Confederation of Indian Industry

BEST O&M PRACTICES FOR FLEXIBLE OPERATION OF TPPs

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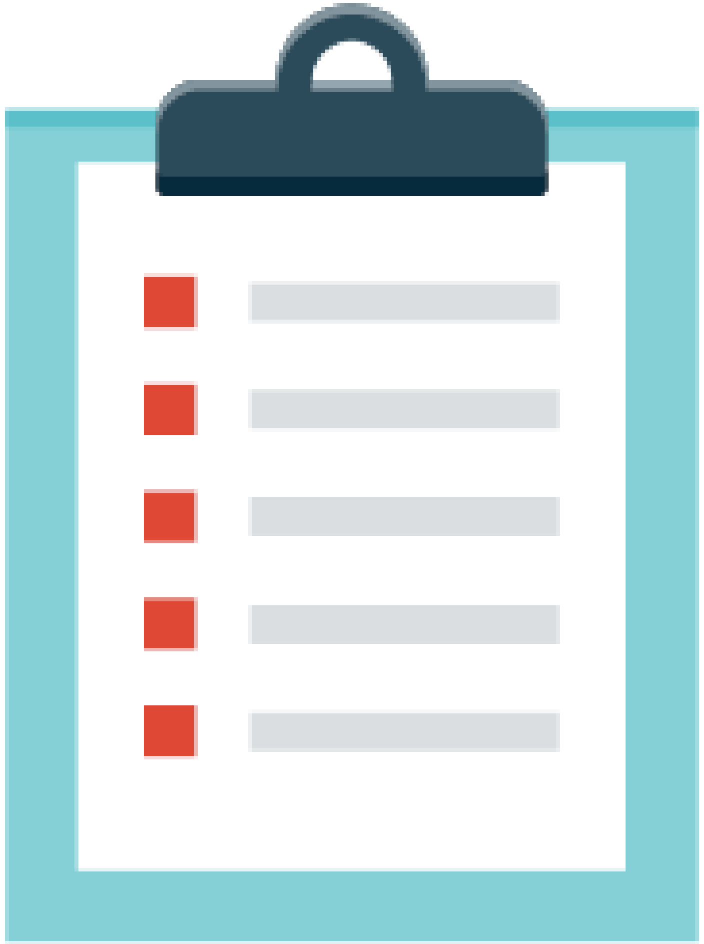


CII – Green Business Centre, Hyderabad

India's first Platinum rated **Net-Zero building**

Use **bi-facial solar panels** – generating 10% more than demand

Key Activities

IGBC

- 10.26 billion ft^2 of Green Buildings
- 2nd Largest footprint in the world
- 92% of Green Building Footprint in the country

GreenCo

- First of its kind in the world
- > 850 companies involved
- USD 400 million annual recurring savings

GreenPro

- 6,400 + green products certified
- >90% of Building Materials are under GreenPro

Energy Efficiency & Renewable Energy

- 2,000+ energy audits and largest energy auditors
- 100+ projects in energy efficiency, climate mitigation and RE

CII - GREEN ENTREPRENEURSHIP COUNCIL

- Accelerating the growth of innovative Clean Technology startups
- > 25 Startups part of cohort

Sector overview

50% by 2030

Renewable Energy

Net-zero by 2070

Economy-wide emissions

- A total of **174 GW** of capacity from **non-fossil fuel** sources has been installed in the country as of Dec 2023

	Present June 2023		Projected 2029-2030	
	Capacity (GW)	**%**	**Capacity (GW)**	**%**
Coal	**212.6**	**50.9**	267.2	32.7
Gas	**25.1**	**6.0**	25.3	3.1
Nuclear	6.7	1.6	18.8	2.3
Hydro	47.2	11.3	71.1	8.7
Biomass	10.4	2.5	9.8	1.2
Small hydro	5.0	1.2	4.9	0.6
Solar	**67.2**	**16.1**	280.3	34.3
Wind	**43.0**	**10.3**	139.7	17.1
Other	1.3	0.3		
Total	417.6		817.2	

