AGENDA

FOR

214TH OCC MEETING

Date: 23.04.2024

Eastern Regional Power Committee

14, Golf Club Road, Tollygunge

Kolkata: 700033

Contents

EASTERN REGIONAL POWER COMMITTEE

AGENDA FOR 214TH OCC MEETING TO BE HELD ON 23.04.2024 (TUESAY) AT 10:30 HRS

1. PART-A: CONFIRMATION OF MINUTES

1.1. Confirmation of Minutes of 213th OCC Meeting held on 14th March 2024 physically at ERPC Secretariat, Kolkata

The minutes of 213th Operation Coordination Sub-Committee meeting held on 14.03.2024 was circulated vide letter dated 26.03.2024.

Members may confirm the minutes of 213th OCC meeting.

2. PART-B: ITEMS FOR DISCUSSION

2.1 Flexible Operation of Coal based Thermal Power Plants: CEA

As per gazette notification dated 30.01.2023 issued by CEA regarding flexible operation of coal fired thermal generating units, ramp rate of 2% between 55-70% along with a ramp rate of 3% above 70% was mandated within one year of notification of the regulations,i.e by Jan 2024. The SOP for operating at 55% load with recommendation for necessary training of the plant operators, was also circulated.(enclosed at **Annexure B.2.1.1**)

Relevant communication in this regard was also passed on to State Electricity regulatory Commissions as well as principal secretaries of concerned states outlining measures for execution of CEA regulations.

As per above mentioned regulations, coal based thermal generating units, whose implementation shall be as per phasing plan specified by CEA.Implementation plan for unit operation at 40% minimum load in phased manner(pilot+4 phases) (attached at **Annexure B.2.1.2)**

A comprehensive report published by CEA on flexible operation coal based thermal power plants highlighting various challenges as well as mitigation plan for achieving 40% minimum technical load (enclosed at **Annexure B.2.1.3)**

2.1.1 Regarding 55% Minimum Technical Load (MTL)

Thermal GENCOs may share details w.r.t the following:

a) Whether the target of achieving 55% Technical Minimum Load (MTL) has been met & if not, the reasons for the same & tentative date for achieving the same.

b) Whether the specified ramp rates outlined in the regulations i.e., 3% for 100-70% load & 2% for 70-55% load have been adhered to, if not, the reasons & tentative date for achieving the same.

c) How many operators have been trained in your organisation? (May treat this matter as Most Urgent)

Further, it is requested that attendees bring duly filled progress report (**Annexure- B.2.1.4**) as per enclosed format on the date of meeting.

2.1.2 Regarding 40% Minimum Technical Load (MTL) & status of units under pilot phase (May,2023-March,2024).

Phase	Sector	Organization	Name of Project	Unit No.	Capacity (MW)	Region
Pilot	Central	DVC	MEIJA TPS	8	500	ER
Pilot	State	WBPDCL	SAGARDIGHI TPS	3	500	ER

Thermal GENCOs may share details w.r.t the following:

a) Whether the target of achieving 40% Technical Minimum Load (TML) has been met and if not, the reasons for the same and tentative date for achieving.

b) Whether the specified ramp rates outlined in the regulations, i.e., 3% for 100-70% load, 2% for 70%-55% load, 1% for 40%-55% have been adhered to. If not, the reasons for behind and tentative date for achieving the target.

Furthermore, it is requested that attendees bring duly filled Progress report (**Annexure-B.2.1.5**) as per enclosed format on the date of the meeting.

Thermal GENCOs may update. Members may discuss.

2.2 Proposal for installation of 5th 400/220 KV 315 MVA ICT in place of existing age old 50 MVAR (3x16.6 MVAR single phase units) ISTS Reactor at Jeerat 400 KV SS of WBSETCL to maintain N-1 condition. : WBSETCL

- At present the total installed capacity of 400/220 KV ICTs at Jeerat 400 KV SS of WBSETCL is 4X315 MVA. The defective 4th 315 MVA ICT which was out of system for over 2 years has been replaced with a Regional pool spare 315 MVA ICT & put into service on 14th March-2024.
- Peak demand of Jeerat 400 KV SS in 2023-24 was 971 MVA (Jun-2023) i.e. more than full load capacity of the ICTs in service at that time i.e. 3X315 MVA.
- After recommissioning of the 4th ICT, it is evident from the load flow studies that the load shared by Jeerat SS with 4 nos of ICTs will increase considerably as compared to earlier load sharing with 3 nos of ICTs. The anticipated load during 2024-25 will increase further & may approach the full load capacity of all the four ICTs thus violating (N-1) criterion.

