Council of Enviro Excellence

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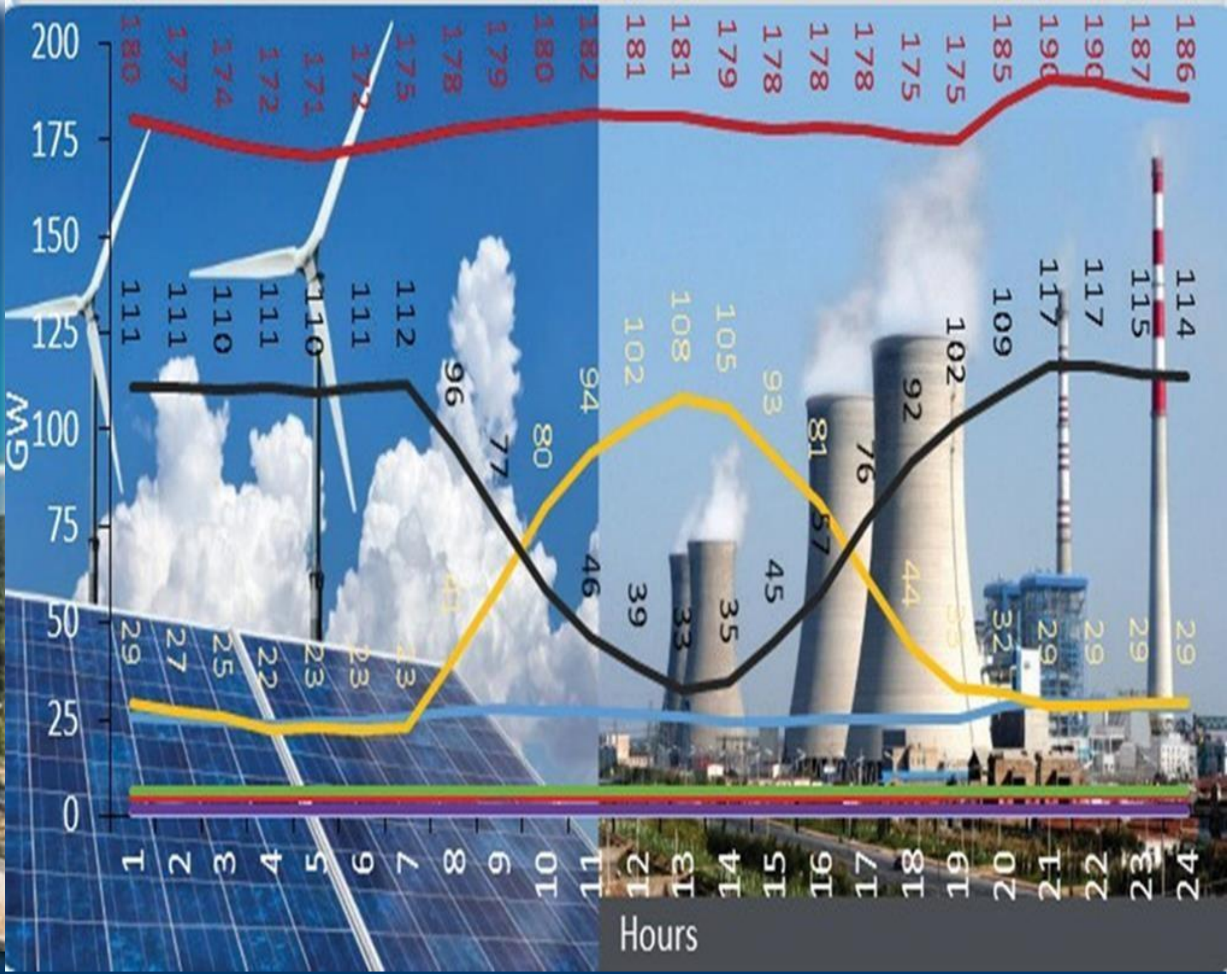
FLEXIBLE OPERATIONS IN THERMAL POWER PLANT

Technical Measures to Achieve Coal Plant Flexible Operation

Mr Kamal Kishore Mundhada
Freelance Consultant/NTPC



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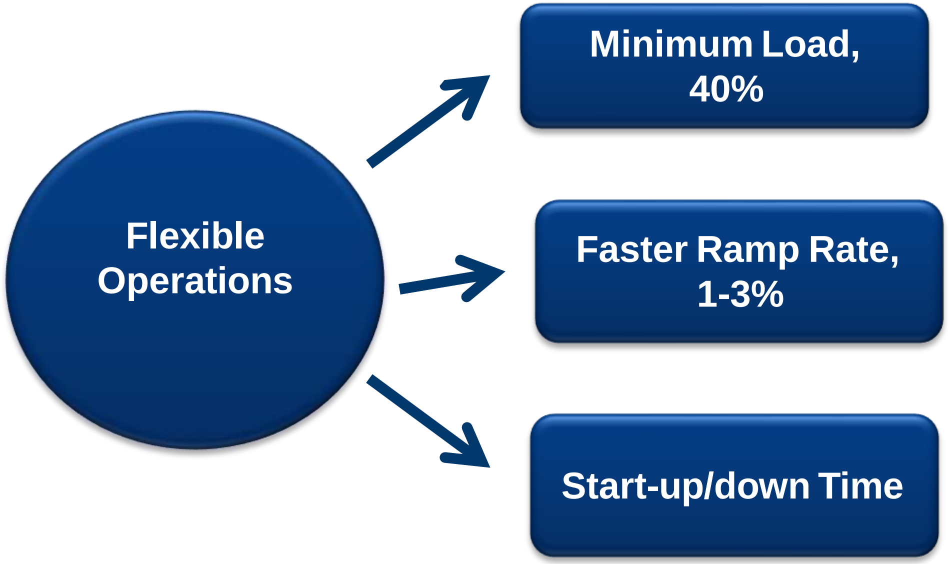
Understanding Key Area of Concern in Flexible Operation

