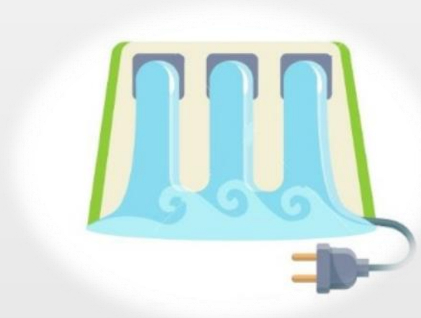
Flexible Operation

Integrating thermal power with Renewable Energy
&
Challenges



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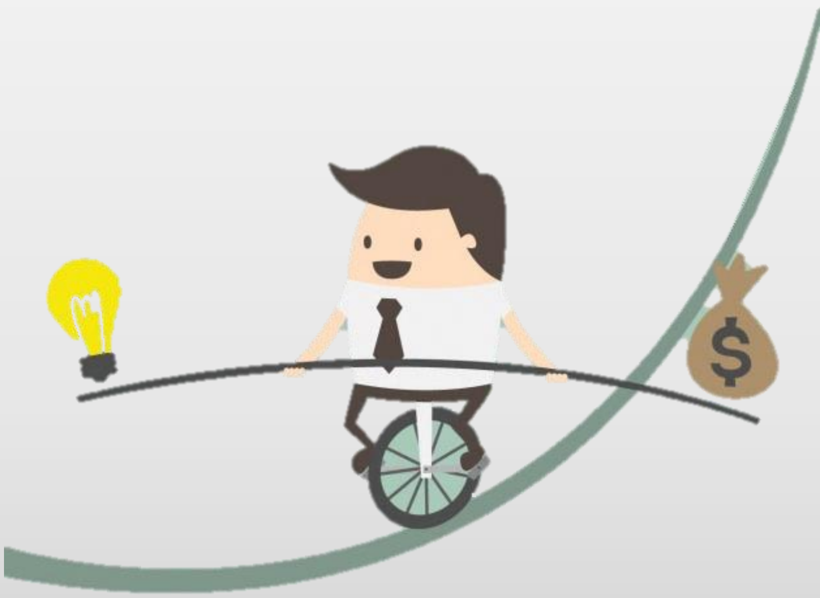
Why Flexible Operation?

Limitations with Renewable generation has called for flexible operation:

- Intermittent and variable
- Season and Weather dependent
- Location and time of day dependent
- Does not match the load demand curve
- Wind generation is unpredictable
- Solar generation is predictable but non controllable

Integration of Renewable Energy in Grid

- Balancing by conventional energy sources (large part of which is thermal) is required.
- Greater the penetration of RE in grid, greater is the requirement of balancing.



Expectation from Thermal plants

- Backing down and cyclic loading
- Frequent start/stops may be required
- Higher ramping rates during loading and unloading

But base load conventional plants are not designed for such cyclic loading.

Start-up of Steam turbines (BHEL make)

Start type	Outage hours	Mean HP Rotor temperature (deg C)	Start-up time (Rolling to full load in min. approx)
Cold Start	190 hr	150 deg C	255
Warm Start	48 hr	380 deg C	155
Hot Start	8 hr	500 deg C	55