- So to cater the load growth at Jeerat 400 KV SS at 400/220 KV level maintaining (N-1) condition, augmentation of 400/220 KV ICT capacity from 4X315 MVA to 5X315 MVA is necessary at an early date.
- Clear space for construction of 220 KV bay for 5th ICT is available at Jeerat SS but there is no space for construction of new 400 KV bay & installation of 5th ICT.
- Due to space constraint, it is hereby proposed to use the 400 KV bay & equipment space of existing 50 MVAR (3X16.6 MVAR single phase units) Bus reactor which is at present operating with another 3-Ph 50 MVAR reactor in group control, both of which were installed under ISTS scheme a long time ago.
- Feasibility for keeping the 3-Ph 50 MVAR reactor in service by alternative arrangement is being explored by WBSETCL. WBSETCL is also considering the possibility for installation of a 3-Ph 125 MVAR Bus Reactor in place of the age old 50 MVAR 3-Ph Reactor depending on VAR compensation requirement as per system study.
- Considering the above facts proposal for installation of 5th ICT at Jeerat 400 KV SS was placed in the 29th CMETS-ER on 27.03.2024 Region for consideration and approval. It was decided that since the existing ISTS bus reactors (50MVAr (3x16.67MVAr single phase units) & 50MVAr 3-Ph) are to be disconnected and the vacated ISTS bay and space is to be used for installation of 5th ICT, the matter needs stakeholder's consultation & needs to be placed before ERPC forum for further discussion.
- Considering the urgent requirement of installation of the 5th ICT at Jeerat 400 KV SS & in line with the decision of the 29th CMETS-ER, the matter is placed before OCC Forum of ERPC for consideration and necessary approval.

Single line diagram (SLD) of 400 KV Jeerat S/S (WBSETCL) and power map of West Bengal attached at **Annexure B.2.2**

WBSETCL may update. Members may discuss.

2.3 Shutdown proposal of generating units for the month of May'2024-ERPC Secretariat

Maintenance Schedule of Thermal Generating Units of ER during 2024-25 in the month of May '2024							
System	**Station**	**Unit No.**	**Capacity (MW)**	**Period (as per LGBR 2024-25)**		**No. of Days**	**Reason**
				From	**To**		
WBPDCL	Sagardighi TPS	4	500	20-05-2024	26-05-2024	7	PG Test/Boiler License Renewal

Members may discuss.

2.4 Status of ongoing Generation Projects: ERPC

Enhancing thermal capacity is imperative due to escalating load demands. As we approach the summer season, ensuring preparedness is of utmost importance. Possessing adequate capacity during peak load periods is crucial for effective grid management. There are several forthcoming thermal projects within the region, with a few Thermal Power Plants (TPPs) awaiting their CODs such as North Karanpura, Barh, Patratu, IBEUL (Unit #02) and SJVN.

It is necessary for these thermal power plants to strategize for their timely completion and integration into the grid, ensuring the region's readiness for the upcoming demand surge.

As per latest update in 212th OCC meeting, NTPC representative apprised:

- Trial operation is set to commence at North Karanpura TPS on 26.02.2024.Trial operation got delayed inadvertently due to technical problems related to boiler.
- COD of the 2nd unit at North Karanpura is expected within current fiscal year,i.e by 31.03.2024.
- New 660 MW unit at Barh TPS is expected to be declared for commercial operation by March 2025.
- Patratu COD date expected in Q4 of FY 2024-25.

COD of Unit #02(660 MW) of North Karanpura TPP was completed on 20.03.2024. Status of Unit#03(660 MW) may please be confirmed by NTPC.

All concerned Thermal GENCOs may update. Members may discuss.

2.5 Fuel adequacy for thermal generating units: ERPC

As per Revised coal stocking norms for coal based thermal power plants dated 06.12.2021 by CEA, following are prescribed:

Daily coal requirement for both Pithead and Non-Pithead plants would be estimated @85% PLF and number of days for which stock needs to be maintained would vary from 12 to 17 days for Pithead plants and 20 to 26 days for Non-Pithead plants with month-wise variation based on coal despatch/coal consumption pattern during the year.