Impact of flexible operation : Energy efficient base load stable operation to cyclic, inefficient & unstable flexible operation



Trilemma of flexible operation:

- Unit stability at part load / load variation,
- Efficient & cost competitive part load operation
- Long-term damage mitigation from cyclic operation

- Unit operation below 55 % loading with higher ramp rate of 1-3% is unknown territory for most of power plants
- Even flexible operation trial test were conducted under guidance of OEM & Experts

First steps in arriving at technical solutions for flexible operation : Understanding pain areas in flexible operation

Understanding Challenges in Achieving Flexibilization : Control Optimization of Slow Acting Boiler with Fast Acting Turbine

Biggest challenge : Control Optimization in slow acting Boiler with fast acting Turbine

Feeder → **Mill** → **Steam Generator** → **Turbine** → **Generator**

Σ Time constant > 180 seconds

Coal to power process: slow-reacting > Wide variation in unit terminal parameter > high time of Stabilization

Further aggravated by:

- ✓ Low automation levels
- ✓ Combustion un-stability at low loads & during load variation
- ✓ Coal quality change from designed / wide variation
- ✓ High moisture, high ash & low VM coal challenging for flexible operation

Understanding Challenges in Achieving Flexibilization : Poor Boiler Combustion

Stable & complete combustion in varying unit load condition is key enabler for sustained stable flexible operation & Boiler efficiency

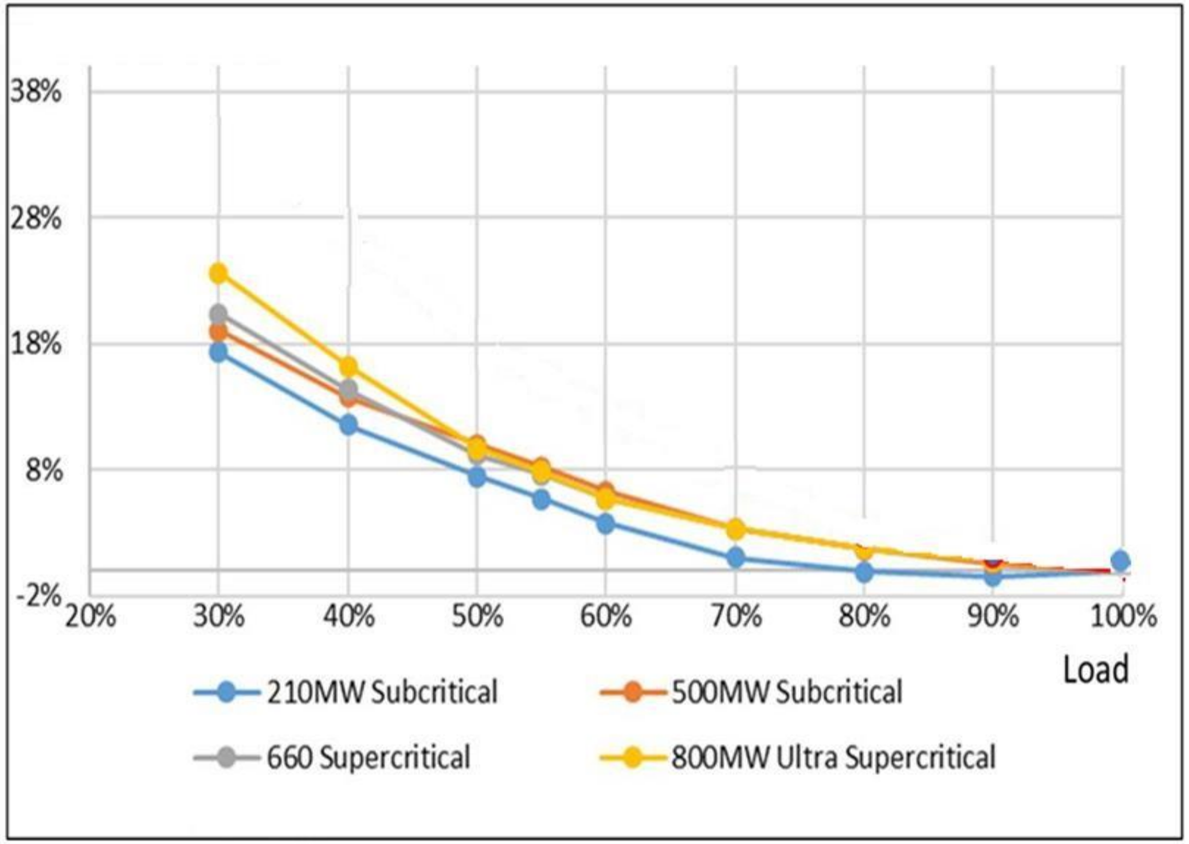
Combustion Issues

- Combustion stability issues in flexible operation :
  - ✓ Coal characteristics & coal constituents away from design & vary widely
  - ✓ SADC operation : Non-optimization as per fuel & unit load
  - ✓ High PA flow as per OEM curve , lean mixture
  - ✓ High Boiler Excess air
  - ✓ Mill non-availability leading to non-consecutive mill in operation
  - ✓ Lack of confidence of Coal mill reliability forcing to run extra mill
  - ✓ Poor scanner response & their reliability

