

U.P. RAJYA VIDYUT UTPADAN NIGAM LIMITED

(U.P. Government Undertaking)



1X660 MW 'E' TPS Harduaganj Thermal Power Project

◀ “FLEXIBLE OPERATION STATUS” ▶



RELIABLE
GENERATION



SAFE & EFFICIENT
OPERATIONS



ENVIRONMENT
RESPONSIBLE



POWERING
PROGRESS

J K Sirsaiya Rohit Kaithwar
EE (C&IMD) AE(Operation)
1x660 M.W, HTPS

Flexible Operation & Challenges



“Introduction”



FLEXIBILITY

Adapt operations to
changing conditions



PERFORMANCE

Optimize output and
improve efficiency



CHALLENGES

Address operational
and technical issues



INSIGHTS

Gain knowledge for
better decision making



SOLUTIONS

Implement strategies
for sustainable success

Flexible Operation – CEA 2023 Guidelines

- ▶ As per the CEA regulation 2023 flexible operation capabilities should be adhered by all running and upcoming coal based thermal power plant as per below table:

S. No.	Load range (% of installed capacity)	Ramp rate (MW/min)
1.	100 - 70 %	3 %
2.	70 - 55 %	2 %
3.	55 - 40 %	1 %



Flexible Operation – Introduction

PRESENT POWER SCENARIO

CURRENT LANDSCAPE OF POWER GENERATION ⚡



THERMAL POWER PLANT



Min Plant back down
55–70%



Some compensation
HR, APC, SOC loss



Ramp rate
< 1%



WIDEGAP

Peak-nonpeak,
weekday-weekend,
seasonal demand



COAL PLANT IS BACKBONE

of power generation with
70–75% power share in
total generation.



NO CAPACITY ADDITION

expected in Gas based
power plant.



LIMITED CAPACITY RISE

in Hydro, PSH & Nuclear,
though identified as
thrust areas.



BESS (BATTERY ENERGY STORAGE SYSTEM)

on major commercial scale
expected post 2026–27



Coal continues to be
the cornerstone of
power generation.



Demand pattern
is highly variable
across time.



Operational flexibility
is constrained in
thermal assets.



System balancing
remains a key
challenge.



Energy storage will play
a critical role in future
power system.

Flexible Operation – Introduction

WHY COAL PLANTS MUST BE FLEXIBLE

Flexibility Today, Reliability Tomorrow



FLEXIBLE COAL PLANTS

Powering a reliable and sustainable future.

01



ADJUSTING POWER OUTPUT RAPIDLY to balance the intermittency of renewable energy sources.

02



BALANCING THE GRID in the Era of renewable energy.

03



TRANSITION FROM BASE LOAD TO FALL LOAD OPERATIONS.

04



MAINTAIN GRID STABILITY and prevent power disturbance.

05



MINIMUM STABLE LOAD.

06



RAMP RATES (MW/MIN OR % PER MINUTE) operation.

07



FLEXIBILITY ALLOW THE GRID to absorb more green energy rather than shutting it down.

08



CYCLIC OPERATION: Ability to handle frequent start up and shut down without severely degrading.



FLEXIBILITY IS THE KEY to a reliable, resilient and renewable-ready grid.



RENEWABLE ENERGY

+



FLEXIBLE COAL PLANTS

=



RELIABLE GRID

=



SUSTAINABLE FUTURE

Flexible Operation – Introduction



EMERGING SCENARIOS

— FOR FLEXIBLE POWER PLANT OPERATION —



1 FREQUENT LOAD VARIATION

Load cycles between minimum to full load frequently.



2 LOW-LOAD OPERATION

Prolong unit operation at minimum load level.



3 WEEKEND SHUTDOWN

Unit shut down during week-end period & restart at beginning of week.



4 TWO-SHIFT OPERATION

Plant to shut down & restart every day to balance solar power.



5 LONG DOWNTIME (E.G., SEASONAL)

Longer period s/d involving preservation & cold start.



6 FLEXIBLE COAL POWER GENERATION TO ABSORB RE POWER GENERATION

EXTENT TO WHICH GENERATION CAN BE INCREASED/REDUCED AT FASTER RATE FOR FEW MINUTES TO SEVERAL HOURS FOR ANY NUMBER OF TIME



ENHANCED FLEXIBILITY

Quick ramp up & carry down capacity



IMPROVED RELIABILITY

Stable operation across varying conditions



OPTIMIZED EFFICIENCY

Operate at optimal load levels



SUPPORTS CLEAN ENERGY TRANSITION

Balances intermittent renewable energy



Flexible Operation



“Operation in 1X660 MW HTPS”



Flexible Operation : Testing in Harduaganj (1X660 MW)






- Ramp rate testing on 1.5%, 1.7%, 3% and 5% was done in Harduaganj (1X660MW) by EPC OEM M/s TJPS between 27th March 2024 to 6th April 2024 and 21st May 2024 to 28th May 2024.

S. No.	Ramp Rate Tested (%/min)	Unit Details	Tested By	Test Period
1.	1.5 %	Harduaganj TPS (1x660 MW)	EPC OEM – M/s TJPS	27 March 2024 – 6 April 2024
2.	1.7 %			
3.	3 %			21 May 2024 – 28 May 2024
4.	5 %			



Flexible Operation : Testing in Harduaganj (1X660 MW)

- Challenges to maintain the critical parameters during the Ramp rate test :

S. No.	Parameter		Allowable Deviation
1.	Throttle pressure deviation		+/- 2 kg/cm ²
2.	Flue gas O ₂ deviation (%O ₂)		+/- 0.4 % O ₂
3.	Furnace Pressure deviation		+/- 8 mmWC
4.	SH Temp deviation (degC)		+/- 5 °C
5.	RH Temp deviation (degC)		+/- 5 °C



Ramp Rate Test Monitoring Checklist



01

UNIT OPERATION CHECKS

- ✓ Machine in CMC with all auto loops in service.
- ✓ Sliding pressure mode operation.
- ✓ Stable load achievement at 90/75/55% unit load.



02

RAMP PERFORMANCE MONITORING

- ✓ Actual ramp rate achieved.
- ✓ Time taken to stabilize load.
- ✓ Load response characteristics.



03

EQUIPMENT & RELIABILITY MONITORING

- ✓ Boiler metal temperature excursion at 90/75/55% unit load.
- ✓ Turbine & generator vibration.
- ✓ Steam source from Aux-steam for TBFP.