Accordingly, the new coal stocking norms would be as under:

a. ***For Pithead Plants:*** Coal required at 85% PLF for 'N1' number of days (in thousand tonnes)

b. ***For Non-Pithead Plants:*** Coal required at 85% PLF for 'N2' number of days (in thousand tonnes)

Where N1 and N2 are No. of days as given below:

Month	Coal Stock to be maintained by the power plant during the month (in no. of days)	
	PITHEAD (N1)	NON-PITHEAD (N2)
April	17	26
May	17	26
June	17	26
July	14	22
August	13	21
September	12	20
October	13	21
November	14	22
December	15	23
January	16	24
February	17	26
March	17	26

The coal stock has been kept minimum during rainy season (Q2) and based on increase in dispatch pattern during Q3 & Q4; the plants have been mandated to keep adequate stock especially during Q4 when supply is maximum. The stock maintained at the end of Q4 may be utilised during rainy season.

Details of Coal stock position of all Thermal generating stations of ER as on 17.04.2024 attached at **Annexure B.2.5** *(Source: Daily Coal Reports by CEA (Fuel Management Division))*

Penalty for non-maintenance of coal stock:

(i) In the event that availability by any power plant is less than the Normative availability (as per prevailing regulatory norms of CERC/SERC - as applicable) due to less coal stock maintained by the plant, the penalty shall be determined as detailed below:

a) **Power plant designed on domestic coal:**

In the event the availability is less by 5% or more from the Normative Availability (as applicable) on quarterly basis, the fixed charge shall be reduced to the extent of shortfall in Normative Availability and in addition, the reduction below the Normative Availability shall be multiplied by a factor of 0.2 (i.e levy of additional 20% due to reduced availability) to determine the penalty for non-maintenance of coal stock on quarterly basis.

b) **Power plant designed on imported coal:**

In the event the availability is less by 5% or more from the Normative Availability (as applicable) on quarterly basis, the fixed charge shall be reduced to the extent of shortfall in Normative Availability and in addition, the reduction below the Normative Availability shall be multiplied by a factor of 0.5 (i.e levy of additional 50% due to reduced availability) to determine the penalty for non-maintenance of coal stock on quarterly basis.

Further, in case the availability is less by 25% or more from the Normative Availability (as applicable) on quarterly basis, the fixed charge shall be reduced to the extent of shortfall in Normative Availability and in addition, the reduction beyond 25% below the Normative Availability shall be multiplied by a factor of 1 (one) (i.e levy of additional 100% due to reduced availability) to determine the penalty for non-maintenance of coal stock on quarterly basis.

Thermal GENCOs may update. Members may discuss.

2.6 Crunch period preparedness: ERLDC

2.6.1 ADMS Healthiness:

All feeders under the ADMS scheme need to be operational to get proper support in case of any contingency. Healthiness of the entire ADMS system is required to be ensured in this coming crunch period. Current status & settings of ADMS are as follows:

Sl No	State/Utility	Logic for ADMS operation	Implementation status/target
1	Bihar	F <49.7 AND deviation > 12 % or 150 MW	**Last phase of testing completed.**
2	Jharkhand	System Frequency< 49.9 Hz AND deviation > 12 % or 25/50/75 MW. Block I, II & III feeders will be selected for load shedding depending on the Over drawl**. Total 90 Mw load under ADMS.**	Implemented and in service.
3	DVC	F <49.9 Hz AND deviation > 12 % or 150 MW for 3 minutes. Loads in 7 Blocks. **Total 281 Mw load under ADMS.**	Implemented and in service.
4	Odisha	System Frequency < 49.9 Hz, Odisha over-drawl > 150 MW,& Discom **>40 MW**	Implemented and in service.
5	West Bengal	F <49.7 AND deviation > 12 % or 150 MW for 1 Minute. Operation of Block Load tripping one by one if condition satisfies. Loads in 4 Blocks. **Total 225 Mw load under ADMS.**	Implemented and in service.

There were multiple occasions on 15th April 2024 where frequency & state deviation satisfied the ADMS operation condition for Odisha, Jharkhand & DVC and follow up mail was initiated to intimate actual load relief in those instances. So far, response received from Jharkhand only. Odisha & DVC may submit the actual load relief quantum. ADMS instances are attached as **Annexure B.2.6.1.1**

ADMS operation information may be furnished and analysis needs to be done on a priority basis. In case of any issue in reduced load relief or technical issue in ADMS, that required to be resolved at earliest.