Understanding Challenges in Achieving Flexibilization : Efficiency Management at Part Load Operation

Efficiency related challenge :

- ✓ Heat rate deterioration at part load operation
- ✓ Unit Auxiliaries optimization
  - Reduction in no of running Auxiliaries in part load operation
  - Auxiliary reliability & Operator’s confidence is key issue in reducing auxiliaries during load variation



Source: Flexibilization Reports

Understanding Challenges of Flexibilization : Impact on Plant Life

Flexible operation : Cyclic operation

- Increases creep-fatigue damage caused by thermal stresses
- Accelerated Corrosion fatigue damage

Long term damage in severely affected components:

Thick wall components	▪ MS, CRH, HRH headers (especially Y- piece section) ▪ Casting such as turbine valves and casings ▪ Turbine Rotor
High temperature component	▪ Superheater, Reheater ▪ Ties used to support SH, RH tubing ▪ Tube to header joints etc. ▪ Gas duct work
Corrosion and scaling prone component	▪ Water wall tubing at attachments (wind box, corner tubes, wall box opening, buck stay) Heater tube ▪ APH - cold end ▪ Condenser tubes ▪ Welded joints
Degeneration of insulation due to thermal transients	▪ Generator insulation ▪ Transformer insulation ▪ Insulation of HV drives (FD, ID, PA fans, mills motor)

Flexible operation can lead to : Increased forced outages & life consumption leads to increased maintenance & overhaul capital expenditures

Second steps in arriving at technical solutions for flexible operation : Observations & analysis of flexible operation trial runs done so far, guide us to probable technical measures for achieving sustained flexible operation

Flexible Operation Trial Runs in India

Flexibilization Study & Test Carried Out

- Indian flexible operation study & trial runs since year 2017 & onward
- Flexibilization study & test carried out in association with national/international partners at many central/state/private plants
- Purpose of flexible operation study & trial runs :
  - ✓ **Identification of process & control system limitations**
  - ✓ **Identification of retrofits for plant : Required & Possible**
- **Successfully demonstrated :**
  - **Unit safe load reduction & operation at 40% load**
  - **Ramp rate : 1% & 3%**

Nos of important observations were noted in flexible operation trial runs

Source: Flexibilization Reports

Common Observation for Flexibilization Test Case Studies

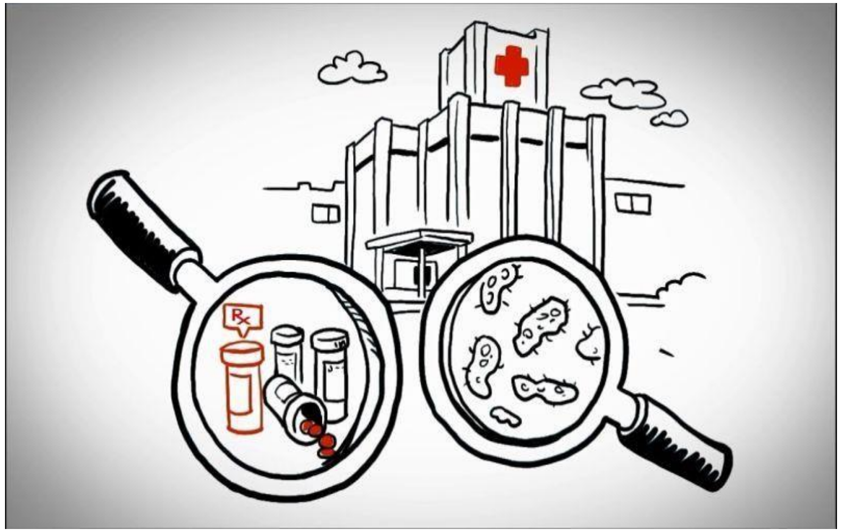
Main observations of flexible operation trial runs :

- Most of **group/sub-group controls were in auto & unit running in CMC**.
- **Burner tilt in manual**.
  - ✓ **RH temp. excursion by ~ 30^{0}C**.
  - ✓ Heavy passing in RH spray valve , RH temp. maintained with manual burner tilt operation.
- **Though fuel master on auto, intermediate** operator interventions
- **Coal mill stop/start operation manually**
- **SHO & RHO temperature** setpoints altered by operator based on SH & RH coils metal temperature excursions apprehension.