TEMPERATURE
MONITORING



VIBRATION
MONITORING



AUX-STEAM
FOR TBFP



Coal Properties from Operating Coal Feeders during Ramp up/down Testing

OPERATING FEEDER - MIXED COAL PROXIMATE ANALYSIS REPORT (CLCS Tuning)

S. N.	Date of sampling	Time of sampling (Hrs)	Feeder Name	T.M. %	A.R.B			G.C.V (A.R.B) Kcal/kg	Fuel Ratio
					ASH %	V.M. %	F.C. %		
1	21-May-24	11:15	Composite Coal Sample (A, B, C, D, E, H)	6.02	43.77	17.36	32.85	3771	1.89
2	21-May-24	15:15	Composite Coal Sample (A, B, C, D, E)	5.60	42.07	16.24	36.09	4101	2.22
3	22-May-24	11:55	Composite Coal Sample (A, C, D, E, F, H)	11.58	39.04	16.6	32.78	3568	1.97
4	23-May-24	11:45	Composite Coal Sample (A, B, C, D, E, G, H)	12.11	40.22	18.59	29.08	3661	1.56
5	24-May-24	11:45	Composite Coal Sample (A, B, C, D, E, G)	5.99	38.44	16.97	38.6	4460	2.27
6	25-May-24	10:45	Composite Coal Sample (A, B, C, D, E, G)	6.66	39.7	16.78	36.86	4268	2.20
7	28-May-24	10:15	Composite Coal Sample (A, B, C, D, E, G)	6.37	37.69	16.93	39.01	4512	2.30

Coal data comparison during Ramp up/down Testing

	Unit	Best Coal	Design Coal	Worst Coal	Coal during CLCS tuning
Calorific Value	kCal/ kg	4200	3700	3200	3568 – 4512
Fixed Carbon	%	30	28.5	26	29.08 – 39.01
Volatile Matter	%	27	26	19	16.24 – 18.59
Fuel Ratio (FC/ VM)	-	1.11	1.09	1.36	1.56 – 2.30

Ramp up/down Test result for 1.5%/min

RAMP RATE (REFERENCE VALUE) $\pm 1.5\%$, -1.5%

MAXIMUM DEVIATION OF OUTPUT PARAMETERS FROM SET POINT

Test Description	Date & Time	Load Change (MW)	Load rate of change (1.5% MIN)	Bottle Pressure Deviation (Kg/cm ²)	Fls Gas O2 Deviation (%O2)	Furnace Pressure Deviation (mmHG)	SI Temp Deviation (°C)		BI Temp Deviation (°C)		M/I in Service	Remark
							Left	Right	Left	Right		
 1.5% MW /min Ramp up for 15 min	3rd April 2024 10:45 to 11:02	495 MW to 460 MW	Criteria	222.60 ~ 271.00	2.37 ~ 3.37	-23 ~ -1.20	588 ~ 598	588 ~ 598	584 ~ 594	585 ~ 596	MII A, B, C D, E, H	Refer Clause No. 7 for the reason related to parameter which are out of range
			+/-2	+/-2	-1.5	+/-8	+/-5	+/-5	+/-5	+/-5		
			Set Value	225.60 ~ 269.00	2.77 ~ 3.77	-10.80	592.98	592.98	588.96	591.02		
			Process Value Max.	268.34	5.09	0.53	595.55	596.67	598.52	594.05		
			Process Value Min.	223.21	3.17	-19.85	586.50	584.08	578.98	578.05		
			Deviation - Max.	45.74	2.31	11.32	-6.57	-3.69	-9.56	-3.03		
			Judgement	Within range	Out of range	Within range	Out of range	Within range	Out of range	Within range		
			Deviation - Min.	-2.39	0.40	-9.05	-6.48	-8.89	-9.98	-12.97		
Judgement	Within range	Within range	Within range	Out of range	Out of range	Out of range	Out of range					
 1.5% MW /min Ramp down for 15 min	3rd April 2024 12:15 to 12:33	660 MW to 495 MW	Criteria	223.83 ~ 227.83	2.37 ~ 3.17	-19 ~ -2.80	583 ~ 598	588 ~ 598	590 ~ 600	600	MII A, B, C D, E	Refer Clause No. 7 for the reason related to parameter which are out of range
			+/-2	+/-2	+/-0.4	+/-8	+/-5	+/-5	+/-5	+/-5		
			Set Value	225.83 ~ 226.00	2.77 ~ 3.57	-10.80	592.98	592.98	593.27	595.33		
			Process Value Max.	272.58	5.29	-1.08	595.65	592.37	591.15	579.72		
			Process Value Min.	223.96	3.17	-19.88	589.80	591.20	583.48	568.63		
			Deviation - Max.	46.75	2.98	9.72	2.67	3.39	-2.12	-15.61		
			Judgement	Out of range	Out of range	Out of range	Within range	Within range	Within range	Out of range		
			Deviation - Min.	-1.87	0.40	-9.08	-3.18	-1.78	-8.79	-28.70		
Judgement	Within range	Within range	Out of range	Within range	Within range	Out of range	Out of range					

Ramp up/down Test result for 1.7%/min

RAMP RATE (REFERENCE VALUE) $\pm 1.7\%$, -1.7%

MAXIMUM DEVIATION OF OUTPUT PARAMETERS FROM SET POINT

Test Description Ramp Up/Down Test	Date & Time	Load Change (MW)	Load Rate of change (1.5% MIN)	Throttle Pressure Deviation (Kgf/cm ²)	Flue Gas O ₂ Deviation (%O ₂)	Furnace Pressure Deviation (mmWC)	SH Temp Deviation (°C)		RH Temp Deviation (°C)		M/I in Service	Remark
							Left	Right	Left	Right		
 1.7% MW/min Ramp up for 15 min	4th April 2024 10:45 to 11:02	495 MW to 660 MW	 Criteria	222.60 ~ 271.00	3.18 ~ 4.18	-23 ~ -1.20	588 ~ 598	588 ~ 598	585 ~ 595	587 ~ 597	MIA, B, C D, E, W	Refer Clause No. 7 for the reason related to parameter which are out of range
				+/-2	0.6/0.4	+/-8	+/-5	+/-5	+/-5	+/-5		
			 Set Value	225.60 ~ 269.00	3.58 ~ 4.58	-19.80	592.98	592.98	589.87	591.93		
			 Process Value Max.	267.29	5.21	6.05	589.90	595.60	602.63	590.35		
			 Process Value Min.	222.67	3.98	-21.78	562.45	575.37	582.27	572.47		
			 Deviation - Max.	44.69	1.63	16.85	3.08	-2.62	-12.76	1.58		
			 Judgement	Within range	Out of range	Out of range	Within range	Within range	Out of range	Within range		
			 Deviation - Min.	-2.92	0.40	-19.98	-30.53	-17.61	-7.60	-19.43		
 Judgement	Within range	Within range	Out of range	Out of range	Out of range	Out of range	Out of range					
 1.7% MW/min Ramp down for 15 min	4th April 2024 12:15 to 12:33	660 MW to 495 MW	 Criteria	223.99 ~ 227.99	3.18 ~ 3.98	-19 ~ -2.80	588 ~ 598	588 ~ 598	589 ~ 599	591 ~ 601	MIA, B, C D, E	Refer Clause No. 7 for the reason related to parameter which are out of range
				+/-2	0.6/0.4	+/-8	+/-5	+/-5	+/-5	+/-5		
			 Set Value	225.99 ~ 226.25	3.58 ~ 4.38	-19.80	592.98	592.96	593.96	596.02		
			 Process Value Max.	271.27	4.83	-1.38	580.55	587.47	588.10	581.00		
			 Process Value Min.	224.77	3.98	-23.75	569.70	589.07	577.62	568.83		
			 Deviation - Max.	45.28	3.25	9.42	-12.43	4.49	-5.86	-15.02		
			 Judgement	Out of range	Out of range	Out of range	Out of range	Within range	Out of range	Out of range		
			 Deviation - Min.	-1.23	0.40	-12.95	-33.28	-3.91	-16.34	-27.19		
 Judgement	Within range	Within range	Out of range	Out of range	Within range	Out of range	Out of range					

