INDIA

The Techno-economics of Flexibilisation in regulated markets

A.K.Sinha & **O.P.Maken**

Senior Consultant

CEO,EEC & Ex ED,NTPC

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Outline

- Scenario in 2022
- Impact of Variable Renewable power
- Barriers of Flexibilisation
- Benchmarking and Preparation
- Leveraging Digitalization for flexibility
- Flexing Costs
- Operation and Maintenance Strategy
- Conclusion

All India Demand Vs Net demand from Coal on a typical day in 2022

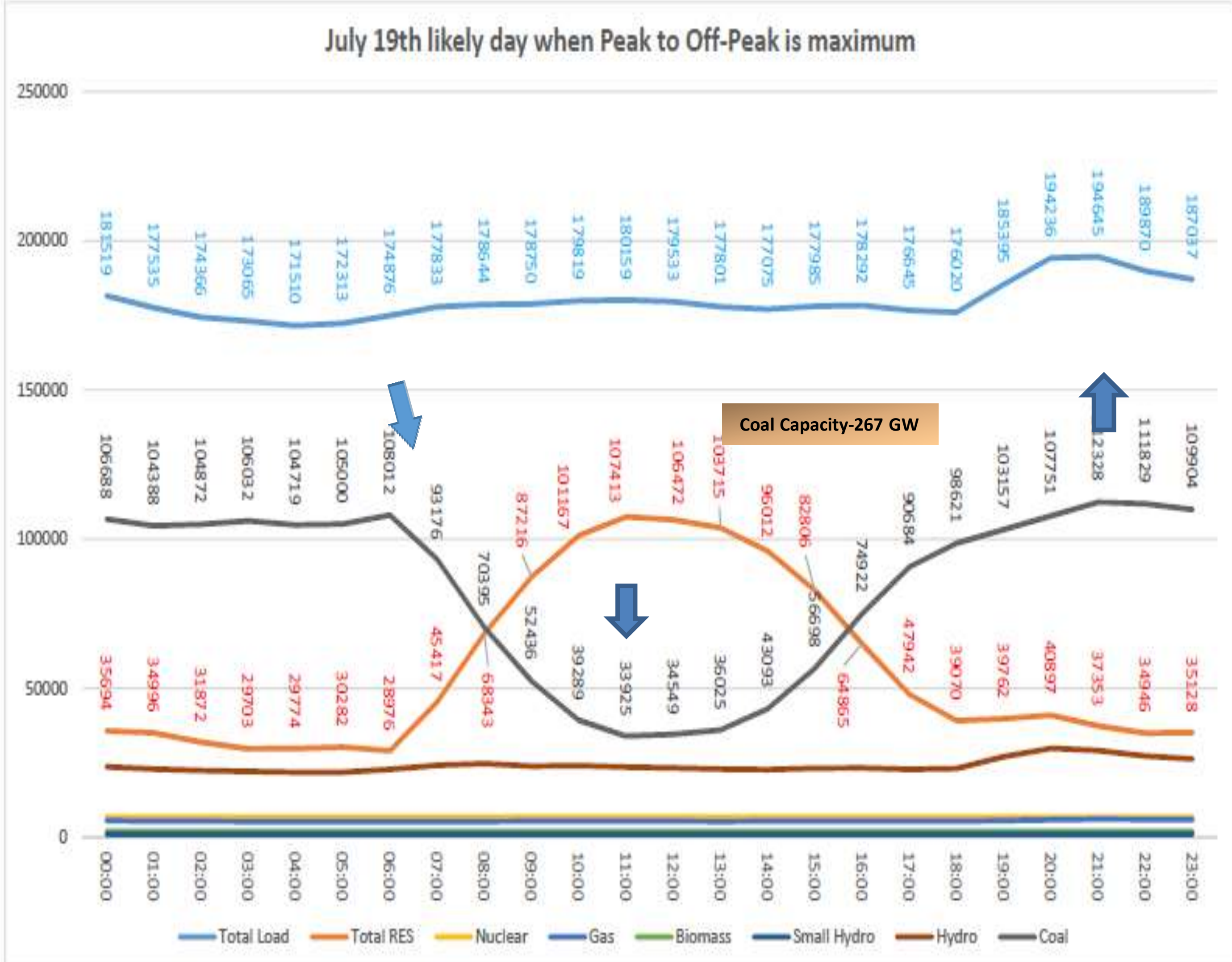
Flexibilisation: Why Bother?
Or Why should I get ready?
...What to do?