The major source of fuel for electricity generation will continue to be coal

Demand Scenario and Flexibilization Requirements

01-Sep-23				Evening 8 PM		Afternoon 2PM		Night- 2 AM	
Fuel Type	MW	On Bar %	MW on Bar	LF	MW delivered	LF	MW delivered	LF	MW delivered
Coal+Lig	212516	86%	182764	85%	154435	86%	156263	88%	160832
Gas	25038	60%	15023	72%	10816	55%	8263	65%	9765
Hydro	46850	80%	37480	60%	22488	70%	26236	50%	18740
Nuclear	7480	80%	5984	75%	4488	75%	4488	75%	4488
Solar	71145	70%	49802	0%	0	70%	34861	0%	0
Wind	43940	70%	30758	58%	17840	30%	9227	45%	13841
Other RE	16390	40%	6556	30%	1967	20%	1311	20%	1311
Total	**423359**		**328366**		**212034**		**240649**		**208977**

As per NEP

1 Sep 2023 – Peak demand day (240 GW)

At 2 PM: 65% of Peak demand met by Coal & 14% by Solar. Solar variation 34 GW (14%) absorbed by Wind (5 GW), Hydro (8 GW) Gas (2 GW), coal (8 GW) & demand variation (11 GW)

Expected Scenario (2026-27)									
				Evening 8 PM		Afternoon 2PM		Night 2 AM	
Fuel Type	MW	On Bar %	MW on Bar	LF	MW delivered	LF	MW delivered	LF	MW delivered
Coal+Lig	235133	86%	202214	91%	183004	63%	127395	94%	190082
Gas	24824	40%	9930	72%	7149	42%	4170	65%	6454
Hydro	52446	80%	41957	60%	25174	36%	15104	50%	20978
Nuclear	13080	80%	10464	75%	7848	75%	7848	75%	7848
Solar	185566	70%	129896	0%	0	80%	103917	0%	0
Wind	72896	70%	51027	58%	29596	40%	20411	45%	22962
Other RE	25646	40%	10258	30%	3078	20%	2052	20%	2052
Total	**609591**		**455747**		**255849**		**280897**		**250376**

2026-27

Peak Demand: 281 GW

At 2 PM: 37% from Solar & 45% from Coal. With 37% Solar Generation share, Solar Generation varies by 104 GW which is to be accommodated by Wind (10 GW), Hydro (10 GW) Gas (3 GW), Coal (56 GW) & demand variation (25 GW)

Expected Scenario (2031-32)									
				Evening Peak (8 PM)		Afternoon 2PM		Night- 2 AM	
Fuel Type	MW	On Bar %	MW on Bar	LF	MW delivered	LF	MW delivered	LF	MW delivered
Coal+Lig	259643	86%	223293	100%	223293	44%	98249	100%	223293
Gas	24824	40%	9930	72%	7149	42%	4170	65%	6454
Hydro	62178	80%	49742	60%	29845	36%	17907	50%	24871
Nuclear	19680	80%	15744	75%	11808	75%	11808	75%	11808
Solar	364566	70%	255196	0%	0	80%	204157	0%	0
Wind	121895	70%	85327	58%	49489	40%	34131	45%	38397
Other RE	47636	40%	19054	30%	5716	20%	3811	20%	3811
Total	**900422**		**658286**		**327301**		**374233**		**308634**

2031-32

Peak Demand: 374 GW

At 2 PM: 55% from Solar & 26% from Coal. With 55% Solar Generation share, Solar Generation varies by 204 GW which is to be accommodated by Wind (15 GW), Hydro (12 GW) Gas (3 GW), Coal (125 GW) & demand variation (42 GW). Storage Solutions to supply 10 to 20 GW

Available sources of flexible power

Source	Generation cost (USD/MWh)	Remarks	Source
Battery storage systems	122[1]	Most expensive	Battery storage systems
Pump storage systems	40 - 101[2]	Least expensive	Pump storage systems
Thermal power plants	85[3]	More expensive	Thermal power plants
Hydro power plants	68[3]	Least expensive	Hydro power plants

- ❖The generating capacity of hydroelectric stations is quite low (50 GW as on 2023)
- ❖With the anticipated 175 GW of RE Capacity by end 2022
  - ❖ Target to adapt 60% of the installed fleet of (TPP) to operate at 55% Minimum Technical Load (MTL).
- ❖It is necessary to make TPPs flexible in order to accommodate the uptake of renewable energy
- ❖KPI Target by MoP for thermal fleets to be compliant 55% MTL

	2020	2021	2022	2023	2024
Target fleet capacity (KPI)	20%	30%	45%	50%	60%
Achieved fleet capacity (KPI)	20%	30.4%	45.12%	50.29%	