Ramp up/down Test result for 3%/min

RAMP RATE (REFERENCE VALUE) $\pm 3\%$, -3%




MAXIMUM DEVIATION OF OUTPUT PARAMETERS FROM SET POINT

Test Description	Date & Time	Load Change (MW)	Load Rate of change (3% MW/MIN)	Throttle Pressure Deviation (Kg/cm ²)	Flue Gas O ₂ Deviation (%O ₂)	Furnace Pressure Deviation (mmWC)	Silt Temp Deviation (°C)		RH Temp Deviation (°C)	
							Left	Right	Left	Right
 3% MW /min Ramp up for 5 min	21st May 2024 11:15 to 11:21	 495 MW to 506 MW	Criteria	222.60 - 272.00 +/-3	3.11 - 4.75 0.6/-0.4	-23 - 1.20 +/-12	583 - 601 +/-8	583 - 599 +/-8	584 - 600 +/-8	584 - 600 +/-8
			Set Value	225.60 - 269.00	3.51 - 4.15	-10.80	593.02	591.00	592.21	592.18
			Process Value Max.	246.68	4.11	-0.68	594.85	594.43	600.13	591.83
			Process Value Min.	219.49	2.91	-18.95	587.90	590.40	591.33	582.03
			Deviation - Max.	24.08	0.59	10.13	-1.83	-3.44	-7.93	0.35
			Judgement	Within range	Within range	Within range	Within range	Within range	Within range	Within range
			Deviation - Min.	-6.11	-0.60	-8.15	-5.12	-0.60	-0.87	-10.15
			Judgement	Out of range	Out of range	Within range	Within range	Within range	Within range	Out of range
 3% MW /min Ramp down for 5 min	21st May 2024 12:30 to 12:37	 594 MW to 495 MW	Criteria	222.60 - 272.00 +/-3	3.11 - 4.75 0.6/-0.4	-23 - 1.20 +/-12	583 - 601 +/-8	583 - 599 +/-8	588 - 604 +/-8	587 - 603 +/-8
			Set Value	225.60 - 269.00	3.51 - 4.15	-10.80	593.02	591.00	595.50	595.48
			Process Value Max.	271.97	5.09	5.08	595.25	595.17	589.03	583.90
			Process Value Min.	226.65	3.39	-22.83	588.20	588.12	574.40	575.53
			Deviation - Max.	46.37	3.39	15.88	2.23	4.17	-6.47	-11.58
			Judgement	Within range	Out of range	Out of range	Within range	Within range	Within range	Out of range
			Deviation - Min.	1.05	-0.13	-12.02	-4.82	-2.88	-21.10	-19.95
			Judgement	Within range	Within range	Out of range	Within range	Within range	Out of range	Out of range

Ramp up/down Test result for 5%/min

RAMP RATE (REFERENCE VALUE) +5%, -5%

MAXIMUM DEVIATION OF OUTPUT PARAMETERS FROM SET POINT

Test Description	Date & Time	Load Change (MW)	Load Rate of change (5% MIN)	Throttle Pressure Deviation (Kg/cm ²)	Flue Gas O ₂ Deviation (%O ₂)	Furnace Pressure Deviation (mmWC)	SH Temp Deviation (°C)		RH Temp Deviation (°C)	
							Left	Right	Left	Right
 5% MW /min Ramp up for 5 min	 28th May 2024 09:00 to 09:07	 396 MW to 495 MW	 Criteria	179.40 ~ 228.60 +/-3	3.73 ~ 5.72 0.8/-0.4	-22 ~ 2.00 +/-12	583 ~ 603 +/-10	581 ~ 601 +/-10	584 ~ 604 +/-10	584 ~ 604 +/-10
			 Set Value	182.40 ~ 225.60	4.13 ~ 4.92	-10.00	593.02	591.00	594.07	594.05
			 Process Value Max.	201.60	5.00	1.80	592.75	597.78	605.85	595.23
			 Process Value Min.	173.75	2.64	-18.58	588.50	590.93	594.00	580.83
			 Deviation - Max.	22.20	0.87	11.80	0.27	-6.79	-11.78	-1.18
			 Judgement	Within range	Within range	Within range	Within range	Within range	Out of range	Within range
			 Deviation - Min.	-8.65	-1.49	-8.58	-4.52	-0.06	-0.07	-13.22
			 Judgement	Out of range	Out of range	Within range	Within range	Within range	Within range	Out of range
 5% MW /min Ramp down for 5 min	 28th May 2024 11:45 to 12:07	 495 MW to 396 MW	 Criteria	179.40 ~ 228.60 +/-3	3.73 ~ 5.72 0.8/-0.4	-22 ~ 2.00 +/-12	583 ~ 603 +/-10	581 ~ 601 +/-10	584 ~ 604 +/-10	585 ~ 605 +/-10
			 Set Value	182.40 ~ 225.60	4.13 ~ 4.92	-10.00	593.02	591.00	595.50	595.48
			 Process Value Max.	231.31	6.46	8.33	600.20	594.33	590.48	574.95
			 Process Value Min.	182.09	3.84	-24.68	578.65	580.28	550.42	555.27
			 Deviation - Max.	48.91	3.84	18.33	7.18	3.34	-5.02	-20.53
			 Judgement	Out of range	Out of range	Out of range	Within range	Within range	Within range	Out of range
			 Deviation - Min.	-0.31	-0.29	-14.68	-14.37	-10.71	-45.08	-40.21
			 Judgement	Within range	Within range	Out of range	Out of range	Out of range	Out of range	Out of range

Flexible Operation : Testing in Harduaganj (1X660 MW)

HAU2_Ramp Rate Test Result during CLCS Tuning

Sr. No.	Test Date	Time		Load Ramp up-down	Step Load Change (%)	Ramp Rate Selected (%MW/min)	Ramp Rate Achieved (%MW/min)
		From	To				
Ramp up							
1	3-Apr-24	9:00:03	9:09:54	396 MW to 495 MW	15	1.5	1.52
		10:45:02	11:01:41	495 MW to 660 MW	25		1.50
2	4-Apr-24	9:00:03	9:09:07	396 MW to 495 MW	15	1.7	1.65
		10:45:01	10:59:51	495 MW to 660 MW	25		1.69
3	21-May-24	9:30:04	9:36:04	396 MW to 495 MW	15	3	2.50
		11:15:03	11:20:55	495 MW to 594 MW	15		2.56
4	22-May-24	9:00:00	9:06:11	396 MW to 495 MW	15	3	2.43
		11:45:07	11:50:57	495 MW to 594 MW	15		2.57
Ramp Down							
5	3-Apr-24	12:15:03	12:32:45	660 MW to 495 MW	25	1.5	1.41
		14:15:29	14:26:24	495 MW to 396 MW	15		1.37
6	4-Apr-24	12:15:19	12:30:54	660 MW to 495 MW	25	1.7	1.60
		14:44:05	14:53:25	495 MW to 396 MW	15		1.61
7	21-May-24	12:30:03	12:36:53	594 MW to 495 MW	15	3	2.20
		14:59:51	15:07:15	495 MW to 396 MW	15		2.03
8	22-May-24	13:15:05	13:22:05	594 MW to 495 MW	15	3	2.14
		15:44:55	15:52:20	495 MW to 396 MW	15		2.02