Grid Evolution,
Baseload ➡ Cycling

Impacts of Plant Cycling on Damage Rates and the ultimate Costs of providing power

Critical risks of process safety, increased costs, higher probability of equipment failure and reduction in unit life associated with cycling will need effective management

Building a Business Case for Flexibilisation



Impact of Variable Renewable power

The Variability, Uncertainity,and the Geographically Confined VRE will be challenging for the grid operators as well as generators.

Impact on System

- Difficulty in load frequency control
- Difficulty in scheduling of tertiary reserves
- Requirement of enhanced transmission network and its under utilisation
- Increase in requirement of ancillary services and hence increased system operation cost
- Increase in transmission cost due to all above factors

Impact on existing Plant

- Lower PLF due to ducking of load curve
- High ramping requirement
- Two shifting and cycling of plants
- Increased forced outage and O&M cost
- Equipments life time reduction
- Poor heat rate and high Aux. Power

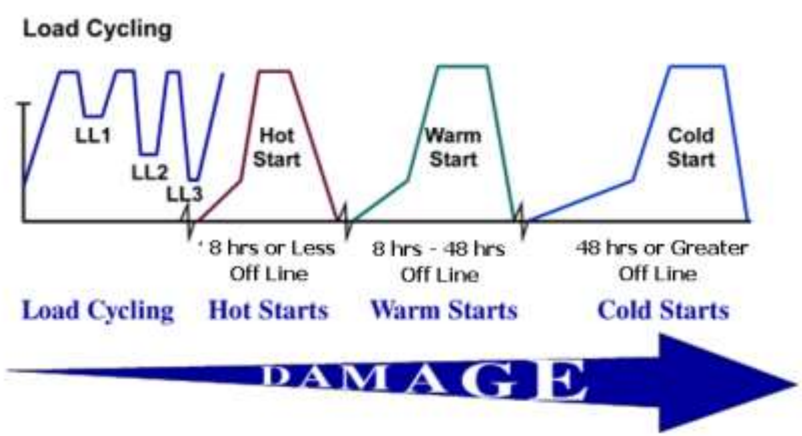
Cost of Flexibilisation

System Costs

- **Variability**
- **Uncertainity**

Generator Costs

- Opex
- CAPEX



Key Facts of Cycling

- Almost any unit can be cycled.
- This can be done with minimal capital investment.
- However, we have to account for:
  - Long term penalty of increased wear & tear damage and reduced reliability.
  - Short term penalty of higher heat rate, increased O&M, training requirements, and equipment efficiency.
- Component Damage can be determined
- Understand amount of damage present
  - Rate of accumulation
  - Total damage before failure
- Cycling a power plant is more difficult operating mode than baseload operation.

Barriers to Flexiblisation

Varying Coal Quality posed a major challenge to flexibilisation

	GCV (KCal/Kg)	VM	ASH
A	4000	18%	36%
	3400	14%	40%
B	4600	21%	34%
	3700	18%	37%
C	6000	22%	30%
	3300	15%	40%

Min. Load - 55%-30%

Coal Quality

Limited participation

Most of the state Utilities yet to reduce minimum load levels

Geographical Concentration of Renewable

Transmission constraints

Curtailment of RE

Flexibilisation for Integration of 175 GW RE

Capacity building & Investment

Operating Expertise to be created

Simulators for flexible operation

New Analytical Tools required

Increased Digitilisation

One time investment for making units flex ready. Country-wide cost estimated at **14,000 crores for 82** GW capacity.

Policy support, Regulatory Framework

In India ,Market participation is limited. (Net Traded Energy is < 5%) Largely under Long Term Contract arrangements(PPA),which have limited flexibility.

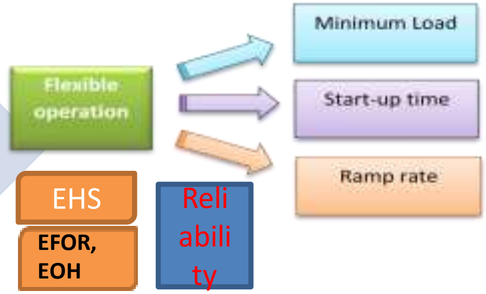
Incentivization through regulation or market needed.

Grid codes..

AGC,Anciliary services

Flexibilization: Benchmarking and Preparation
…for what level?