References
[1]SECI, [2]SSEF, [3]IEA & NEA

Major concerns during flexible operation

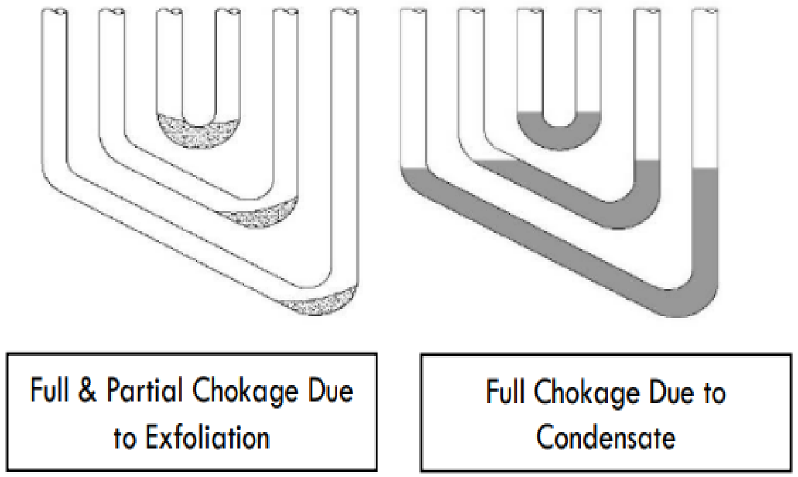
At 55% load	At 40% load
In transient load condition, drum level fluctuation due to opening of BFP recirculation valve	Flame instability
Higher APC due to marginal condition for BTG & BOP auxiliaries	Low wind box pressure hence chance of overheating in Water wall
Load increase will take longer time if one CW pump is taken out from service	Less Reliability with single FD Fan, BFP, and CEP as any tripping may cause Unit tripping
Reduction of operating coal mill takes higher time at higher ramp and quantum	Any tripping of coal mill @ 30% Load, possibility may increase of malfunctioning of control loop including Drum Level
Frequent load cycles increases fatigue loading of component and may causing Boiler tube leakage in attachment weld failure	TDBFP steam source from CRH: at low load it works good but at higher load with higher CRH pressure, control by TDBFP Aux control valve is difficult

Major concerns during flexible operation

At 55% load	At 40% load
Coal pipe choking & ash accumulation in ducts	Proper tuning of control system required especially SH temp, Drum level
Severe Deposition on Turbine Blades	Supercritical plants may operate very near to benson point. The feedwater flow control is also very challenging in this zone
Damage to Turbine Valves	The available domestic coal at some mines is having Low volatile matter (even less than 15%). It will be quite challenging to have a stable flame with low VM coal against design
Excessive Exhaust Hood spray leading to LP blade erosion	There may be a chance of a high exhaust temperature in the HP Turbine because of the low steam flow through it
	Final main steam and reheater temperatures significantly reduced at 40% load condition. There was a more than 15 degree C differential temperature between MS and HRH
	CRH supply steam to TDBFP through aux PRDS. Line during 40% load. This leads to limit value of NPSH of TDBFP, so deaerator need to be charged from aux PRDS. This may cause less RH flow through reheater coil

Best O&M Practices
Case 01: Boiler-Fatigue failure control

- Fatigue failure was experienced in the super heater tubes
- Failure occurs due to cyclic nature of the load which causes microscopic material imperfections (flaws) to grow into a macroscopic crack (initiation phase)
- Crack can then propagate to a critical size that results in structural or pressure boundary failure of the component
- Pendant tubes are arranged vertically having condensate blockage during high spray to control metal temperature