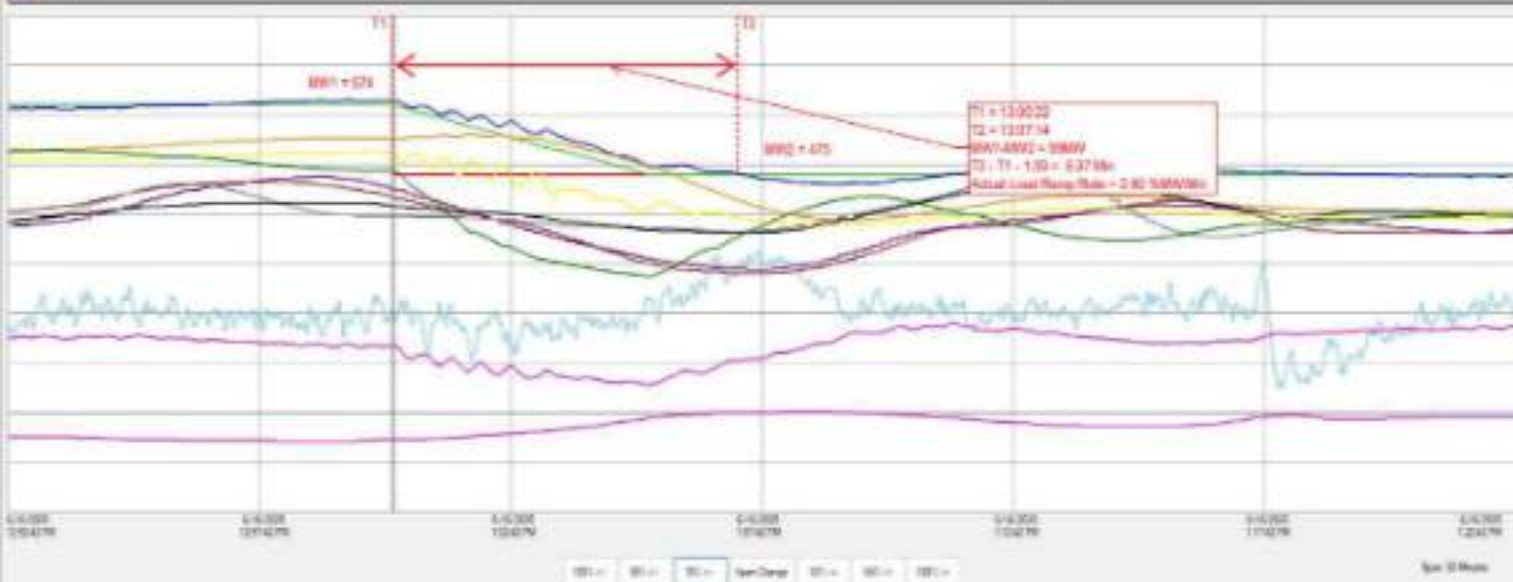
Ramp Up and Down Test Summary

Sr. No.	Test Date	Time		Load Ramp up-down	Ramp Rate Selected (%MW/min)	Ramp Rate Achieved (%MW/min)
		From	To			
3% Ramp Up and Down Test						
1	16-Jun-25	12:26:45	12:32:39	474 MW to 574 MW	3	3.44
		13:00:22	13:07:14	574 MW to 475 MW		2.80
5% Ramp Up and Down Test						
2	17-Jun-25	11:45:03	11:50:58	499 MW to 598 MW	5	3.40
		12:15:03	12:21:40	598 MW to 499 MW		2.93

Flexible Operation : Trend Data (1X660 MW)

3% MW/min Ramp down Test from 574 MW to 475 MW 16th June 2025

No.	Tag	Description	Unit	Type	Range (%)	Range (min)
1	1000000000	SGD TR TARGET	574 MW	Target	574	574
2	1000000000	SGD CURRENT TARGET	574 MW	Target	574	574
3	1000000000	SGD LOAD	574 MW	Target	574	574
4	1000000000	SGD PWR	574 MW	Target	574	574
5	1000000000	SGD TRIP CDS TV	574 MW	Target	574	574
6	1000000000	SGD TRIP CDS TV	574 MW	Target	574	574
7	1000000000	SGD TRIP CDS TV	574 MW	Target	574	574
8	1000000000	SGD TRIP CDS TV	574 MW	Target	574	574
9	1000000000	SGD TRIP CDS TV	574 MW	Target	574	574
10	1000000000	SGD TRIP CDS TV	574 MW	Target	574	574
11	1000000000	SGD TRIP CDS TV	574 MW	Target	574	574
12	1000000000	SGD TRIP CDS TV	574 MW	Target	574	574
13	1000000000	SGD TRIP CDS TV	574 MW	Target	574	574
14	1000000000	SGD TRIP CDS TV	574 MW	Target	574	574
15	1000000000	SGD TRIP CDS TV	574 MW	Target	574	574
16	1000000000	SGD TRIP CDS TV	574 MW	Target	574	574
17	1000000000	SGD TRIP CDS TV	574 MW	Target	574	574
18	1000000000	SGD TRIP CDS TV	574 MW	Target	574	574
19	1000000000	SGD TRIP CDS TV	574 MW	Target	574	574
20	1000000000	SGD TRIP CDS TV	574 MW	Target	574	574