Defining
- **Defining from different perspectives**



Measuring
- **Metrics**
- **Quantifying**

Merit order based on?
- Variable Cost
- Heat Rate
- Emissions

Operational -isation
- **Sources, options**
- **Preparedness for Coal based plants**

Compensation/ Incentivisation
- **Regulatory framework**
- **Market structure and mechanisms**

Mechanisms for operationalization Ancillary service, DSM, AGC

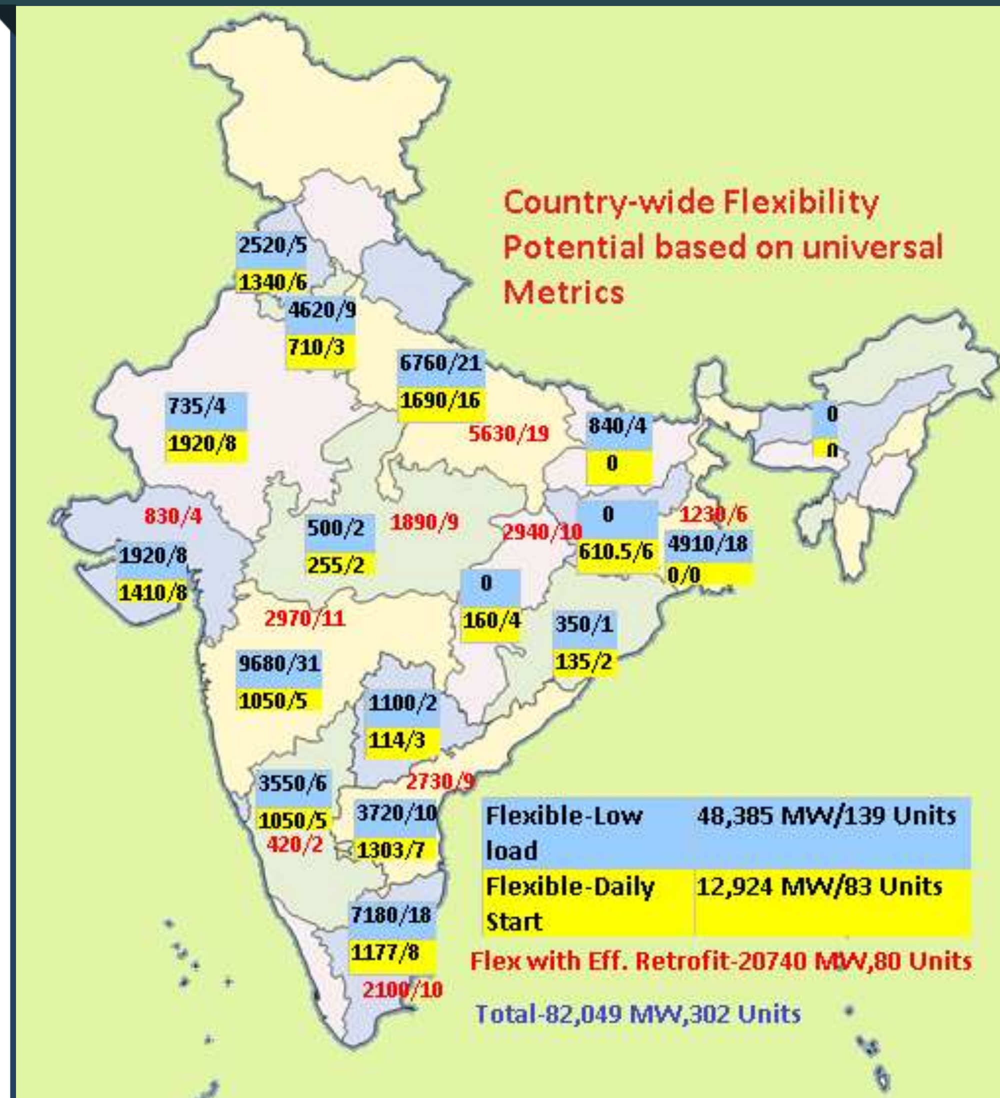
Choosing which units to flex?
- **Units on base load**-Energy supply sources stacking to meet the total state energy need are classified as sources that will always have demand and hence shall run on max. allocated share …base load operation.
- **Flexible Units on low load & evening peak-** Daily in the evening generation from Solar would come to zero and this energy need would be satisfied by units on merit, who would run on min. load and support his evening need + portion of the demand peak.
- **Flexible Units-Daily start & peaking-** If the peak is not met by the low load and peaking units up in the merit order, then new sources shall be started daily till the balance peak need is met.