ERLDC may update Members may discuss.

2.6.2 Data integration of UFR feeders in SCADA system

Surge in demand and shortage of resources especially in the ongoing crunch period, particularly during non-solar hours, the likelihood of operating the UFR is significantly raised.

IEGC clause 29 sub-clause 13(d) mandates SLDC to integrate UFR feeders with the telemetry system for proper monitoring.

Quote:

SLDC shall ensure that telemetered data of feeders (MW power flow in real time and circuit breaker status) on which UFR and df/dt relays are installed is available at its control centre. SLDC shall monitor the combined load in MW of these feeders at all times. SLDC shall share the above data with the respective RLDC in real time and submit a monthly exception report to the respective RPC. RLDC shall inform SLDCs as well as the concerned RPC on a quarterly basis, durations during the quarter when the combined load in MW of these feeders was below the level considered while designing the UFR scheme by the RPC. SLDC shall take corrective measures within a reasonable period and inform the respective RLDC and RPC, failing which suitable action may be initiated by the respective RPC.

Unquote

This matter was discussed in the 207th OCC meeting under agenda point B.10. All the constituents were advised to ensure real-time availability of UFR telemetry data to SLDC as well as RLDC. ERLDC was advised to carry out a further detailed study highlighting the feeder-wise non-receipt of UFR data under the jurisdiction of each SLDC. ERLDC followed up with all the SLDCs regarding this matter and conducted meetings with SLDCs.The percentage of feeders that are reporting to ERLDC is mentioned below:

UFR EASTERN REGION

UFR_JH UFR_DVC FREQ 50.02 UFR_OPTCL UFR_BH UFR_WB

	STAGE I		STAGE II		STAGE III		STAGE IV		Overall Reporting Percentage (Constituent wise)
DVC	46 / 134	100%	33 / 135.5	100%	23 / 136	50%	12 / 137	100%	88%
OPTCL	116 / 181.5	100%	73 / 183.5	94%	110 / 184	93%	29 / 186	92%	95%
BIHAR	23 / 126	60%	50 / 117.92	56%	47 / 153	0 %	27 / 84.47	33%	38%
JHARKHAND	17 / 61	60%	15 / 62	40%	15 / 61	67%	45 / 62	80%	61%
WEST BENGAL (incl CESC)	97 / 381	15%	125 / 374	47%	55 / 390	16%	54 / 386	38%	28%
TOTAL	299 / 883.5	49%	296 / 872.92	63%	250 / 924	36%	167 / 855.47	58%	
TOTAL FOR ALL STAGES AND ALL CONSTITUENTS							1013 / 3536	51%	

Figure to the right shows the percentage of feeders that are reporting to ERLDC.

It is observed that 100% of UFR stage-1 feeders are not integrated (as on date) with the telemetry system of the few states. UFR feeder data integration may be prioritized for proper load visibility to get prepare for any greater contingency. State wise SCADA availability of UFR data enclosed at **Annexure B.2.6.2.1**

States may share the firm timeline for data integration with the telemetry system of SLDCs.

ERLDC may update Members may discuss.

2.6.3 Automatic tripping of Pumped Storage Plant or ESS in pumping/charging mode during low frequency: :ERLDC

As per IEGC 29.12(f), "*Pumped storage hydro plants operating in pumping mode or ESS operating in charging mode shall be automatically disconnected before the first stage of UFR.*"

As per the report of Task Force on Automatic Under Frequency Load Shedding (AUFLS) and df/dt scheme,

“

All Energy Storage Systems would change from charging mode to discharging mode at 49.50 Hz. If it is not possible then they would be tripped at 49.50 Hz. If ESS is injecting active power at 49.50 Hz not to be tripped.

Pumping load will be tripped before AUFLS first stage. Irrigation Pumps would be tripped at 49.50 Hz.

All the relays procured in future to have a sampling period ranging from three (03) cycles to five (05) Cycles. No additional time delay to be incorporated in the relay other than the inherent measuring time.

”

In the eastern region, only West Bengal has such an energy storage system, i.e. Purulia Pump Storage Plant. In this regard, SLDC WB is required to take immediate action to implement automatic tripping mechanisms for the Purulia Pumped Storage Plant when it operates in pumping mode at 49.5 Hz.

ERLDC may update Members may discuss.