Normal Mode : 2000-2200 starts

Slow Mode : 8000 starts

Fast Mode : 800 starts

Effect of Load Cycling on Power Plant Components

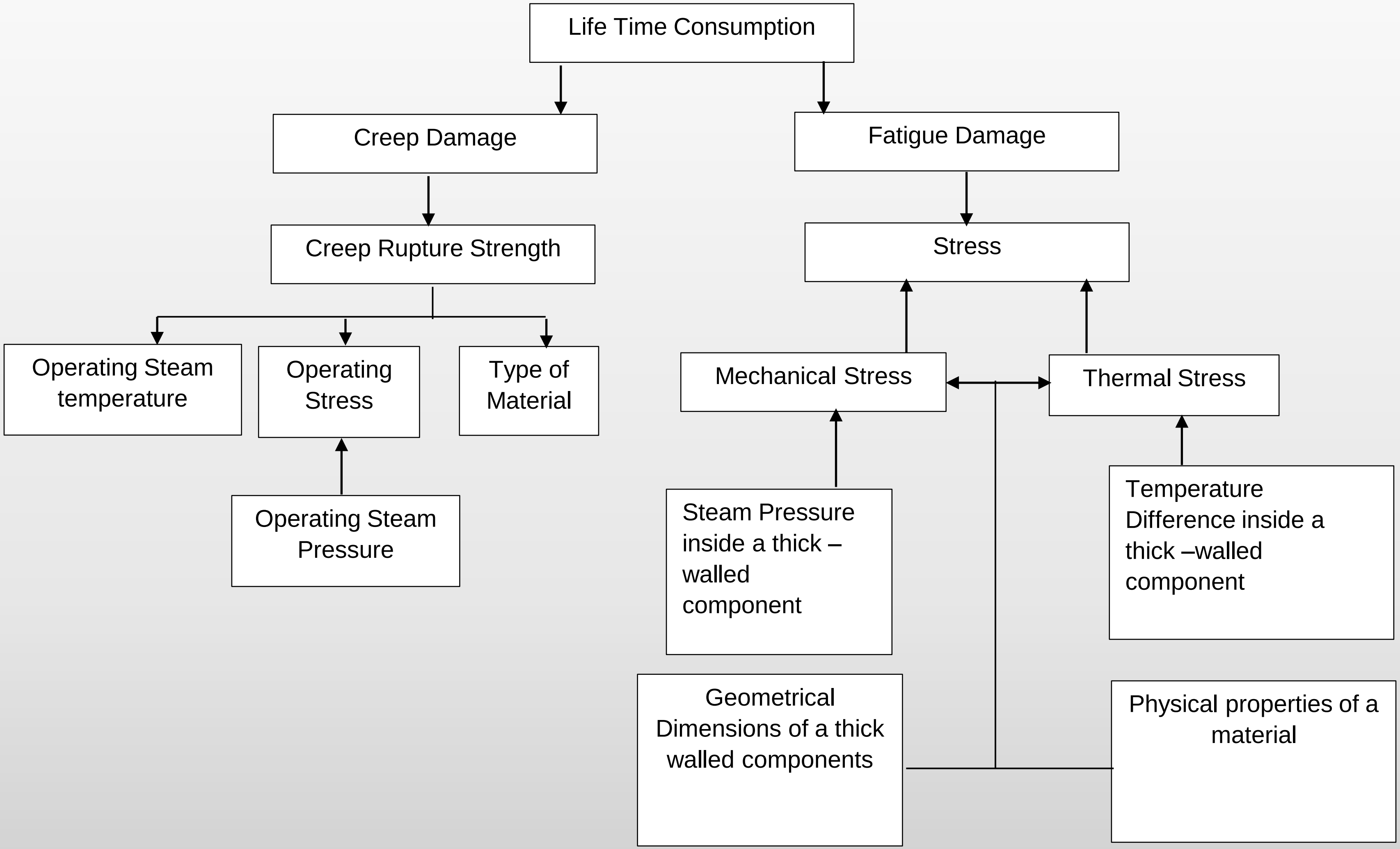
Depending on the operational conditions, turbine and boiler components are exposed to various damage mechanisms

Creep – Slow and continuous deformation of materials due to high temperature exposure even at constant load

Thermal Fatigue – Failure of metal when subjected to repeated or fluctuating stresses due to thermal cycling of components

Components affected – HP/IP rotors, Blades, Casings, Valves, Header, Y-Piece, T-piece, MS/HRH Pipelines and pressure parts.