Maintenance schedule … Retrofits/R&M..

Knowing the component-wise cycling costs is necessary for deciding maintenance schedules

Identification of Units for different modes of operation

Category	Metrics
Base Load 140GW/299Units	ECR<< State M.O. GCV < 2800,VM<15% Supercr. (except 14 Units)
Flexible-Low Load	ECR=> State M.O.(>Rs.2.5/KWH) GCV >2800,VM > 15%
Flex with Efficiency Retrofit	Units>25 Years Unit size-200 and above HR> 2500
Two-Shift	ECR>> State M.O. (unlikely to get schedule in 2022) HR>2500, GCV>3400
Retire/replace	>25Years HR>2600 Unit sizes<200 MW



OVERVIEW OF COAL FLEXING COSTS

"Considering the price of natural gas vs. cat food, I calculated that it's cheaper to heat the house with the body heat of 50 cats."

Flexing Costs

CAPEX

One-time cost required for preparing units for Flexing

OPEX

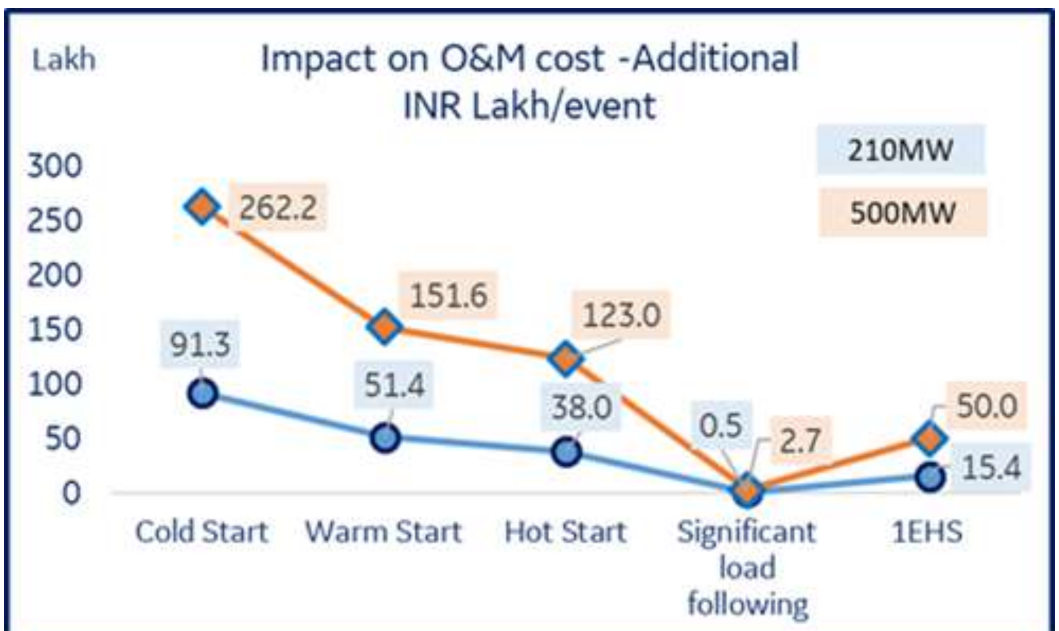
O&M costs

1. Increased Forced Outage
2. Life consumption costs
3. Load Following Costs (significant load follows)
4. Increased Ramp Rates