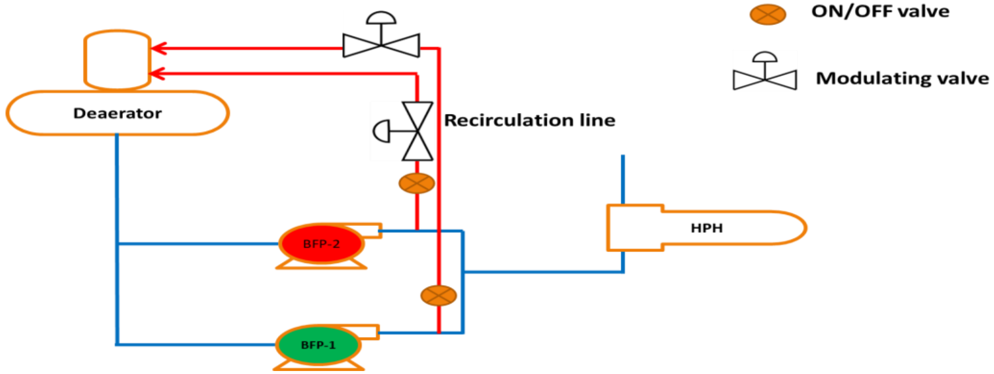
Source: EPRI

Mitigation measures

- ❖ Control loop tuning
- ❖ Optimum scheduling: Engagement with grid agency to optimize load variations
- ❖ Identifying incipient defects by cyclic Hydro test
- ❖ Dry air preservation to prevent tube pitting
- ❖ Attachment modifications as per EPRI guidelines
- ❖ Both Side Fin Welding (earlier if only one side)
- ❖ Checking of attachments by DPT
- ❖ Checking of innermost bend for cracks
- ❖ Adoption of RFET, AET, Exfoliation, Ther Flow, Thermovision test
- ❖ Implementation of Fatigue monitoring system (FMS)

Best O&M Practices
Case 02: Boiler drum level control

- Ensuring constant level in drum during the flexible operation is very difficult
- There can be issues in TDBFP pumps during load changes, when change in steam source is required (from extraction steam to CRH or Auxiliary steam)



Mitigation measures

❖ One TDBFP can supply the required amount of feed water at 40% load
❖ Manual operation of the drum level control was necessary for switching off the TDBFP only
❖ Every BFP will feature an automated starting and shutdown procedure

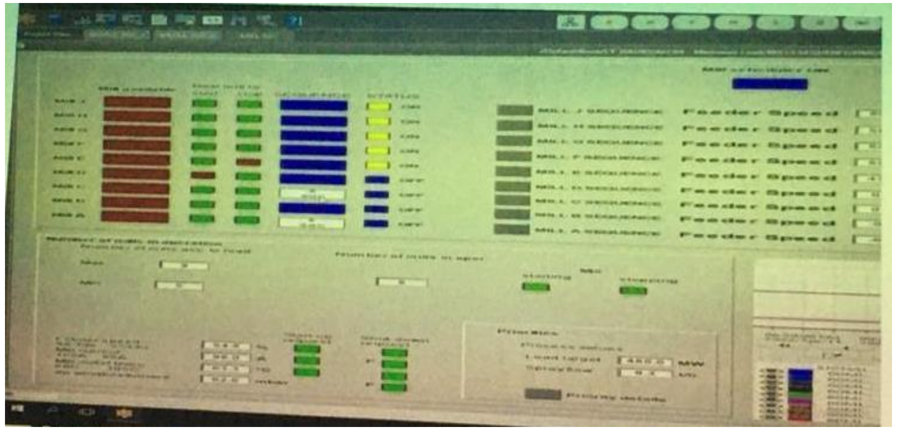
❖ Ensuring smooth operation of BFP at low load is required
❖ Modifications of BFP recirculation valve from on/off type to regulating type along with changes in operating logic is required

❖ An automated master group controller will create commands to start and stop the BFPs
❖ Primarily dictated by the intended load set-point, will also be used to bring the BFPs into and out of service in addition to the actual load

Best O&M Practices
Case 03: Auto mill scheduling

- Setting the steam generator and turbine's set points to fulfil operator or load dispatcher-specified criteria is the primary function of the unit control
- Steam pressure and unit load are the two primary factors that need to be managed by the fast-acting turbine and the slow-acting boiler
- In order to achieve completely automated load operation, burners or coal mills must be turned on and off automatically based on the load and the real number of burners and mills operating

Mitigation measures in a 500 MW units



- ❖ A coal mill scheduler operates autonomously, responding to the number of firing devices actually in use as well as the firing demand, and is subservient to the unit control
- ❖ In the event that a mill fails while in use or does not start up, the system features an automated replacement plan
- ❖ A priority for turning on and off each mill or burner is continually determined