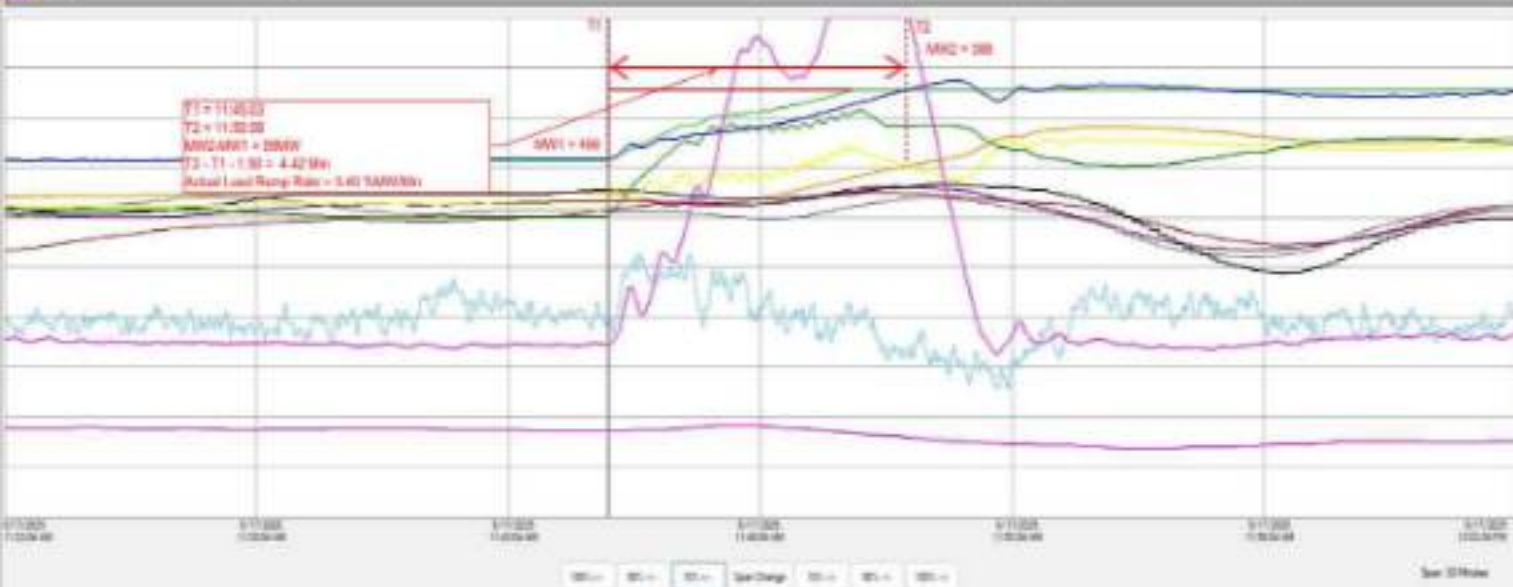


Flexible Operation : Trend Data (1X660 MW)

Plant Name: 6173207100040

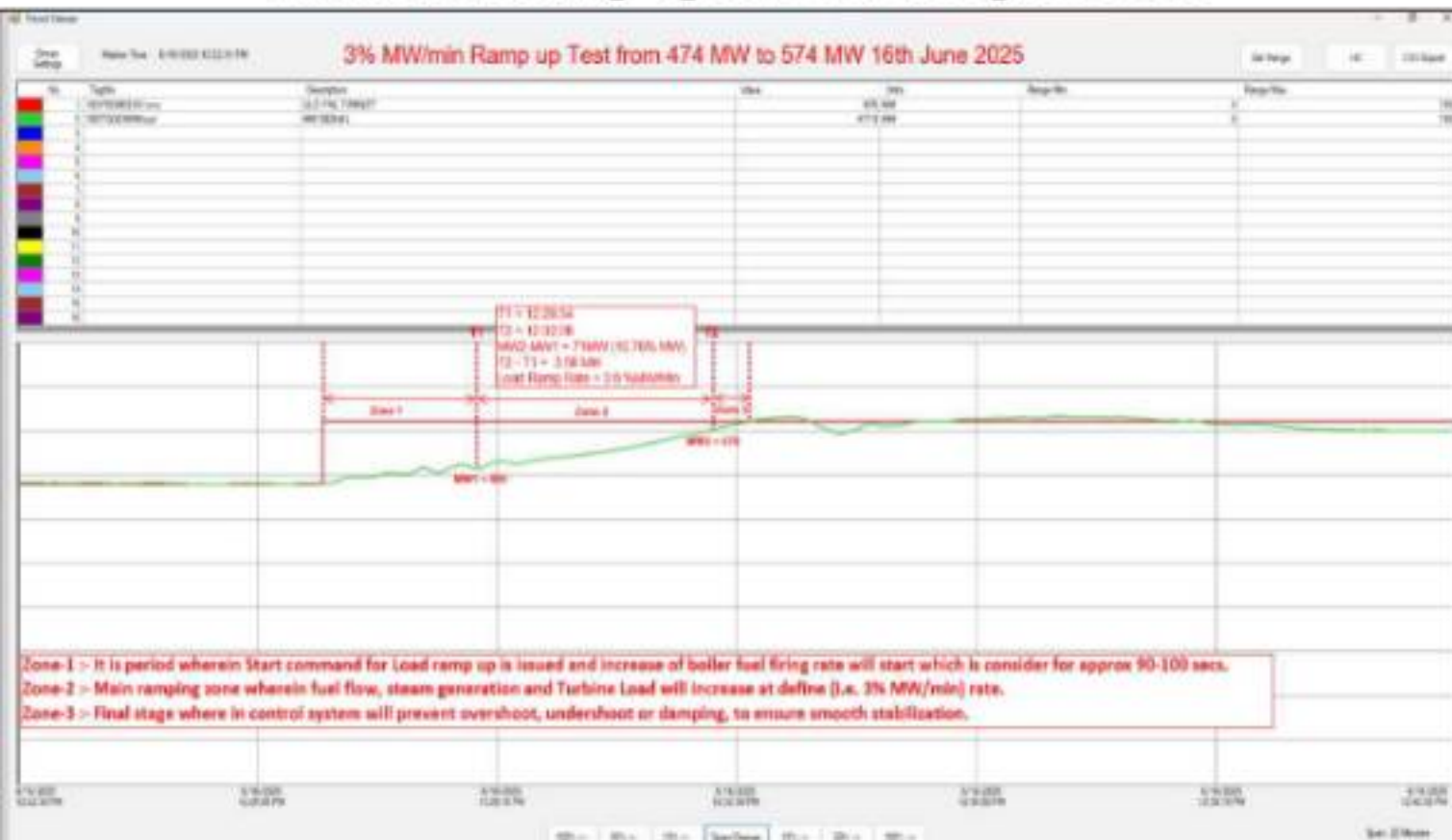
5% MW/min Ramp up Test from 499 MW to 598 MW 17th June 2025

No	Tag	Description	Unit	Low	High	Alarm
1	6173207100040	503 FV THERM	503 FV	503 FV	503 FV	503 FV
2	6173207100040	503 CURRENT WHEEL	503 CUR	503 CUR	503 CUR	503 CUR
3	6173207100040	503 CLAMP	503 CLAMP	503 CLAMP	503 CLAMP	503 CLAMP
4	6173207100040	503 FEED	503 FEED	503 FEED	503 FEED	503 FEED
5	6173207100040	503 THERM IN	503 THERM IN	503 THERM IN	503 THERM IN	503 THERM IN
6	6173207100040	503 FV REGULATED IN	503 FV	503 FV	503 FV	503 FV
7	6173207100040	503 FV REGULATED IN	503 FV	503 FV	503 FV	503 FV
8	6173207100040	503 FV REGULATED IN	503 FV	503 FV	503 FV	503 FV
9	6173207100040	503 FV REGULATED IN	503 FV	503 FV	503 FV	503 FV
10	6173207100040	503 FV REGULATED IN	503 FV	503 FV	503 FV	503 FV
11	6173207100040	503 FV REGULATED IN	503 FV	503 FV	503 FV	503 FV
12	6173207100040	503 FV REGULATED IN	503 FV	503 FV	503 FV	503 FV
13	6173207100040	503 FV REGULATED IN	503 FV	503 FV	503 FV	503 FV
14						
15						
16						



Flexible Operation : Trend Data (1X660 MW)

Saturated Ramp up rate on designed coal



Flexible Operation : Trend Data (1X660 MW)

Saturated Ramp down rate on designed coal



Challenges in Flexible Operation



“Effect on Ramp rate due to various Coal parameters”



Attributes of Flexible Power Plant Operation Affecting Plant Performance



- Thermal plant particularly coal plants were inherently designed for **base load operation**.