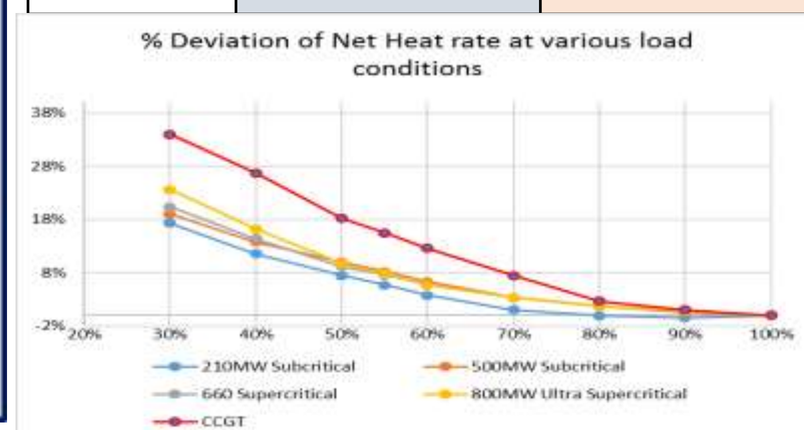
ECR costs

1. Start-up Cost (Aux. Power + Chemicals + Water)
2. Start-up Oil
3. Heat Rate effects due to Power Plant Cycling

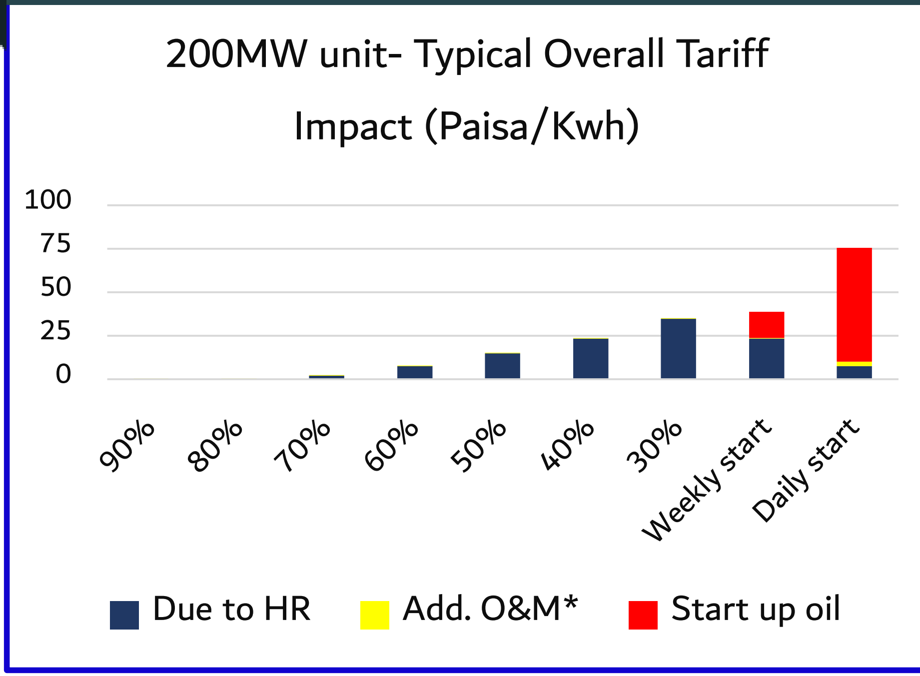
Under-utilization/ oppor. loss

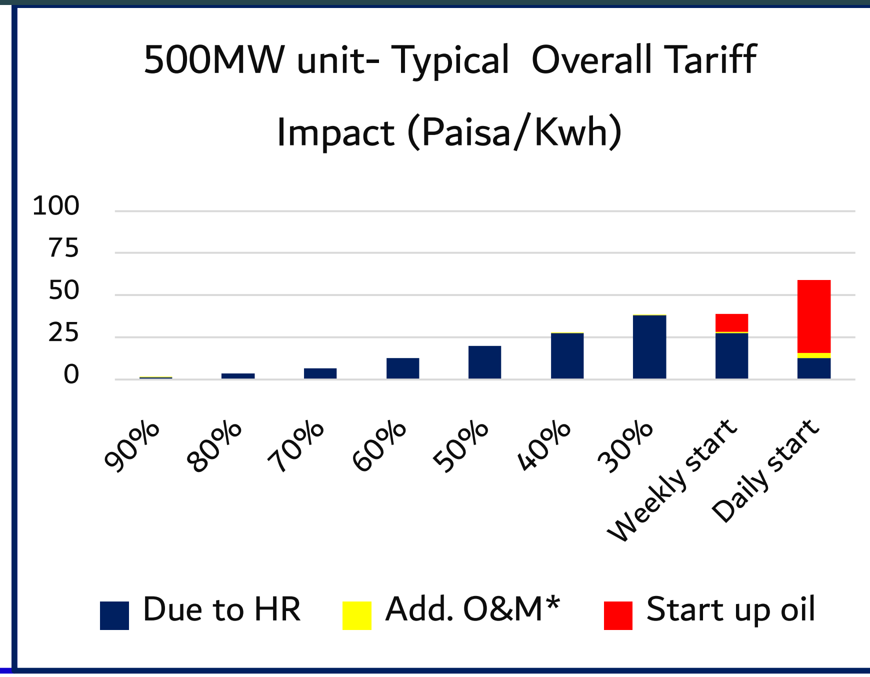


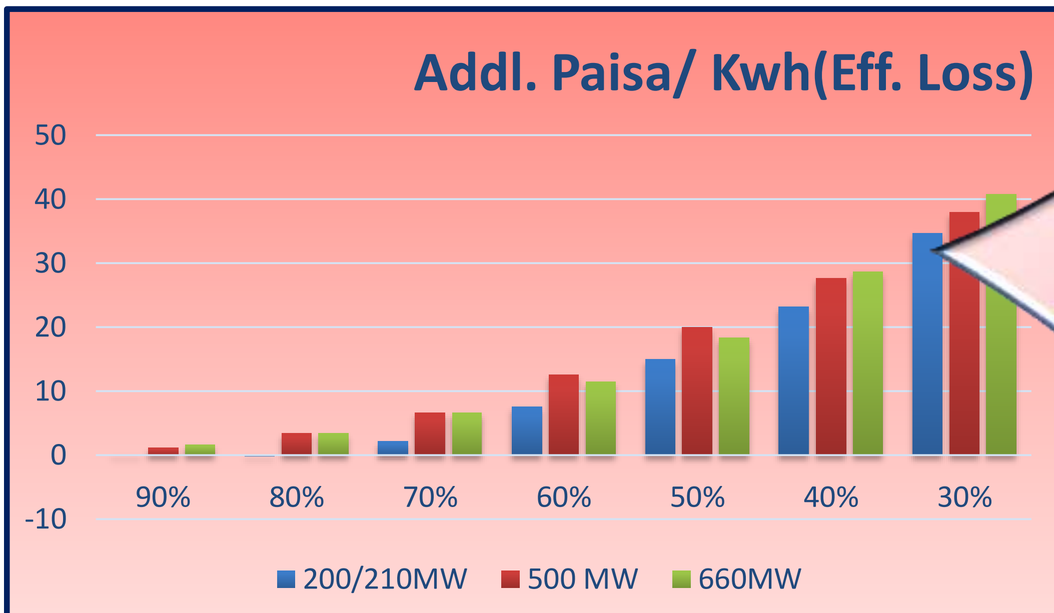
	500 MW UNIT Oil cons. in Kl	200/210 MW Oil cons.in Kl
COLD	90	50
WARM	50	30
HOT	30	20



Flex Costs







Sub C units 200-MW Units are economically better suited for Flexible operation

Details of calculation for All India scenario for 2022

Item No.	Balancing Cost	Rs./Unit
1	Total balancing charge for Gas based station (fixed +fuel charge)(Rs/kWh)-Spread over renewable generation	0.04
2	Impact of DSM per unit- Spread over renewable generation	0.30
3	Impact on tariff (Rs/kWh) for All India discom for backing down Coal based generation assuming solar and wind at Rs. 2.50/kWh and tariff of coal based generation at Rs. 3.50/kWh- Spread over renewable generation	0.1
4	Stand by charge (Rs/kWh)- Spread over renewable generation	0.50
5	Extra transmission charge (Rs/kWh)- Spread over renewable generation	0.26
	Total Impact- Spread over renewable generation (Rs/kWh)	1.11