Source: Flexibilization Reports

Common Observation for Flexibilization Test Case Studies

- **Extra mill kept in service** to take care of apprehension of mill tripping, though demonstrated that **flame stability improved by reducing number of mills**.
- Selection of mills (upper or lower) based on operator's operating experience.**Adjacent mills** kept in service
- At 40% load, **flame scanners showed stable flame**
- As Primary air flow maintained higher, secondary air flow maintained less resulting in :
  - ✓ **Low Wind box pressure**
  - ✓ WB pressure improved by closing secondary air dampers of mills not in service and optimizing primary air flow.
- Flue gas O_2 maintained at 5-6 % at 40% load.
- **Mill out temperatures** maintained by closing cold air dampers



Source: Flexibilization Reports

Common Observation for Flexibilization Test Case Studies

- **Steam coil APH** not available though required at 40% loading.
- **Sliding pressure operation done**.
  - ✓ During load decrease, sliding pressure adjusted (increased set point by 5kg/cm2), to avoid economiser steaming and DNB.
  - ✓ Decrease in SH spray after adjusting sliding pressure setting
- **Higher thermal transients in SH** areas during load ramping
- **Drum level control :**
  - ✓ Deviations occurred when switching off Boiler feed pump.
  - ✓ For switching off TDBFP drum level maintained manually.
  - ✓ Instable **TDBFP steam pressure control** causing fluctuations of FW flow & drum level.
  - ✓ **Boiler feed pumps recirculation valves Designed to full open/closed,** wide variation in FW flow on opening of recirculation valves.

Source: Flexibilization Reports

Common Observation for Flexibilization Test Case Studies

- **Both PA Fans and TDBFP** in service at minimum load. Though, one set can be stopped during continuous low load operation.
- Turbine & generator vibrations within acceptable range during ramp tests.
- Generator stator & rotor operating parameters within acceptable range
- Dirty air flow test in all running Mills at **40% minimum loads stable operation,** with coal fineness, BA & FA unburnt, Flue gas O_2, coal analysis and temperature measurements, reveals
  - ✓ **Imbalance in coal flow across pipes**, although at higher loads, imbalance was negligible.

1. Analysis of flexible operation trial run observations guide us to probable technical measures for achieving sustained flexible operation
2. Need to understand : No common solutions in achieving sustained Coal plant flexible operation fitting all
3. Variation due to Plant ageing, automation level, Sub/Super critical, technology used

Source: Flexibilization Reports

Measures to Achieve Flexible Operation : For Minimum Load Operation

Control Optimization in slow acting Boiler & fast acting Turbine

Feeder → Mill → Steam Generator → Turbine → Generator

- Thorough analysis of subordinate controls & hardware
  - ✓ Optimization of subordinate control
  - ✓ Need based replacement : Sensors, actuators & electronic cards
- Unit Controller enhancement to ensure better Coordination between slow acting Boiler & fast acting Turbine by adjusting all relevant process variables. viz. –
  - ✓ Temperature, Pressure , FW flow in water-steam circuit, loading of coal mills & Turbine valve positions.
- Based on plant specific needs control modifications, for improving flexibility :
  - ✓ Adaptive predictive controller in place of PID controller &
  - ✓ Combustion tuning using artificial intelligence (AI) technique

Measures to Achieve Flexible Operation : For Minimum Load Operation

Drum Level Control

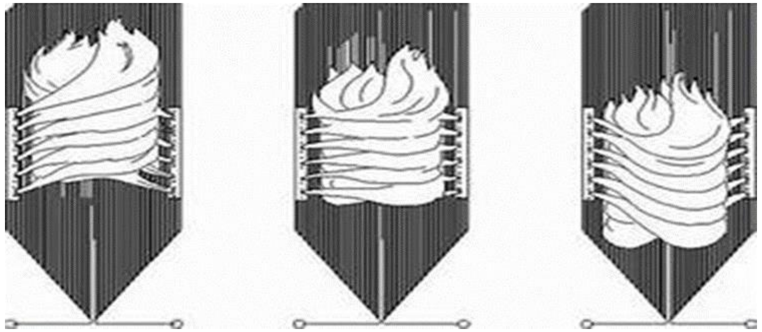
- Replacement of BFP recirculation valves with modulating type valves
- Upgrade / new controls may be required for TDBFP when fed by auxiliary steam from another unit

Flue Gas Temperature Control

- At low load APH flue gas outlet temperature may fall below acid dew point temperature causing APH cold end corrosion
- **SCAPH should control flue gas temperature automatically**

Burner Tilt Auto Control

- Burner tilts to be used to control RH MTMs in addition to RH steam temperatures.
- **Adding Feed forward from load to burner tilts, with validation through physical tests**.
- **Predictive observer to both RH steam and RH MTM to** be added to predict where temperature will be in few minutes based on actual temperature developments., to anticipate changes and enhance control.



Measures to Achieve Flexible Operation : Control Optimization Measures

CMC

- Enabling load to change sooner in upward direction & pressure later in CMC have two effects:
  - ✓ Better cooling of RH tubes when steam flow increases, less MTM increase
  - ✓ Better drum level stability

SADC Damper Control

- Automatic variable set point for wind box to furnace Dp depending on load
- SADC passing to minimized to make control effective & scheduled checking
- Modifications in O2 vs Load curve to be reviewed in consultation with OEM