Life Expenditure of Components



Life Expenditure Computation

The consumed life of a component is the sum of the life consumed by Creep & Low Cycle Fatigue

MINER SUM M_C IS INDICATOR OF THE LIFE EXPENDED DUE TO CREEP

&

MINER SUM M_F IS INDICATOR OF THE LIFE EXPENDED DUE TO LOW CYCLE FATIGUE

Life Expenditure Computation

FOR STATIONARY COMPONENTS :

M = MC + MF = 1   *WARNING POINT*

FOR ROTATING COMPONENTS :

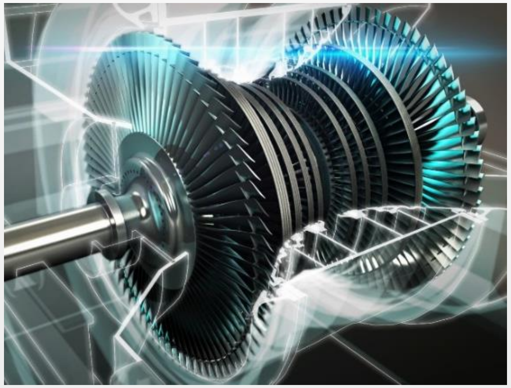
M = M C + MF = 0.5   *WARNING POINT*

Approaching the Warning Point of Effective Miner Sum indicates that the life of the component has reached its limit.

Impact of Cycling on Equipment and Operation

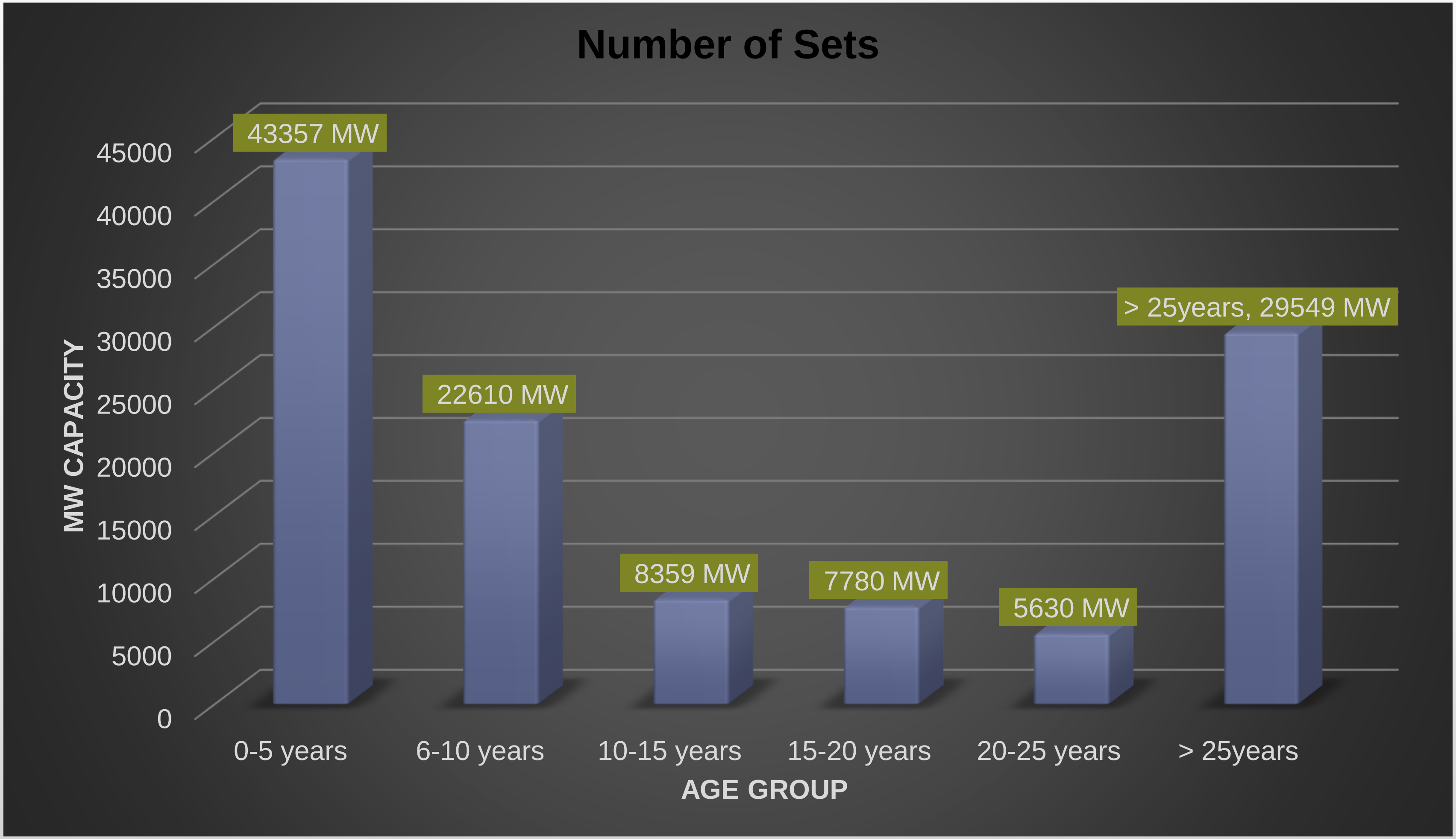
- Critical components are subjected to thermal stresses which are cyclic in nature
- Higher fatigue rates leading to shorter life of components
- Advanced ageing of Generator insulation system due to increased thermal stresses
- Efficiency degradation at part loads
- More wear and tear of components
- Damage to equipment if not replaced/attended in time
- Shorter inspection periods
- Increased fuel cost due to frequent start-ups
- Increased O&M cost

