   Operating Modes

2. Pressure Part Management
   Conventional and/or HRSG

3. Operations

4. Maintenance

5. Combustion & Boiler Performance (coal)
   Or CTs (oil, gas)

6. Instrumentation, Controls & Automation

7. Environmental Controls

8. Cycle Chemistry

9. Turbine/Generator

10. Balance of Plant, Auxiliary Equipment

Collaborative Assessment and Gap Identification

Train Communication and Awareness

Mitigate Risk Management
Asset Management: Prioritizing w/ Impact vs. Probability

Probability

- Very High (5)
- High (4)
- Moderate (3)
- Low (2)
- Very Low (1)

Impact
- Critical (5)
- Severe (4)
- Significant (3)
- Moderate (2)
- Minimal (1)

The diagram illustrates a spider chart with various categories such as Maintenance, Boiler, Commercial, Steam Turbine, Generation/Electrical, Feedwater/Condensing, BOP, I&C, and Spares. Each category is rated on a scale of 0 to 3, with the Overall Score calculated accordingly. The probability matrix is divided into Very High (5), High (4), Moderate (3), Low (2), and Very Low (1) categories, corresponding to Minimal (1), Moderate (2), Significant (3), Severe (4), and Critical (5) levels of impact.
Offsetting Implications through Programmatic Actions

**Cycling Impact**
- Thermal Fatigue
- Layup Corrosion
- Balance of Plant
- Corrosion Fatigue
- Creep Fatigue

**Economics Impact**
- Fuels Management
- Heat Rate
- Operator Skills
- Environmental Controls
- Layup O&M

**Reliability Offset**
- Asset Management
- Controls and Sensors
- Damage Tracking; Improved Layups
- Process Optimization
- Heat Retention

**Economics Offset**
- Training and Awareness
- Assessments
- Diagnostic Reporting
- Alarm Management
- People Resource Management

Managing O&M, Capital $ and Assessments

Flexible Operations Cost Management

Both Inspection and Operational data is needed to assess actual impact of cost and life assessment.
Assessment via Monitoring & Diagnostics

FLEXIBLE OPERATIONS

People → Process → Technology

High Velocity Zones in Yellow & Red; Keeping in mind that this is not corrected for flow mal-distribution.
Optimization of Flexibility - People, Process, Technology

Annual Load Profile

Combustion Optimization

Start-up Protection

Steam Temperature Control

SCR Optimization

P-71 Pilot Project on a 1,200MW Unit

- Initial data analysis and model development (PEOPLE)
- Characterize roadmap and KPIs (PROCESS)
- Improve controls with application of an open architecture optimizer to help manage big data applications to help improve a systems flexibility, functionality, interoperability, potential use and useful life (TECHOLOGY).
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