Measures to Achieve Flexible Operation : For Boiler Combustion System

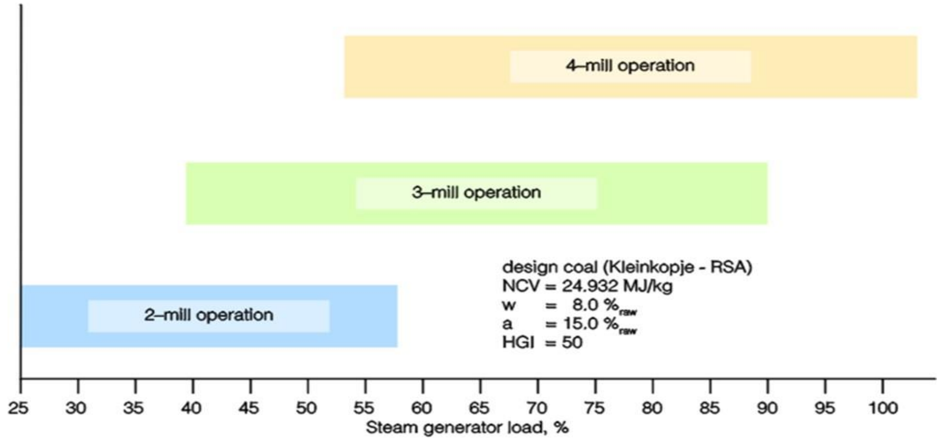
Minimum Coal mill operation

- **In low load operation "mills in service" should operate closer to their design point**

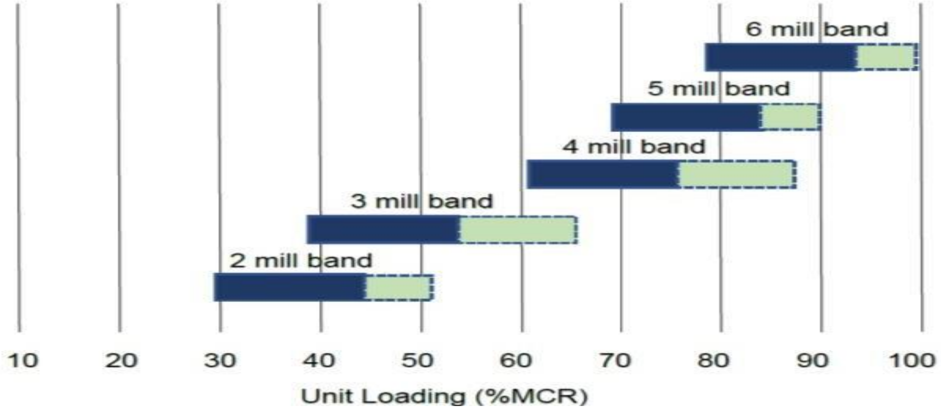
  Mills should not be operated < 60% of mill capacity or 50% of feeder speed to maintain uniform air/fuel mixture
- Adjacent mill operation to achieve stable flames and fire ball.
- Modification of control philosophy to control primary air flow.
- Key challenge is smooth stop/start of mills without Operator inertia

To achieve timely minimum Coal mill operation : Automated Start/Stop of Mills

- **Automated start-up & shut-down sequences for mills** necessary to enhance flexible operation by avoiding redundant start/stop time & operator inertia



Min . Mills 210 MW set operation

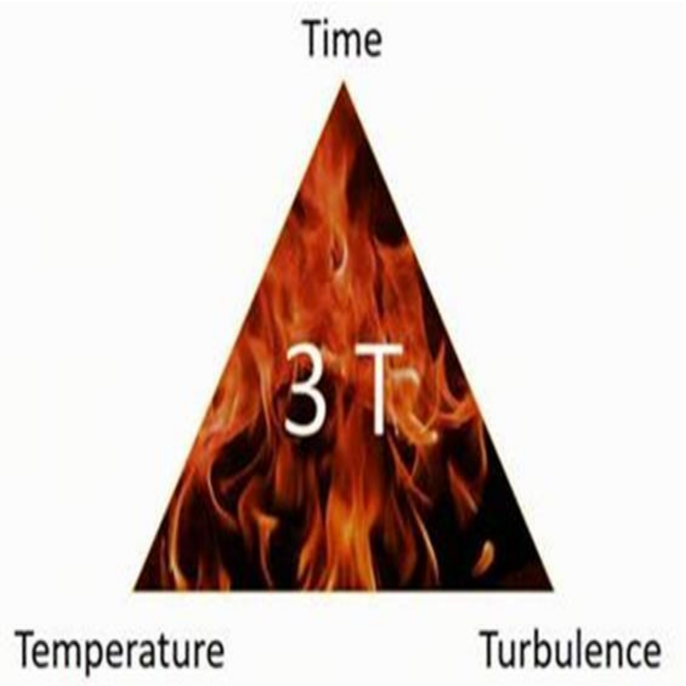


Min.Mills for 500 MW & above operation

Measures to Achieve Flexible Operation : For Boiler Combustion System

Combustion/Flame monitoring

- In low load operation, fireball condition & combustion stability is utmost importance
- Due to lean air/fuel mixtures flame stability may be issue
- Combustion monitoring through flame scanners sensors should have a wide dynamic range that can prove flame at full load as well as at lowest loads without recalibration.
  - ✓ **Need based Flame scanner upgrade in control & repositioning of scanners avoid "nuisance" trips where a scanner may not "see" a still stable flame**
- **Need based Combustion tuning using artificial intelligence (AI) technique**
- **Auto mill scheduler start/stop : Prevent lean combustion**
- Balancing of Coal flow across coal pipes
  - ✓ Periodical dirty air flow test & corrective action