- Flexible operation with **low grade coal** poses typical requirements.

Requirements of flexible operation

01



Stable operation at unit MPL

02



Unit reliability during wide load variation

03



Faster load ramp up / down

04



Efficient & Cost competitive flexible operation

05



Higher **startups**/shutdowns, load cycles

06



Mitigating long term damage



Attributes of Flexible Power Plant Operation Affecting Plant Performance

FLEXIBILIZATION IMPACT:

“From energy efficient base load stable operation to cyclic inefficient flexible operation with poor grade coal.”



TRIO CHALLENGES IN FLEXIBLE OPERATION



01 UNIT STABILITY AT PART LOAD/ LOAD VARIATION



02 EFFICIENCY MANAGEMENT AT PART LOAD



03 LONG-TERM DAMAGE MITIGATION



Challenges in Achieving Flexible Operation



Inferior quality of coal:



- **Combustion Stability** at low loads & during load variation



- Change from **designed coal** / wide **variation in coal quality**



- **High moisture, high ash & low VM** most challenging for flexible operation



- High moisture has a flame quenching tendency & **poor Boiler efficiency**



- Challenging to achieve combustion stability with **low VM coal**



- High Ash content leading to higher components erosion



The Flexibility Challenge

SLOW BURNING OF HIGH RANK COAL WITH HIGH FUEL RATIO (FC/VM)



BURNOUT EFFICIENCY

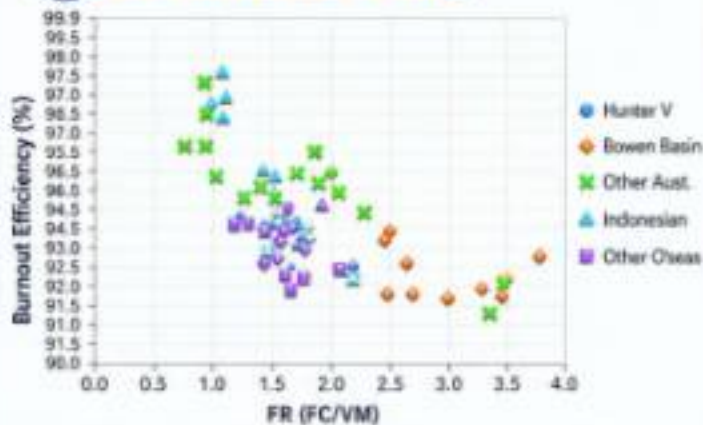


Figure-1: Burnout efficiency vs fuel ratio of coal

WHY IT MATTERS



Understanding the impact of high FC/VM ratio helps optimize combustion, improve efficiency, and ensure stable boiler operation.

KEY TAKEAWAYS



Coal properties strongly influence boiler response.



High FC/VM ratio causes slower combustion.



Low volatile matter delays ignition and burnout.



Slow heat release reduces ramp responsiveness.



Indian bituminous coal has high ash and inertinite content.

01



Delayed char combustion affects heat pickup.

02



Burnout efficiency decreases with higher fuel ratio.

03



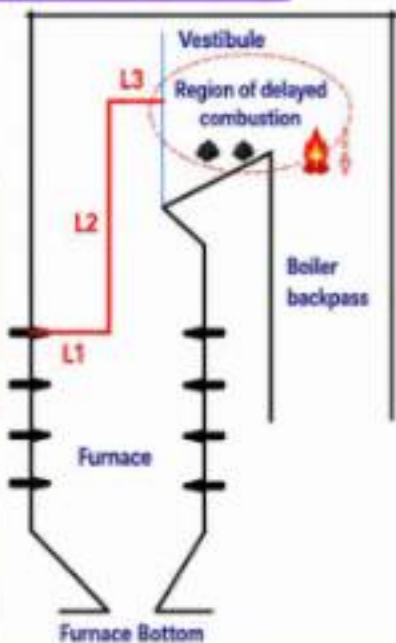
Boiler response becomes slower during load changes.

04



DELAYED COMBUSTION OF CHAR PARTICLES ON HIGH FUEL RATIO AND LOWER BURNOUT EFFICIENCY

BOILER FURNACE SCHEMATIC



DISTANCES

- L1:** Lower furnace zone (primary combustion)
- L2:** Upper furnace zone (secondary combustion)
- L3:** Vestibule region (horizontal pass)

KEY

- Unburnt char particles
- Delayed combustion



1. RESIDENCE TIME FOR COAL COMBUSTION

The residence time for coal combustion (burnout efficiency = 98%) is defined as time taken for char particle to traverse the distance L1, L2 and L3 in boiler furnace.

TARGET

Burnout Efficiency (η_b) = 98%
Unburnt Carbon = 2%



2. INEFFECTIVE HEAT RELEASE

The heat released in boiler vestibule region (horizontal pass) shall not be effective in steam evaporation / steam output.

Heat released too late in vestibule

Less heat available in furnace walls



3. SLOWED BOILER RESPONSE

The boiler response is slowed down due to this phenomenon.

IMPACT

- Slower steam generation ↓
- Delayed load response ↓

EFFECTS AT A GLANCE



Delayed char combustion in vestibule



Lower burnout efficiency (higher unburnt carbon)



Less effective heat transfer & lower steam generation



Slower boiler response & load changes

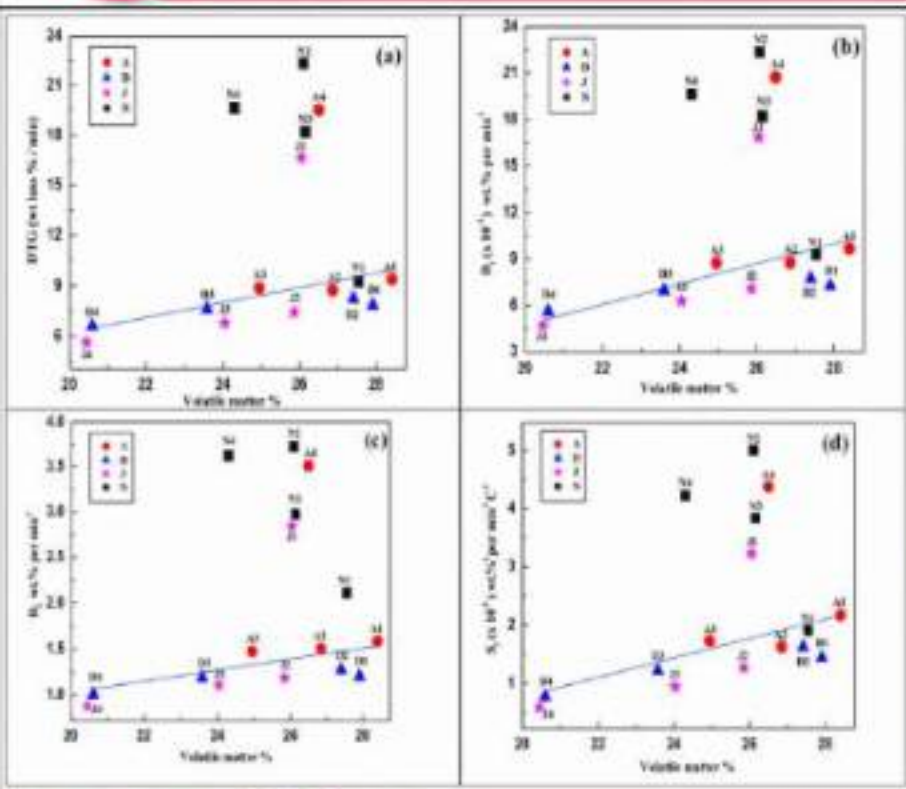
GOOD TO KNOW

Higher fuel ratio and poor air distribution increase the distance char particles travel before complete combustion, reducing overall boiler efficiency.