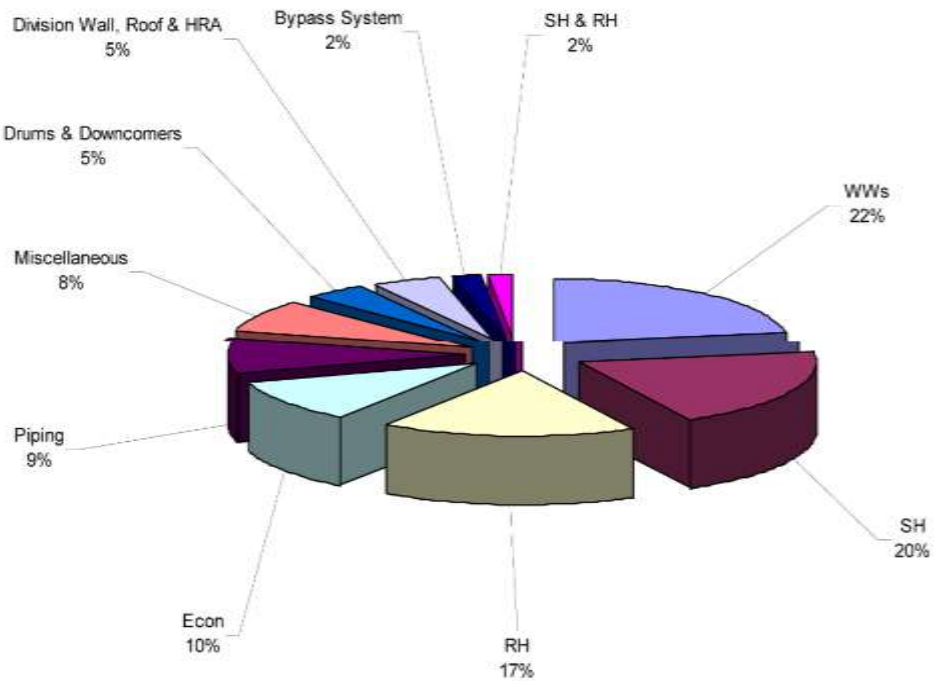
Source: CEA

THE NEXT STEPS…..
Inside the plant

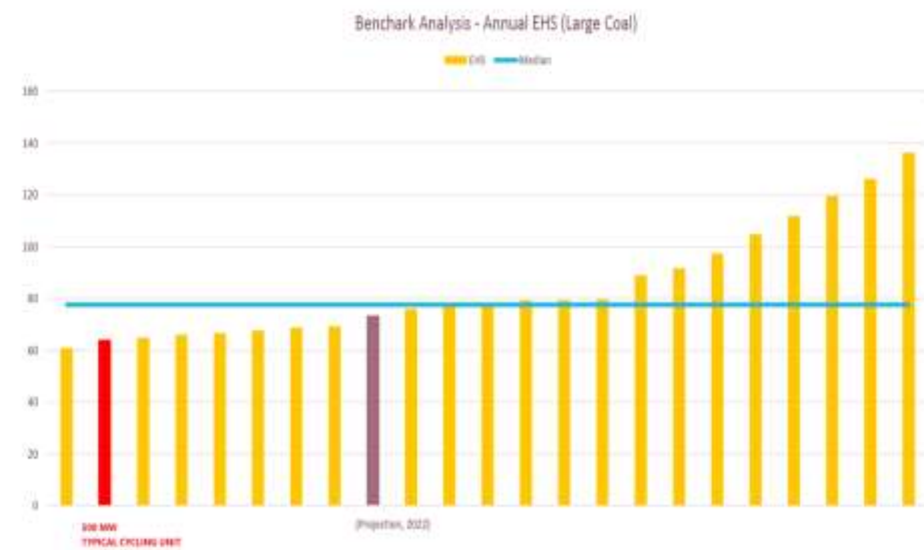
Operational practices for minimising cycling damages

- Modifying start-up/shutdown ,ramping procedures to lower the component fatigue stresses
- Plant lay-up procedure
- Operations like forced cooling of boiler must be based on economics rather than maintenance requirement
- Modified chemistry chemistry monitoring
- Use of nitrogen blanketing
- Ensure deaerater heating and SCAPH during start-up
- Modifying inspection plans around cycling plants
- Tuning of auto control loops
- Judicious use of HP/LP bypass
- Sliding pressure operation
- Taking oil guns for short run may be worthwhile instead of jeopardising the integrity of assets
- Ensure operation of dampers, dranis and vents

Cycling Damages in boiler components-Global Benchmark



BENCHMARK ANALYSIS (LARGE COAL)



In the Indian condition,we have limited data. Benchmarking for other units will be done.