Measures to Achieve Flexible Operation : For Ramp Rate Improvement

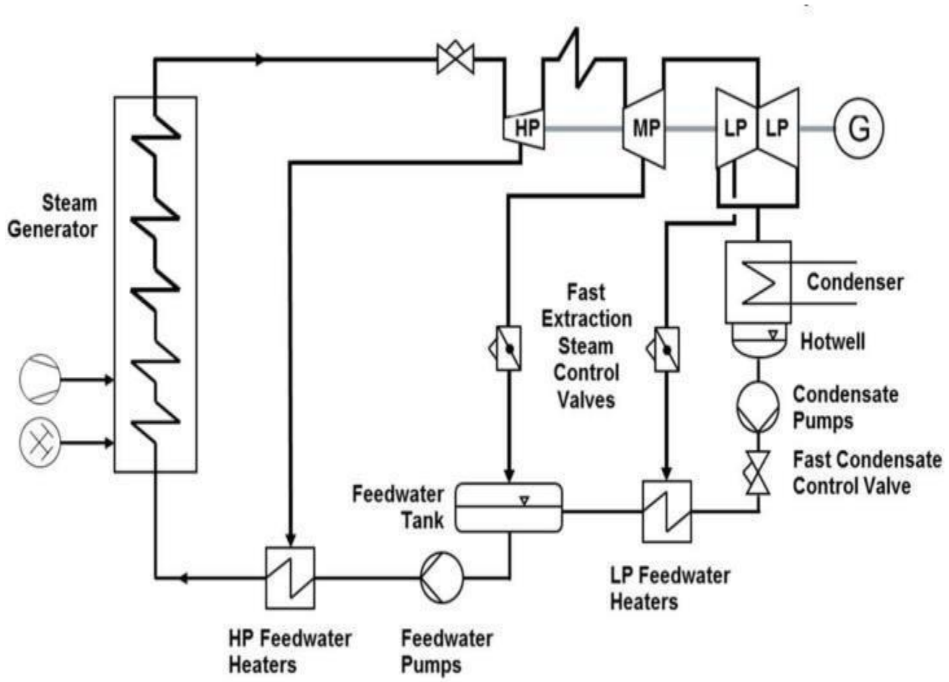
Measures for Ramp Rate Improvement

- “Thermal feasibility study of boiler model” study, can lead to explore measures to decrease SH and RH MTMs in cycling operation regimes, e.g., by effectively applying burner tilts

Condensate Throttling

- Condensate throttling to enable fast increase of turbine power in case of grid frequency deviations.
- Main condensate control valve throttled to a pre-calculated position allowing a reduced condensate mass flow flowing through LP feed water heaters & then extraction steam flows of LPHs & D/A reduces
- Surplus steam in turbine & generates additional power.
- Condensate throttling compensates transient time behavior of Boiler
- Accumulated condensate stored in condenser hotwell or a separate tank. Firing rate of boiler increased to meet load requirements.
- Fast acting main condensate control valve & additional fast acting extraction steam lines valves response time behavior to be optimized

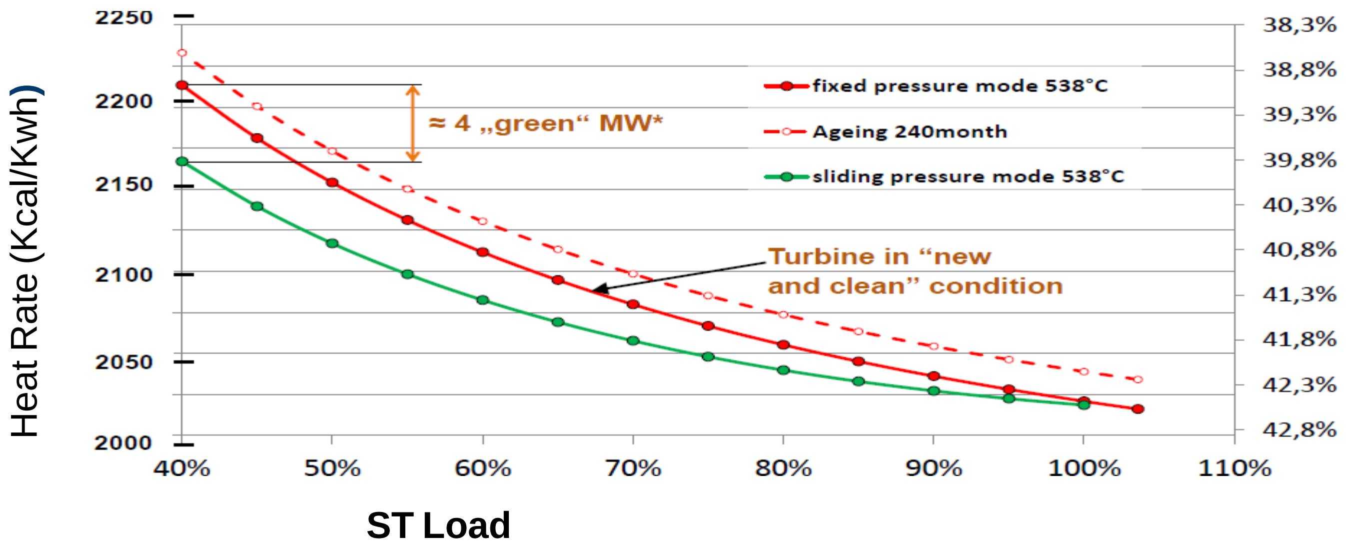
Response time of 20s for 7% extra power at 100% load has been achieved through condensate throttling & main steam valve throttling at NTPC Dadri 490 MW unit