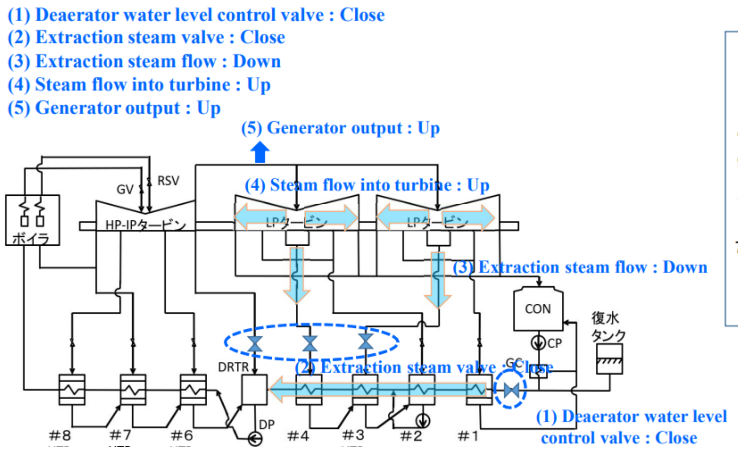
- ❖ Feeder loading more than 80%
- ❖ Average mill motor current >105 A
- ❖ Mill outlet temperature of all running mill <60 deg c
- ❖ Feeder loading less than 60%
- ❖ Average mill motor current <65 A
- ❖ Any mill outlet temperature >105 deg c

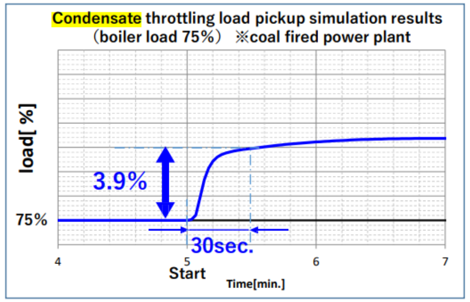
Best O&M Practices
Case 04: Condensate throttling for improved ramp rates

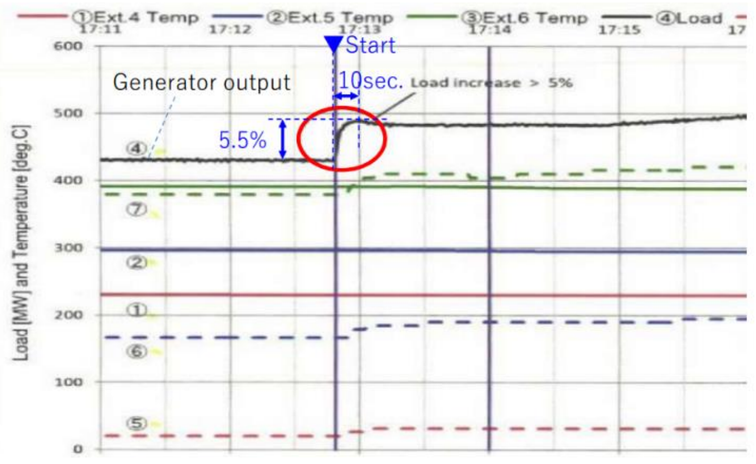
- ❖It is difficult to fulfil the quickly changing supply/demand gaps, frequently
- ❖Frequency control is not offered by renewable energy generators
- ❖Fossil fuel-fired units will continue to be required for both primary and secondary response in the future
  - ❖The steam turbine control valve (fast-acting) is required to regulate the generator power
  - ❖Power plant boiler (slow-acting) is required to regulate main steam pressure
- ❖Due to the steam generator's sluggish action, there is an imbalance in the amount of steam produced by the boiler and extracted by the turbine

Best O&M Practices
Case 04: Condensate throttling for improved ramp rates

- ❖ Condensate throttling is a tried-and-true method of primary frequency control
- ❖ Condensate flow is decreased when more power is required, generally by throttling the condensate control valve
- ❖ The feed water tank and LP heaters' extraction flow is decreased after a certain response time
- ❖ In order to react to the frequency shift, more power is produced by the turbine's leftover excess steam
- ❖ Condensate throttling at one of the NTPC Plants has allowed for a reaction time of 20 seconds for a 7% power increase at 100% load
- ❖ Condensate throttling is used to generate extra power quickly—within a minute. Typically, frequency regulation is accomplished with this extra power