2.7 Provision of construction power supply for FGD and New Nabinagar 3 X 800 MW project from existing commercialized units of Nabinagar (3 X 660 MW): NTPC ER-I

The construction power will be required for upcoming Stage-II (3X800MW). As all the units of NSTPS are commercialised and operational, the provision for construction power shall be made from existing units of NSTPS by incorporating power drawn for construction activities in to Metering system.

Considering above, kindly approve drawl of construction power from existing units by providing appropriate meters by SBPDCL and ERLDC.

Accordingly metering logic may be incorporated for the same.

NTPC ER-I may update. Members may discuss.

2.8 Incurring DSM loss due to scheduled generation exceeding normative DC: NTPC Darlipali

NTPC Darlipali station received SG more than normative DC on 3rd & 8th Apr -24. SG for 3rd April has been corrected. SG correction still pending for 8th Apr. On 8th Apr-24, rev no. 34 there is no URS power. In rev no. 35 SG has been revised to be more than normative DC. As a result the generating station has incurred DSM loss of around 46 lacs.

NTPC Darlipali and ERLDC may update. Members may discuss.

2.9 Difference in ABT(SCADA) vs SEM meters-NTPC Darlipalli

In 213th OCC meeting, "*OCC suggested NTPC Darlipalli to replace the existing meters (SEM and SCADA meters) with different serial numbers of the same OEM in coordination with the concerned OEM and Powergrid* "

Power Grid has agreed to supply the meters and existing meters shall be replaced on receipt of new meters.

NTPC Darlipali may update. Members may discuss.

2.10 Finalization of dates for mock black start in capable units of Eastern region: ERLDC

As per IEGC 2023,Clause 3 of regulation 34, each user is required to carry out a mock trial run of the restoration procedure for different sub-systems including black-start of generating units along with grid forming capability of inverter-based generating station and VSC-based HVDC black-start support at least once a year under intimation to the concerned SLDC and RLDC***. A tentative schedule for conducting mock Blackstart tests of capable hydro units in the Eastern Region for the year 2024 has been prepared. The dates are aligned with previous years' testing schedules.***

Sl No	Name of Hydro Station	Actual Date of Test	Actual Date of Test	Tentative Schedule of Mock Black Start	Actual Date of Test
		2022	2023	2024	
1	**U. Kolab**	23rd,June2022		Jun-24	
2	**Balimela**	8th Sep- 2022		Jul-24	
3	**Rengali**	8th Dec 2022	12th July 2023	Jun-24	
4	**Burla**	23rd June- 2022		Jul-24	
5	**U. Indravati**	25th May-2022		May-24	
6	**Maithon**		14th August 2023	Dec-24	
7	**TLDP-III**			Oct-24	
8	**TLDP-IV**			Oct-24	
9	**Subarnarekha**	13th December 2022		Sep-24	
10	**Teesta-V**			N/A	
11	**Chuzachen**			Oct-24	

12	**Teesta-III**	08th April- 2022		N/A	
13	**Jorethang**		19th and 20th December 2023	Oct-24	
14	**Tasheding**		12th December 2023	Oct-24	
15	**Dikchu**			N/A	
16	**Rongnichu**			Mar-24	18th March and 20th March 2024

The users, in this case, include the generating company and they are requested to kindly respond and review the tentative dates specific to their plant units and update the ***list within a week***. For intra-state blackstart capable hydro units, SLDCs are requested to respond on their behalf.

A relevant email on this behalf has already been sent on 10th April 2024.

ERLDC may update. Members may discuss.

2.11 Regarding Non-Submission of FRC data: ERLDC

Adhering to IEGC clauses 30.8 and 30.10.(a) to 30.10.(q), generating stations within the eastern region are required to submit essential data to ERLDC within two days of receiving a notification regarding a reportable frequency event. Additionally, according to clause 30.10.(n), all control areas within the eastern region must assess their frequency response characteristics and share the evaluation, along with high-resolution data, with the ERLDC.

After each reportable frequency event, ERLDC sends out a format to entities to facilitate the collection of necessary data for performance assessment. If any data is not received or is incomplete, ERLDC resorts to using Scada data (low resolution) to calculate the performance of the respective control area. Further based on this assessment, re-testing of primary frequency response may be recommended. Therefore, timely submission of primary response data is crucial for compliance with the IEGC.