Measures to Achieve Flexible Operation : For Heat Rate Improvement

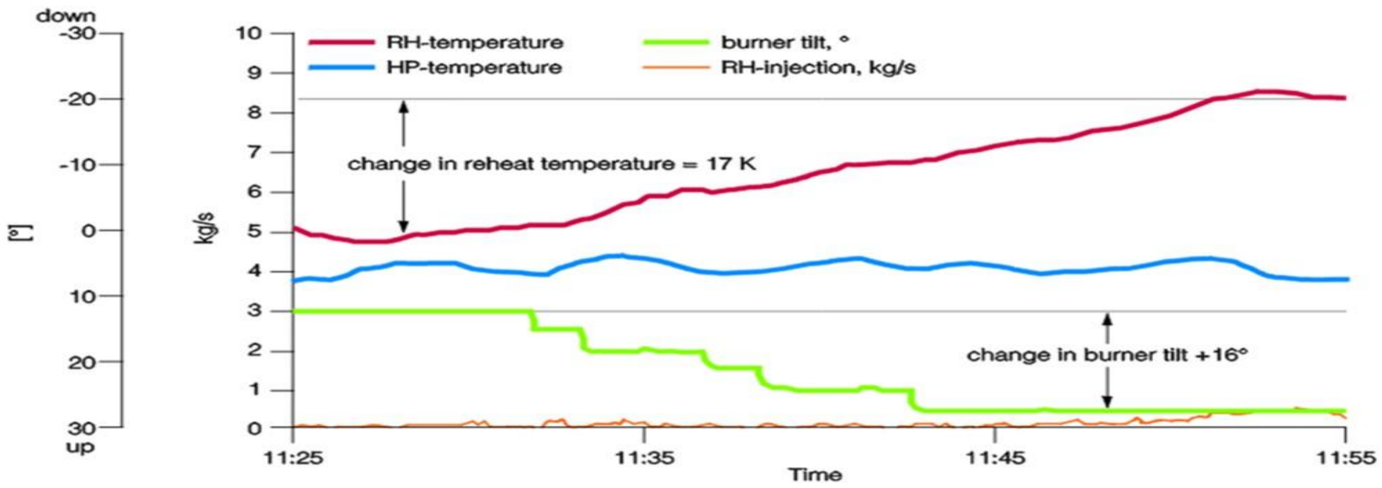
Sliding pressure operation :

- Control loop modification in sliding set pressure required for flexible operation
- Better unit efficiency & reduce BFP power



Steam temperature (MS/HRH)

- To be maintained at rated in part load operation for better efficiency
  - ✓ **Use of MS/HRH Temperature optimizer control keeping material temp. limit**
  - ✓ Judiciously operating burner tilt on auto with predictive control

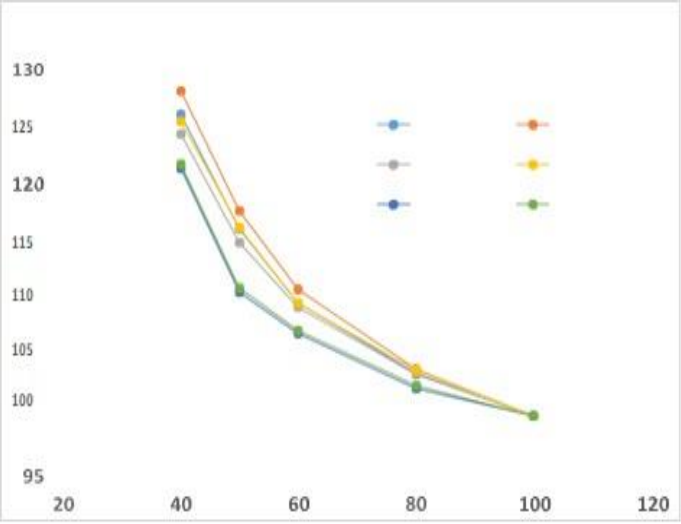


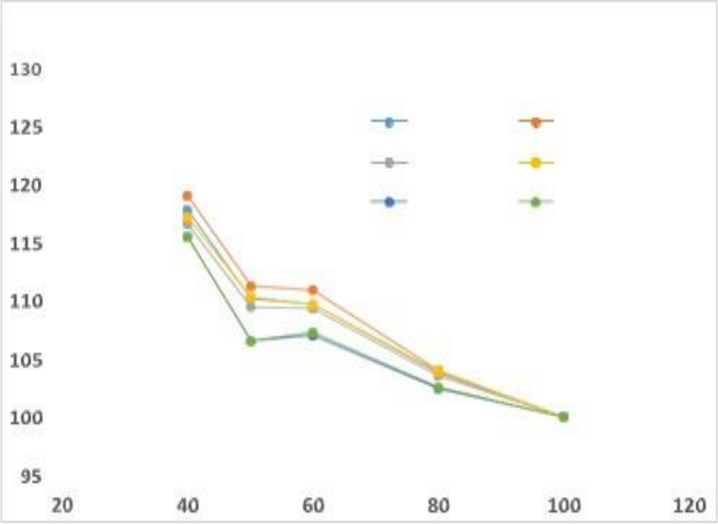
Source: Flexibilization Reports

Measures to Achieve Flexible Operation : For Heat Rate Improvement

Optimization of Unit/Station Auxiliaries

- Net heat rate of unit can be improved by reducing auxiliary power consumption
- To reduce auxiliary power consumption at loads < 50% auxiliaries should be operated as 1x50% from 2x50% mode without affecting safety & security of plant.
- Sliding load operation of unit from 100-40% reduces BFP Aux.power
- **Flexible operation measures** :
  - ✓ **Mill scheduler**
  - ✓ **Single Drive Operation- Automated Start/Stop of ID/FD/PA Fans to overcome operator's inertia**
  - ✓ Variable frequency drives