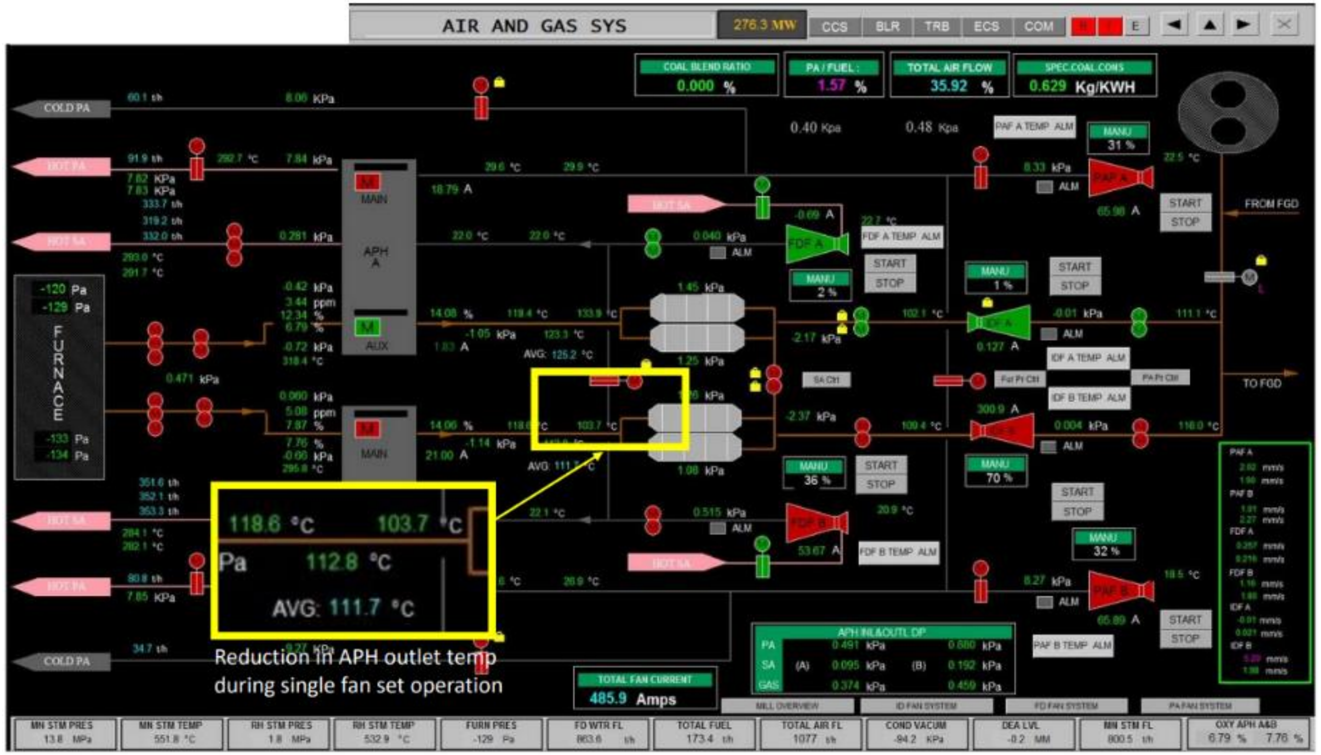




5.5% load pickup in about 10 sec at 40% load

Best O&M Practices
Case 05: Low boiler flue gas exit temperature

- ❖When the units are required to operate below 50% load, there it may required to switch off one set of fans
- ❖In one the supercritical plant, it was observed to be 104 deg c at 40% load
- ❖it may go below 100 deg c if the low load operation would have continued
- ❖APH, duct, and ESP corrosion are impacted by SO_2 emissions and sulfur concentration