Other Operational Risks

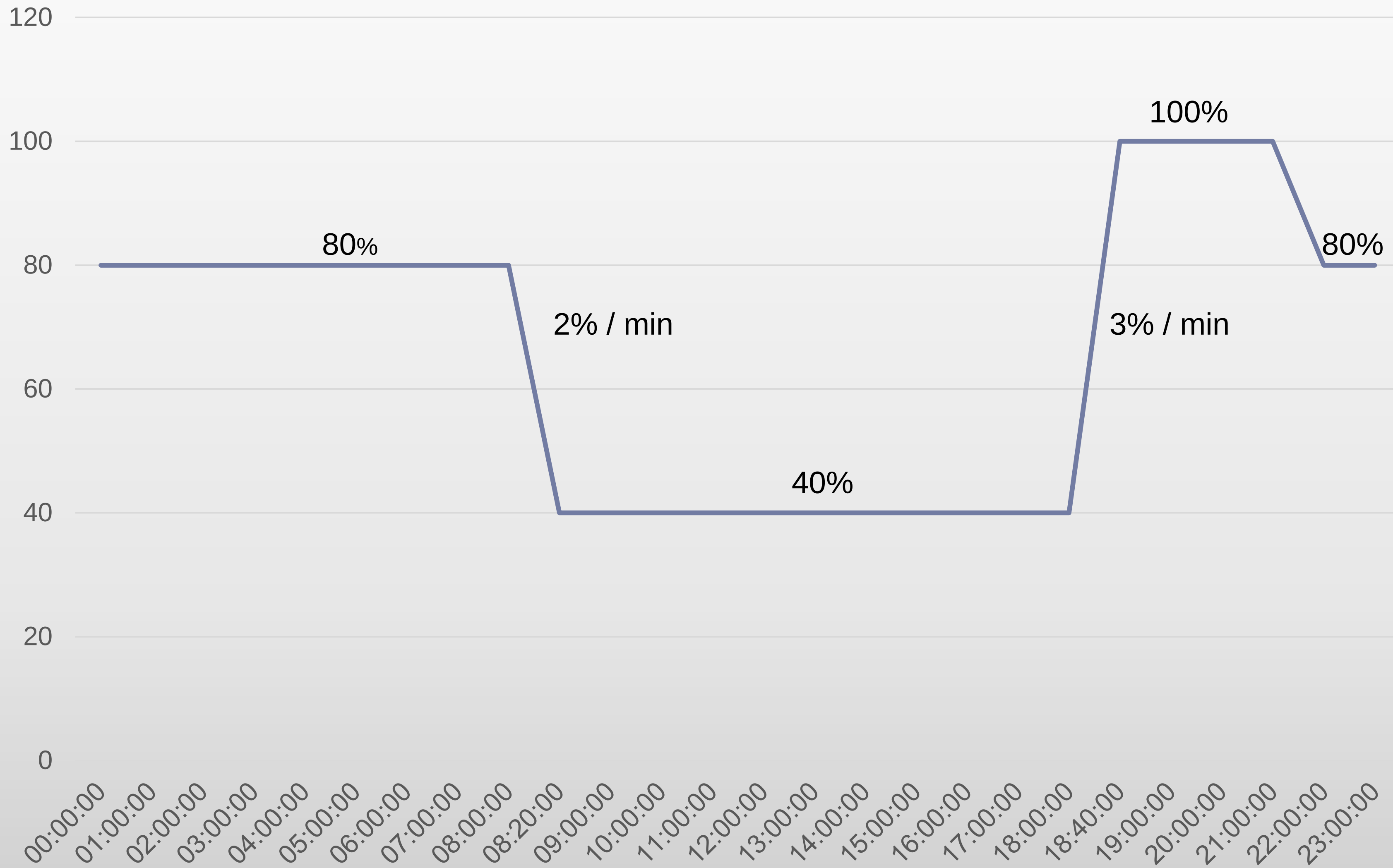


- Ventilation in HP and LP Turbine at lower loads
- Droplet erosion of LP blades
- Excitation of LP blades due to ventilation
- Frequent start/stop of major auxiliaries (PA/FD/ID fans, BFP) reduces their reliability.
- Increased risk for pre-fatigued components.
- Drop in efficiency & high Auxiliary Power Consumption (APC) at partial loads

Age of Thermal Power Plants In India (in Years)



Assumed Load Demand Curve on Thermal Machines



Impact Assessment of Load Cycling

- Impact of cyclic operation on BHEL supplied equipment with assumed load curve has been investigated.
- Lower load upto 55% of rated and a ramp down rate of 2%/min and ramp up rate of 3%/ min. has been established.