Net HR improvement with Auxiliaries optimized

Impact of Auxiliaries optimization on Net heat rate as per BHEL HB study

Auxiliary reliability is key issue for efficiency management at part load operation

Measures to Achieve Flexible Operation : For Condition Monitoring

Digital tools for online condition monitoring & damage assessment like EOH calculator

- ✓ Can be of great help on deciding frequency of maintenance & component replacement
- ✓ Helps identifying operating modes causing higher damages to component life & mitigating/avoiding such operations.

Fatigue Monitoring System

- By computing creep & low-cycle fatigue residual life of Boiler & Turbine, which is dependent on power plant operating mode can be recalculated time & again contributing better scheduling of maintenance.

Vibration Monitoring System

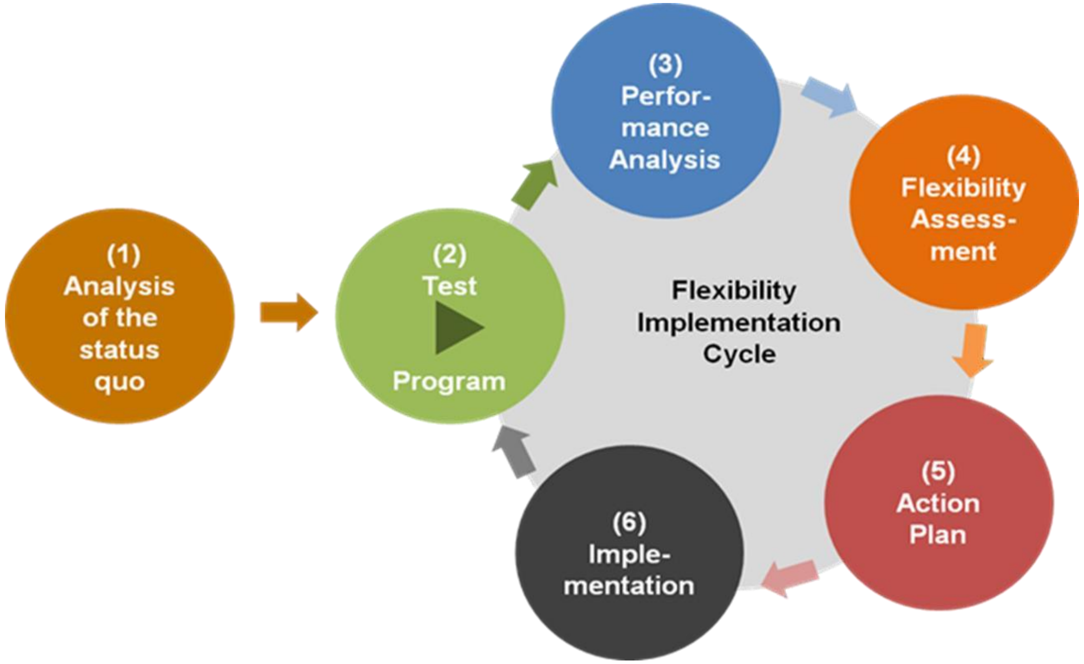
- Operational risks for blade failure could be monitored through non-contact type blade vibration monitoring system.

Generator Monitoring

- Moving to condition-based maintenance (instead of regular preventive maintenance) by real time monitoring key generator parameters like partial discharge (PD), rotor flux, rotor shaft voltage, end winding vibrations, stator temperature etc. are important.

Final words……………..

- Perform flexible operation trial runs as recommended
- Analyse observations
- Drill down to technical measures for flexible operation for specific Unit



Implementation cycle for technical flexibility measures

Minimum Retrofit measures required :

- ✓ Predictive MS T& RH temperature Control
- ✓ Milling Schedule (Auto Stop/start)
- ✓ Flue Gas Temperature Control (SCAPH on auto)
- ✓ Automated Start/Stop of ID/FD/PA Fans.
- ✓ Boiler Fatigue Monitoring System & EOH
- ✓ Installation of Modulating BFP Recirculation Valves

Additional measures: Unit specific flexible operation test:

- ✓ Control loops retrofit including Adaptive predictive controller
- ✓ Boiler Feed Pumps auto On/Off
- ✓ Combustion tuning using AI technique & adaptive predictive controller
- ✓ Upgrade controls for TDBFP
- ✓ Upgradation of Flame scanner
- ✓ Turbine vibration monitoring system
- ✓ Generator monitoring system

Thanks for patience hearing !!

MundhadaKamal

Kamal Kishore Mundhada

7839450615

THANKING YOU!
ON BEHALF OF

Council of Enviro Excellence