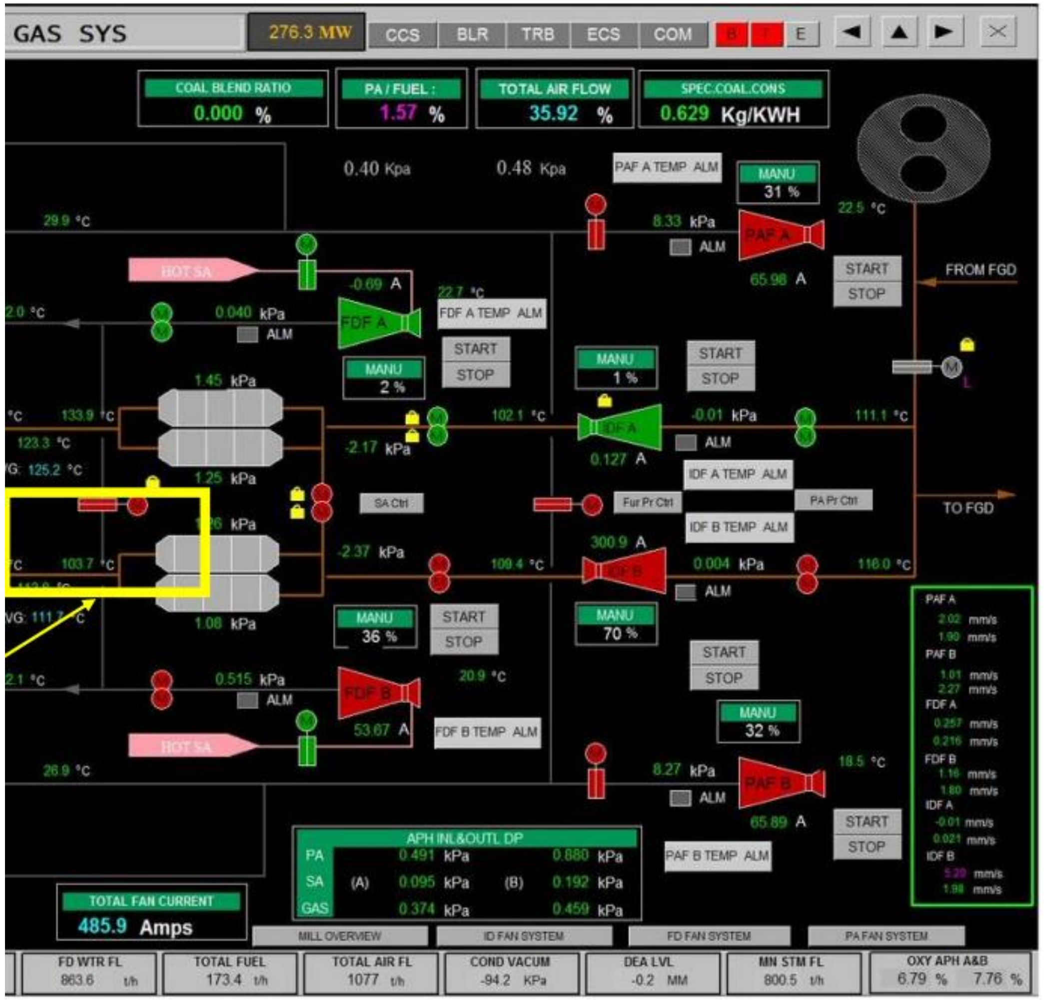
Best O&M Practices
Case 05: Low boiler flue gas exit temperature

Mitigation measures

- The steam coiled air preheater (SCAPH) should be taken into operation automatically
- For example, if the Flue gas temperature at APH outlet is maintaining less than acid dew point (say 110 deg c)
- For plants which do not have a SCAPH it is worthwhile to install it if it will be operated on cycling mode
- Air preheater baskets will need to be corrosion-resistant (enameled or corten) for future cycling
- The replacement of the cold end baskets will be more frequent
- Maintain adequate steam parameters for APH soot blowers and operate periodically, more frequently during oil firing

Best O&M Practices
Case 06: Startup / shutdown of ID / FD / PA Fans through auto sequence

- Major energy consuming auxiliaries like FD fan, PA fan, ID fan, BFP & CEP are provided with each 2 nos. (Say 2 x 60%)
- One set of fans may need to be turned off when the units must run at less than 50% load
- However, reliability is the issue at this zone if the operating equipment fails to run
- One of the most frequent issues with PA (Primary air) fans is their stalling at low load



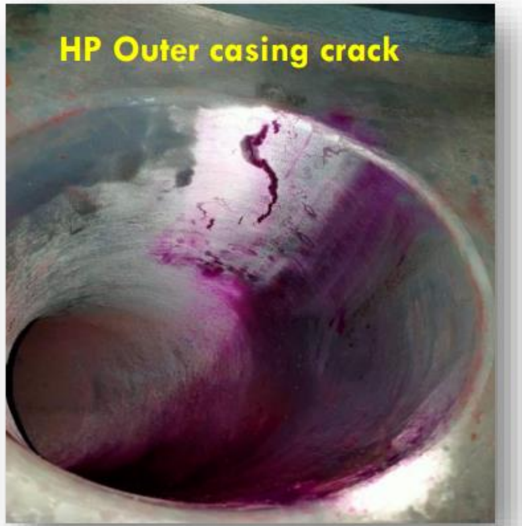
Best O&M Practices
Case 06: Startup / shutdown of ID / FD / PA Fans through auto sequence

Mitigation measures

- ❖ Fans can be taken in and out of service automatically depending on the required load
- ❖ An automatic master group controller can create start and stop orders to the fans (ID, FD, PA)
- ❖ The fans will be taken in and out of service not only by actual load, but also by predicted future load, mainly based on the target load set-point
  - ❖ ID/FD fan individual auto start/stop sequence for loading/unloading in load <300 MW (In a 490 MW plant)
  - ❖ Both PA fan auto start/stop sequence for loading/unloading in load <300 MW (In a 490 MW plant)
  - ❖ To avoid stalling issue, run as per the PA fan flow-pressure curve supplied by the OEM. Before starting PA fans ensure that air and gas dampers of PAPH are open