Impact on combustion parameters due to variation in Coal Volatile matter



As per the paper published in International Journal of Coal and Science Technology in March 2020, the **DTG max** (wt % loss per min upon combustion represents speed of combustion), **D_i** (Ignition Index), **D_f** (burnout index), and **S_f** (Combustibility Index) are all impacted by the VM content as shown in figure.

Combustion Parameters



DTG max
(wt % loss/min)



D_i
(Ignition Index)



D_f
(Burnout Index)



S_f
(Combustibility Index)



Challenges in Achieving Flexible Operation

Control Optimization of Slow Acting Boiler with Fast Acting Turbine



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



Key Challenges



Σ Time constant > 100 seconds



Coal to steam generation : *slow-reacting*



Control system require relook < 55% load



Enhancement of *controls & diagnostics* is needed






Challenges in Achieving Flexible Operation

1 COMBUSTION STABILITY PROBLEMS

At 40% load:

- Furnace temperature reduces significantly.
- Flame stability becomes difficult.
- Pulverized coal ignition deteriorates.
- Risk of flame failure and furnace explosion increases.

This creates:

-  Unstable flame fronts
-  Increased oil support requirement
-  Poor burner performance






2 MILL OPERATION CONSTRAINTS

A 660 MW boiler typically operates with 5-6 coal mills.

At 40% load:

- Only 2-3 mills may remain in service.
- Coal fineness deteriorates.
- Primary air-coal ratio becomes unstable.
- Mill choking and coal accumulation risks increase.

Challenges include:

-  Poor fuel-air mixing
-  Mill vibration
-  Reduced drying capability
-  Slagging and clinker formation



3 BOILER TUBE LEAKAGES AND THERMAL STRESS

Frequent ramping and cyclic operation create:

- Differential expansion in pressure parts
- Thermal fatigue in headers and tubes
- Increased boiler tube failures



4 TURBINE OPERATIONAL CHALLENGES

At low load:

- Steam parameters fluctuate.
- Turbine efficiency drops.
- Last-stage blade erosion risk increases.
- Condensation effects rise in LP stages.



5 POOR HEAT RATE AND HIGHER COAL CONSUMPTION

Low-load operation causes:



Increase in station heat rate



Higher specific coal consumption



Higher oil consumption during stabilization



Challenges in Achieving Flexible Operation



- Flexible operation increases creep-fatigue damage caused by thermal stresses, especially in units designed for base load operation.



- Accelerated Corrosion fatigue damage during flexible operation another common factor.



- Maintaining optimum water/steam chemical parameters is challenging in frequent cycling



Challenges in Achieving Flexible Operation

LONG TERM DAMAGE IN SEVERELY AFFECTED COMPONENTS

COMPONENT CATEGORY	SEVERELY AFFECTED COMPONENTS
THICK WALL COMPONENTS  01	<ul style="list-style-type: none">• Casting such as turbine valves and casings• Turbine Rotor• Thick-walled vessels• MS, CRH, HRH headers (especially Y- piece section)
HIGH TEMPERATURE COMPONENT  02	<ul style="list-style-type: none">• Superheater, Reheater• Ties used to support SH, RH tubing• Tube to header joints etc.• Gas duct work
CORROSION AND SCALING PRONE COMPONENT  03	<ul style="list-style-type: none">• Water wall tubing at attachments (wind box, corner tubes, wall box opening, buck stay) Heater tube• APH - cold end• Condenser tube• Welded joints
DEGENERATION OF INSULATION DUE TO THERMAL TRANSIENTS  04	<ul style="list-style-type: none">• Generator insulation• Transformer insulation• Insulation of drives (FD, ID, PA fans, mills motor)

Flexible Operation



Best Practices & Guidelines



**OPERATIONAL
EXCELLENCE**



**IMPROVED
PERFORMANCE**



**ENHANCED
RELIABILITY**



**ASSET
PROTECTION**



**COST
OPTIMIZATION**

Re-assessment of O&M Procedure

• OUR COMMITMENT TO EXCELLENCE •

01

Strict compliance to O&M requirements.



02

Improvement of maintenance strategy– special focus on critical equipment.



03

Awareness and competency of power plant personnel is important to run the plant in cycling mode– training program should be conducted.



Optimization of Automation and Controls



OPTIMIZING CONTROL LOOPS FOR STABLE & EFFICIENT POWER PLANT OPERATION

01

- ✓ Optimization of the underlying control loops (SH Temp control, Furnace control, Fuel/Air Control, Level Control) is a basic requirement for stable operation of the power plant at nominal load and low load as well as load changes.



02

- ✓ In order to increase part load efficiency "single device" approaches (i.e. Single PAF, FW pump etc in operation) should be considered.



SINGLE DEVICE APPROACHES



IMPROVED PART LOAD EFFICIENCY



REDUCED AUXILIARY POWER CONSUMPTION



LOWER OPERATING COST



Well-optimized control loops and smart operational approaches ensure **STABILITY, EFFICIENCY & RELIABILITY** at every load condition.



Evaluation of Process Limitation



EVALUATION FOR SAFE & RELIABLE OPERATION

- Evaluation includes a Turbine and Boiler calculation (like Boiler stress monitoring system – BOSMON & Turbine stress monitoring system – TSCMON) to assess the influence of low load operation and temperature and pressure gradients on the boiler.



WHAT IS EVALUATED?

- Low load operation effects
- Temperature gradients
- Pressure gradients
- Stress & safety assessment

BOILER STRESS MONITORING SYSTEM - BOSMON



Boiler data acquisition



Stress calculation & analysis



Safe operation insights

TURBINE STRESS MONITORING SYSTEM - TSCMON



Turbine data acquisition



Stress calculation & analysis



Safe operation insights



Enables informed decisions, extends equipment life and ensures safe, efficient & reliable power plant operation.



ENHANCED SAFETY



OPTIMIZED PERFORMANCE



IMPROVED RELIABILITY



REDUCED RISK & COST

Test run to evaluate the Plant Flexibility Potential



TRANSPARENCY ABOUT THE PLANT PERFORMANCE

with respect to minimal load, start up and cycling behavior with current units.



REAL-TIME VISIBILITY

Use monitoring of key performance parameters for complete transparency.



MINIMAL LOAD INSIGHTS

Track minimum stable load efficiently to optimize operations.