- Studies are being conducted to assess the impact on component life with loads as low as 40% of the rated load.
- It is assumed that main steam and HRH temperatures are kept constant and Unit is operated in sliding pressure mode.

Cyclic Operation - Findings

- Preliminary studies indicate that load backing from 100%-55% load at a ramp rate of 2%-3% per minute will not have significant impact on life consumption of Turbine, Boiler, Generator & ESP.
- However this mode of operation will have additional cost in terms of lower efficiency at part loads.

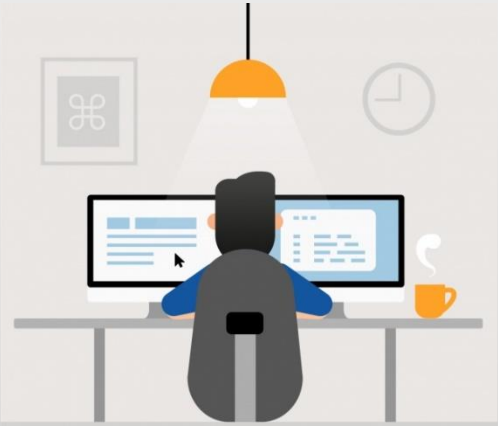
- Backing down below 55% load and/or increase in ramp rates will have effect on the fatigue life of the equipment.
- Backing down below 55% load will also have other negative impacts on the equipment as discussed earlier and need further investigation in detail.