Best practices from plants

Challenges	High Vibration of Rotor Train.
	Increased Ovality & Decreasing hardness of Casings.
	Increased Potential of LP Blade Failure.
	Severe Deposition on Turbine Blades.
	Damage to Turbine Valves
	Excessive Exhaust Hood spray leading to LP blade erosion



Challenges	Actions
HP casing crack	RLA of casing every 6 yrs (13 yrs). Replacement of casings & rotor in 15 yrs (25 Yrs)
Chance of LP blade crack	Frequent inspection- 2 yrs (4 Yrs) , MPI- In-situ PAUT- 2 yrs (4 yrs)
LP Turbine blade fluttering	Mistuning of free standing blades, Installation of BVMS system
High vibration of rotor trains	Turbine Bearings inspection in every 2 yrs (4 yrs).
Increasing ovality & reduction in hardness of Casing	More frequent replacement of casings, rotors.
Damages of steam valve internals	Frequent inspection & maintenance

High metal temperature of blading, seals, Turbine rotating and stationary structures as well as Cold Reheat Piping => excessive distortion and/or creep damage (Casing and Rotor)

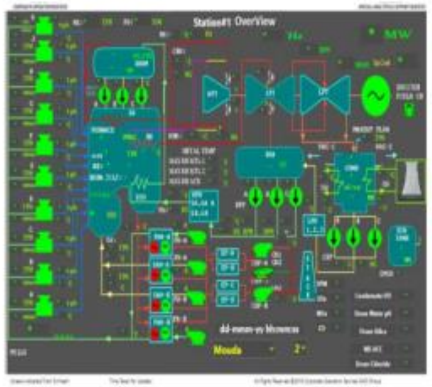
Best practices from plants

Area	Challenges	Mitigation Measures
Operations	• High Ash deposition in ducts. • Soot blowing difficulty, Need > 70% load for 3 hr in a day • Flame disturbance tripping on Coal Quality variations • Higher chances of outage due to single Aux Eqp approach. • Chemistry parameter variation (PH, Conductivity, DO etc)	• Unlearn and Relearn Strategy • New Operational Practices
Controls	• Load Ramps • AGC • RGMO / Primary Frequency Response	• Loop Tuning • Interventions through Policy advocacy for changes in procedures

Variations in coal quality

Combustion and Flame Stability

Ash Deposition at Low Loads



Tuning - Control loops

Best practices from plants

Best Practices

- In case of Flame instability, adjust SADC to optimise air flow. Maintain SA/PA ratio. Check healthiness of coal scanners for its performance improvement.
- The reheat steam temperature should be controlled by Burner Tilting as part of the automated control.
- The steam coiled air preheater (SCAPH) should be taken into operation automatically .In case Flue gas temperature at APH outlet is maintaining less than acid dew point, i.e. 110 degrees.
- An online coal pipe metal temperature provides detailed information about the coal distribution pipe blockage and necessary action may be done accordingly.

UPGRADES / REPLACEMENTS REQUIRED AT MACRO LEVEL

- ❖Boiler Fatigue Monitoring system (BFMS)
- ❖Regulating BFP Recirculation valves with fast opening facility for effective control of drum level
- ❖Automated Milling System – Auto Mill Scheduler
- ❖Startup / shutdown of ID / FD / PA Fans through auto sequence
- ❖Single drive operation (Higher Efficiency but Lower Reliability)
- ❖Condensate throttling for improved ramp rates.
- ❖Equivalent Operating Hours (EOH) for Turbine
- ❖Unit Response Optimisation (fine tuning of auto loops
- ❖Intelligent Proactive Process control (MS HRH temp, Flue gas temp)

To sum up…

- ❖The coal-fired power units shall remain the main source of flexible power
- ❖Flexible operations for coal power plants are technically feasible by upgradation, tuning of controls, etc.,
- ❖The pilot tests conducted at various plants is the proof that Indian plants are capable to flex
- ❖ Lower load operation (40%) shall require measures like
  - ❖automation/optimization of controls,
  - ❖proper flame detection systems,
  - ❖efficient measures to optimize combustion process,
  - ❖stable minimum mill operation,
  - ❖reassessment of O&M practices, etc.

Thank you

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