As per IEGC Annexure 2 Clause 10.a of IEGC, each control area shall be graded based on median Frequency Response Performance annually (at least 10 events) as per the following criteria:

TABLE : FREQUENCY RESPONSE CRITERIA

S. N	Performance*	Grading
i.	FRP≥ 1	Excellent
ii.	0.85 ≤ FRP < 1	Good
iii.	0.75 ≤ FRP <0.85	Average
iv.	0.5≤ FRP < 0.75	Below Average
v.	FRP <0.5	Poor

The plant wise data submission statistics for frequency event flagged by ERLDC up to 08.04.2024 is given below:

STATIONS		17.12.2023	05.01.2024	15.01.2024	15.01.2024	03.03.2024	31.03.2024
		13:01	05:16	13:59	14:06	14:01	14:41
ADHUNIK		Received	Received	Received	Received	Received	Pending
BARH STG1&2	ISGS	Pending	Received	Received	Received	Received	Pending
BRBCL	ISGS	Pending	Pending	Pending	Pending	Pending	Pending
DARLIPALLI	ISGS	Received ONLY ONE UNIT DATA	Received	Received ONLY ONE UNIT DATA	Received ONLY ONE UNIT DATA	Received	Received
DIKCHU		PLANT OUT	PLANT OUT	PLANT OUT	PLANT OUT	PLANT OUT	Pending
TASHIDING		Pending	Pending	Pending	Pending	Pending	Pending
FARAKKA STG1&2	ISGS	Pending	Pending	Pending	Pending	Pending	Pending
FARAKKA STG3		Pending	Pending	Pending	Pending	Pending	Pending
GMR		Received	Received	Received	Received	Received	Received
JITPL		Received	Received	Received	Received	Received	Received
KAHALGAON STG1	ISGS	Received	Pending	Pending	Pending	Pending	Pending
KAHALGAON STG2		Received	Received INCOMPLETE DATA	Received	Received	Received	Pending
MPL		Received	Received	Received	Received	Received	Received
NPGC	ISGS	Received	Received	Received	Received	Pending	Pending
TALCHER STG1	STG-1&2 ISGS	Received	Received INCOMPLETE DATA	Received	Received	Pending	Pending
TALCHER STG2		Received		Received INCOMPLETE DATA	Received INCOMPLETE DATA	Received	Received
TEESTA III	ISGS	PLANT OUT	PLANT OUT	PLANT OUT	PLANT OUT	PLANT OUT	PLANT OUT
TEESTA V	ISGS	PLANT OUT	PLANT OUT	PLANT OUT	PLANT OUT	PLANT OUT	PLANT OUT
North Karanpura	ISGS	Received	Received	Received	Received	Received	Pending
Updated as on		08.04.2024					

= Data received

In view of the same all utilities are once again requested to take necessary action to ensure consistent data submission for every frequency event flagged by ERLDC.

ERLDC may update Members may discuss.

2.12 Regarding Non-Submission of Forecasting Data from States: ERLDC

All SLDCs need to submit the demand estimate data as per the following timeline to the respective RLDC and RPC, as mandated in IEGC 2023, Clause 2 of Regulation 31:

Activity	By SLDCs
Daily Demand estimation	10:00 hrs of previous day

Weekly demand estimation	First working day of the previous week
Monthly demand estimation	Fifth day of the previous month
Yearly demand estimation	30th September of the previous year

Demand estimation data by SLDCs is critical for resource adequacy planning and regional load forecasts conducted by the RLDC. While Jharkhand SLDC consistently provides day-ahead and weekly forecasts data, West Bengal SLDC submits day-ahead forecasts data. However, other states are yet to comply.

Following discussions in the 208th OCC meeting held on 17.10.2023, all constituents were advised to strictly adhere to demand estimation timelines as mandated in IEGC 2023. ***Therefore, we urge all concerned parties to submit demand estimation data to ERLDC at the earliest***. This collaboration is vital for effective planning and preparedness to meet the region's demands efficiently and reliably.

ERLDC may update Members may discuss.

2.13 Availability of ERS in the Eastern Region and update on the status by various utilities including inter-state and intra-state transmission licensees: ERPC

In line with CEA guidelines for the availability of spares and inventories for power transmission system (transmission lines & substation/switchyard) assets 2020 and the CEA disaster management plan for power sector 2021, adequate ERS is required to be maintained in ER grid for early restoration of transmission line due to any tower collapse. The Eastern region is prone to cyclones, Norwester/Kalbaisakhi localized storms, hilly terrain with landslides, floods, changes in river course, substation flooding, etc. due to which each year tower collapse occurs causing forced outages of transmission lines. This necessitates adequate ERS maintenance by various utilities in the eastern region for early restoration.