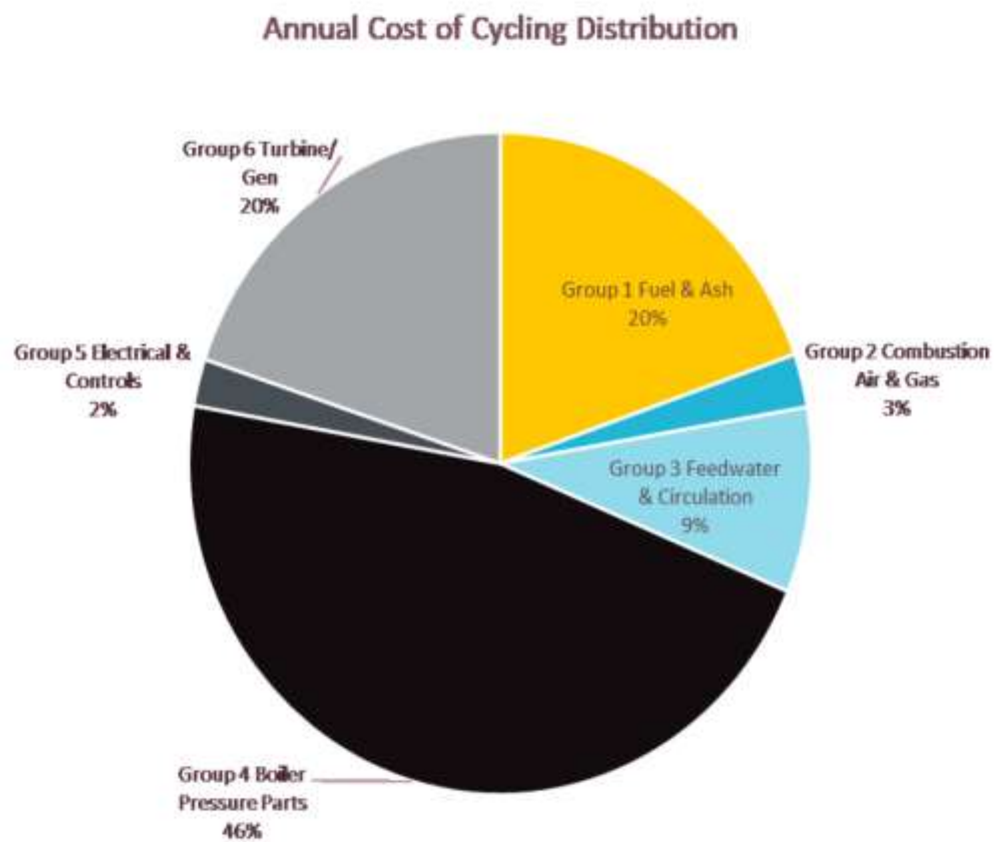
Future maintenance strategy to address the increasing cycling damages will be based on:

- **Cycling frequency and age of unit**
- **Boiler Component/Damage ranked on most affected by cycling**
- **Inspections schedules/Corrective Actions(**anticipated repairs, and Replacements)
- **Cost benefit analysis**

Identification of the damage mechanism by examination and monitoring.
The state of knowledge of the underlying mechanism and root cause
Self-calibrating incremental damage models that can be used to forecast the effect of frequency and severity of cycling, including failure rates

Maintenance planning-scope & schedule

- Systematic records of all components
- Optimise maintenance expenditure
- Overhauling duration, timing and scope-Greater OH frequency in later years of life and cycling
- Failure statistics
- **Failure faults-independent of operation**
    - Due to construction, design, operating errors etc.
- **Predictable faults and dependent on service time**
    - Wear and tear of ageing component
    - Corrosion, erosion and distortion
    - Creep and fatigue damage
    - Cycling



Predictive Tools: Estimated weekly damages, EFOR,Life management actions

It is necessary to tailor the overhauling and maintenance intervals for the particular unit on the basis of data available.The analysis of component-wise cost data is important

Metrics of equivalent operating hours, EHS is helpful.

Component-wise maintenance decisions can be taken on the importance,redundancy,safety etc.

Leveraging Digitalization for supporting flexibility

Fleet wide strategy based on dynamic requirements will require require digitization of the entire commercial operations, maintenance strategy

Digitization will be essential for bringing down the levelized system cost of flexible power ,based on forecasting and AGC

- Process automation/Boiler auto tune
- Online Predictive tools for predicting failures, providing maintenance advisory, tube leakages- by profiling critical parameters
- Combustion stability advanced monitoring system
- Lifetime Monitoring and Control
- Lifetime Assessment
- Strategic Maintenance
- On line coal analyser
- Fleet monitoring
- Predictive tool for predicting Cycling costs –Enable least cost Fleet strategy
- Digitalization for additional safety
- Digitalisation of Training resources

Conclusion

- Any unit can be flexibilised
- Moderate amount of flexibilisation can be achieved with modification of operational practices
- Higher level of flexibilisation can be achieved with retrofits and the decision should be taken on case to case basis as in some cases the retrofit cost may be prohibitive.
- The providers of flexibility must be motivated by incentivisation
- The true cost of flexibilisation must be known
- Broader policy and regulatory approaches to improve generation and access to thermal flexibility and ultimately energy security.
- Market and operational rules affect access to thermal flexibility
- The **Stakeholders engagement including International cooperation** is critical at every step

A.K.SINHA
sinha.anjan@gmail.com

O.P.Maken
mdeecips@gmail.com