Mitigating the Effect of Cycling

- Additional Condition monitoring systems/ Sensors
- Improved design of Boiler and Turbine to allow faster ramping and increased number of cycles
- Adaptation of Control System
- Older plants may require RLA to assess the cycling impact on already fatigued components.
- Replacement of fatigued/ worn-out components
- Shorter inspection period

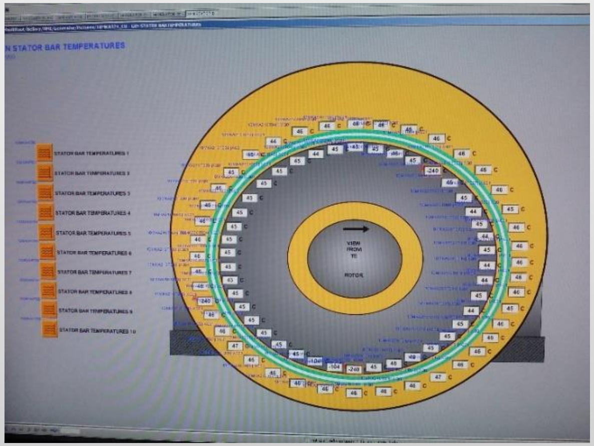
Condition Monitoring for Flexible operation

- Complete operation data is available.
- Scheduling of RLA.
- Continuous online consumption of life expenditure.
- Detection of highly stressed parts for inspection.
- Exploring the margins available for optimization of operating modes.
- Online monitoring of Generator components as early warning system.



Condition Monitoring Systems

- Turbine Stress Controller (TSC)
- Boiler Stress Monitoring System (BOSMON)
- Blade Vibration Monitoring System (BVMS)
- Stator End Winding Vibration Monitoring
- Rotor Flux Monitoring
- Partial Discharge Monitoring
- Additional sensors for health monitoring



Primary frequency control by regulating turbine extraction

- Frequency control technique, allowing for fast response even though boiler response is slow
- Reducing the flow through extractions helps in raising the load as steam is forced through turbines
- Feed forward command given to boiler master for increasing boiler load for further sustaining the load increase.
- Load increase up to 7% is achievable on case to case basis

Model based Predictive Control (MPC)

Existing PID Controller Philosophy

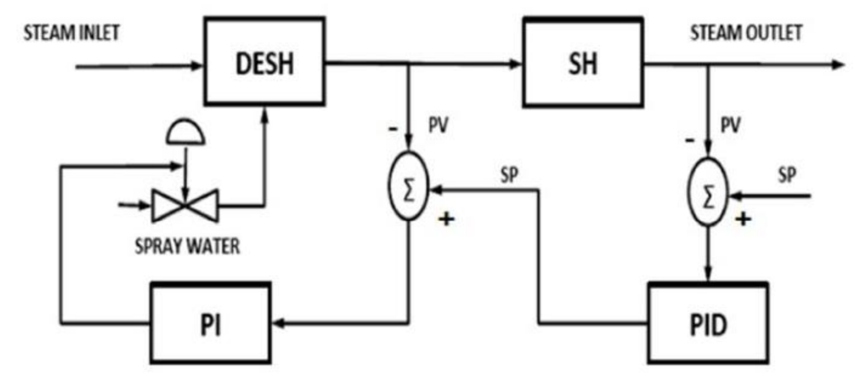
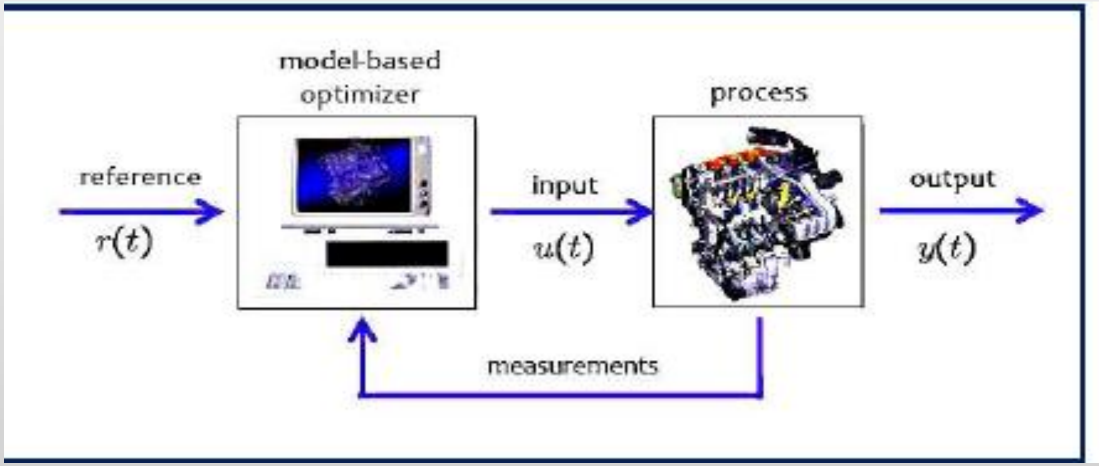