LOAD RAMP UP/DOWN

Monitor ramp up/down performance, costs and reliability to improve flexibility.



CYCLING BEHAVIOR

Analyze cycling frequency and impact to enhance equipment life.

PLANT PERFORMANCE DASHBOARD

PLANT LOAD



MINIMAL LOAD



LOAD RAMP UP/DOWN



✓ WITHIN TARGET

CYCLING BEHAVIOR



✓ WITHIN LIMIT



Data-driven decisions. Reliable operations. Better performance.

Empowering excellence through transparency.



Considering part and low load Operation in the design of Flue gas equipment

01

LOW/CYCLING LOAD OPERATION HAS AN IMPACT ON **NO_x** AND **SO_x** PARAMETER.



LOW LOAD



CYCLING OPERATION



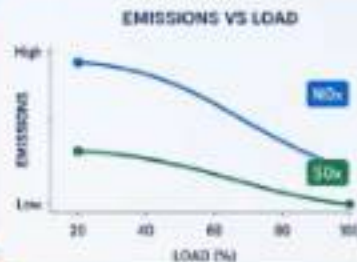
INCREASED NO_x



INCREASED SO_x



IMPACT ON EMISSIONS PARAMETERS



Lower loads and frequent cycling can increase NO_x and SO_x emissions.

02

FLUE GAS TREATMENT NEED TO COMPLY WITH **ENVIRONMENTAL NORMS** AT ALL LOAD CONDITIONS.



FLUE GAS GENERATED



POLLUTANTS (NO_x, SO_x, PM)



FLUE GAS TREATMENT SYSTEM



COMPLIANCE AT ALL LOAD CONDITIONS



CLEANER AIR GREENER FUTURE



ENVIRONMENTAL COMPLIANCE

- ✓ Comply with environmental norms
- ✓ Effective NO_x, SO_x & PM control
- ✓ Reliable performance at all load conditions
- ✓ Sustainable & responsible power generation



OPTIMIZE OPERATION. CONTROL EMISSIONS. PROTECT TOMORROW.



Reliable Flame Stability



PROPER FLAME DETECTION

THE KEY TO RELIABLE MINIMUM LOAD OPERATION



Proper flame detection plays a major role in



Guaranteeing a reliable minimum load operation



Avoiding trip and unplanned shutdowns



Minimizing oil consumption

BENEFITS

- ✓ Enhanced operational reliability
- ✓ Stable combustion at low load
- ✓ Reduced risk of trip and outages
- ✓ Lower fuel (oil) usage and operating cost



OEM MAY PROVIDE A SOLUTION

FOR THE SAME

By modified burners (with **enRICH**) for flame stability at low load operation



Improved flame stability



Better turndown capability



Reliable operation at low load



Reduced oil consumption

enRICH



HOW enRICH HELPS

- ✓ Ensures stable and robust flame
- ✓ Enables lower minimum load operation
- ✓ Supports cleaner and efficient combustion
- ✓ Enhances overall plant performance

Implementation of Condition Monitoring System



CMS SYSTEMS ENABLE SMART MONITORING, NOT JUST FLEXIBILITY

The installation of CMS System (i.e. casing vibration monitoring system – CVMS, Blade vibration monitoring system – BVMS, Rotor flux monitoring etc.) does not enhance the flexibility behavior of the plant itself but plays an important role to manage the consequences of cycling operation.

CMS SYSTEMS INSTALLED



Casing Vibration Monitoring System (CVMS)



Blade Vibration Monitoring System (BVMS)



Rotor Flux Monitoring



And More



PLAYS A CRITICAL ROLE IN

MANAGING CONSEQUENCES OF CYCLING OPERATION



Detects early signs of stress, fatigue & degradation



Helps in risk assessment and decision making



Enables timely alerts & corrective actions



Minimizes unplanned outages and equipment damage



CMS systems ensure safe, reliable and informed operation during frequent start-ups, load changes and shutdowns.



PREDICTIVE MAINTENANCE ENSURES A HEALTHY LIFE CYCLE OF THE EQUIPMENT

Predictive Maintenance needs such systems ensuring an efficient life cycle of the equipment.

1 CONTINUOUS MONITORING



Real-time data from CMS systems

2 DATA ANALYTICS & DIAGNOSIS



Identify trends, anomalies & risk

3 PREDICT POTENTIAL ISSUES



Forecast failures before they happen

4 PLAN & TAKE ACTION



Schedule maintenance at the right time

5 EXTEND ASSET LIFE & IMPROVE RELIABILITY



Lower cost, higher availability



CMS SYSTEMS + PREDICTIVE MAINTENANCE
= RELIABILITY TODAY, RESILIENCE TOMORROW



SAFE OPERATIONS



SMART DECISIONS



HIGHER RELIABILITY



LOWER COST OF OWNERSHIP

Low flow Operation especially in Sub-Critical Units

KEY SYSTEM UPGRADES FOR RELIABLE LOW FLOW OPERATION



ENHANCING SAFETY, STABILITY & PERFORMANCE

01

REPLACEMENT/MODIFICATION OF BFP RECIRCULATION VALVE with modified PID control during BFP low flow operation



Ensures stable control, prevents hunting and improves system responsiveness at low flow.



02

AXIAL FAN STALL PROTECTION at low flow operation is required



Prevents fan stall, vibration and mechanical stress, ensuring safe and reliable operation.



Stall Protection



Vibration Reduction



Equipment Protection



Enhanced Reliability

03

VSP OR LAST STAGE BLADE TEMP PROTECTION FOR LP TURBINE is essentially required during low flow operation at flexible low load operation.



Protects turbine blades from over-temperature, ensuring longevity and safe operation.



Monitors blade temperature continuously



Prevents overheating and damage



Supports flexible low load operation



Improves turbine life and reliability



Smart Control. Strong Protection. Reliable Performance.

Enabling Flexible & Efficient Power Generation

Optimization and Automation of Start-up Sequence

SMART START-UP. FASTER RESPONSE. GREATER FLEXIBILITY.

By optimizing and automating the start up sequence not only unnecessary waiting times may be avoided and faster gradient may be achieved.

OPTIMIZED & AUTOMATED START-UP SEQUENCE



FASTER GRADIENT, BETTER RESPONSE



Optimized start-up means a more flexible plant – ready when the grid needs you.



KEY BENEFITS

Avoid unnecessary waiting times • Achieve faster gradients • Improve plant responsiveness

LOWER OIL CONSUMPTION. LOWER COST.



Oil consumption may be reduced to lower start up cost also.

IMPACT



Reduced Oil Consumption
Less oil used during start-up



Lower Start-up Cost
Reduce O&M cost and improve savings

LESS OIL. MORE SAVINGS.

CONVENTIONAL START-UP



Higher oil consumption
Higher start-up cost

OPTIMIZED START-UP



Lower oil consumption
Lower start-up cost



OPTIMIZE TODAY.
SAVE TOMORROW.



REDUCED WAITING
TIME



FASTER GRADIENT



LOWER OIL
CONSUMPTION



LOWER START-UP
COST

Thank You!

— • *Your attention is highly appreciated.* • —