Figure 1: DESH based SH steam temperature control

MPC Philosophy



Model based Predictive Control (MPC)

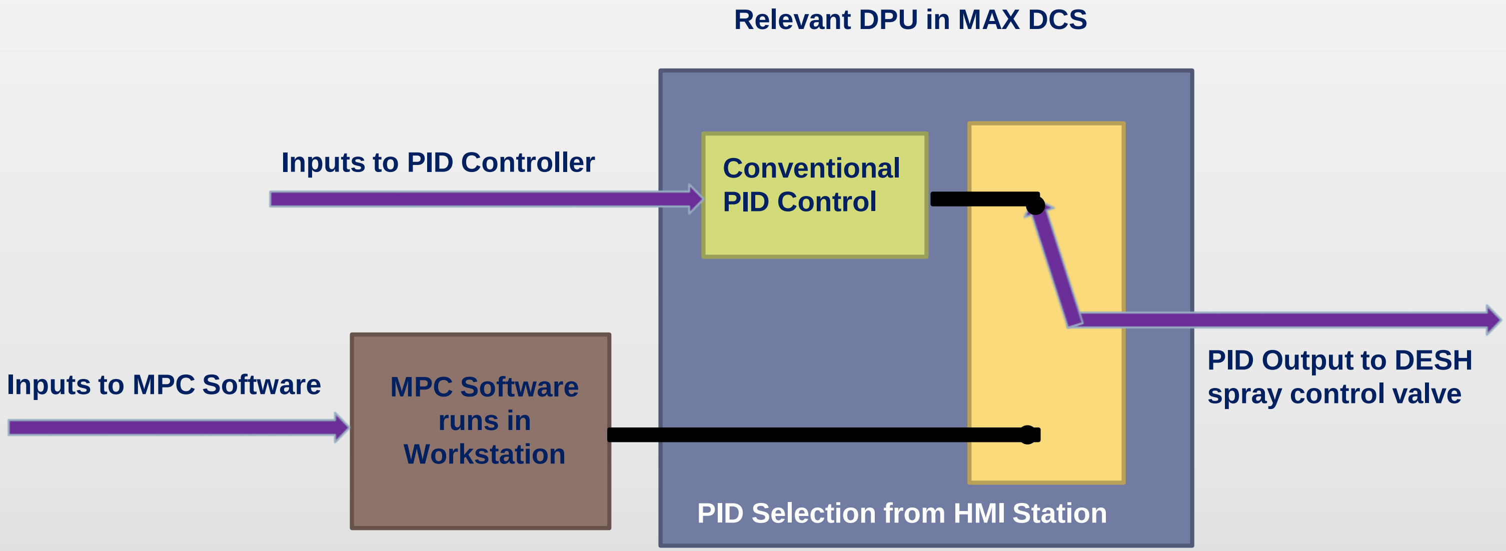
Advanced type controller primarily for steam temperature control for both SH & RH:

- Consists of predictor & controller
- Predictor creates models based on past operating data and then predicts the parameters in future course
- Based on the prediction, the controller regulates the spray control valves.
- Continuous communication between MPC & DCS.
- Automatic updation of models.

Model based Predictive Control (MPC)

Switching scheme for MPC

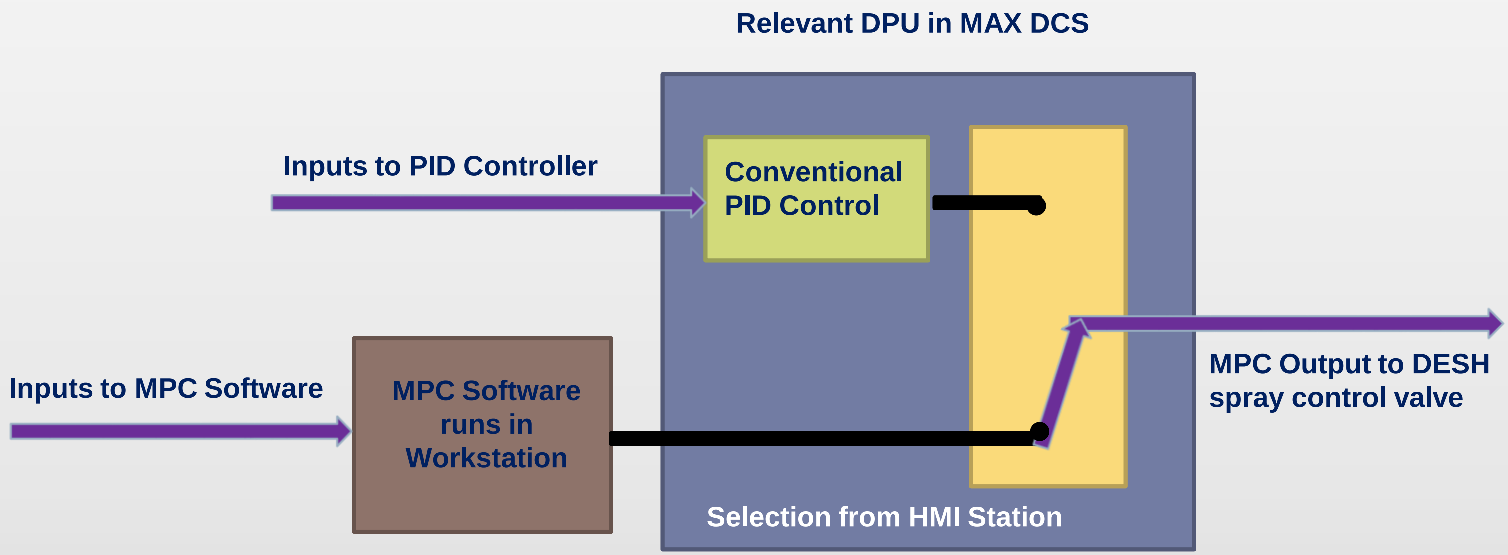
During training of MPC



Model based Predictive Control (MPC)

Switching scheme for MPC

During running of MPC



Online Coal Analyzer

- Experiments with different loading rates are being conducted.
- The online coal analyser is under development stage.

Online Coal Analyzer (Contd.)

- Coal flow & fineness through each pipe can be measured
- Better control over air/ fuel ratio
- Better control over fineness
- Better control over burner performance
- Combustion and temperature profiles within the furnace can be improved.
- Slagging & fouling issues can be reduced

Flame Scanners

- Key requirements:

  - Reliability for detecting flame of coals with low VM.
  - Reliability at low load operation.
  - Reliability for fuel flexible operation.

Flue Gas Temperature Control

- Minimum flue gas temperature to be achieved using SCAPH to meet air heating requirements.
- Avoid acid corrosion in APH baskets and downstream equipment.

Renewables integration – Overall impact

Thus increased penetration of renewables will lead to

- Increased cost due to cycling resulting in higher tariff from conventional sources
- Reduced equipment life and thus earlier replacement of plants

THANK YOU