Present status available at ERLDC on ERS as collected during cyclone Yaas in 2021 is provided in the attached table. All transmission utilities are requested to kindly update the ERS availabilityand any ERS which are already engaged.

Status Update by: PGCIL ERTS 1, PGCIL ERST 2, PGCIL Odisha, WBSETCL and OPTCL (if any ERS is already engaged then same may be put as remarks)

Utility to provide details of available ERS in the attached format:

- State-level: BSPTCL, BGCL, DVC, JUSNL, Sikkim power department (SPD)
- ISTS: Indigrid (OGPTL, PKTCL, ENICL), PGCIL Subsidiaries (CBPTCL, PMTL, PMJTL), Powerlink Transmission limited (PTL), DMTCL, Adani transmission (ATL, NKTL), TPTL

In the 192nd OCC meeting, TPTL representative submitted that they would provide the details by the end of June 2022.

DVC representative submitted that procurement of 7 nos. (Combination of suspension and tension) of ERS is under progress. Further, pile and structures (2 nos.) at Putki and Maithon are available as immediate remedial measures up to 220 KV level.

West Bengal representative submitted that 10 nos. of ERS towers which can be used at all levels are available out of which 6 nos. have been used. Of the remaining, 3 nos. are tension towers and 1 is suspension tower.

JUSNL representative submitted that 8 nos. of ERS are available which could be used for up to 220 KV levels.

Bihar representative submitted that 36 nos. of ERS (for 220 KV and 132 KV level) are available and all are engaged at present.

The details have been received from OPTCL,PGCIL ERTS-1,ATL, PGCIL Odisha, PGCIL ERTS-2,PTL,ENICL,OGPTL,PKTCL. The details are awaited from WBSETCL,TPTL,BSPTCL, JUSNL and Sikkim Power Department. The utilities are requested to share the details at the earliest.

Present status available at ERLDC on ERS as collected during July 2022 is provided in the attached table.

Sl	Utility	voltage levels	Number of ERS towers available	Location of ERS situated	Type of ERS (Suspension/ Tension/ any other)
1	OPTCL	400 kV	14	MancheswarGrid - 4 nos. (Hitech)	Can be used for both suspension and Tension
				Mancheswar store - 8 nos. (Hitech)	
				Mancheswar store - 2 nos. (Lindsey)	
			18 (Newly procured)	Mancheswar store - 18 nos. (Hitech)	
		220 kV	42	Budhipadar - 14 nos. (Lindsey)	
				Mancheswar grid – 14Nos. (Lindsey)	
				Chatrapur - 14 nos. (Lindsey)	
2	PGCIL ERTS 1	765 kV -24 sets	24 Sets	GAYA	15 Suspension & 9 Tension tower
		400 KV -30 sets	30 Sets	Jamshedpur, Purnea, Lakhisarai	Total 20 nos. Suspension & 10 nos. Tension ERS towers
3	Adani transmission limited (ATL)	400 KV	1 set (12 Column). Nos of ERS towers shall depend on line configuration, type of tower and extension of towers. Approximate 6	Central India (Koradi, Maharashtra)- **48 Hours**	Modular aluminum guyed towers- Suspension tower

Sl	Utility	voltage levels	Number of ERS towers available	Location of ERS situated	Type of ERS (Suspension/ Tension/ any other)
			suspension towers/ set for 400kV D/C twin conductor.		
4	PGCIL (Odisha)	400 KV ERS - 3	3	Rourkela	Suspension - 2 & Tension-1
		765 KV ERS - 24	24	Rengali	Suspension - 15 & Tension-9
5	PGCIL ERTS 2	400 KV	1 Set (consisting of 10 towers) -400 KV Voltage level	Durgapur	7 Set-Suspension 03 Set-Tension
6	WBSETCL	400, 220, 132 kV	05+05set (can be used with 400/220/132 kV level) 6 used for Durgapur - asansol line diversion. 4 available	at Arambagh &Gokarno	Can be used for both suspension and Tension
7	TPTL		MoU with PGCIL Tie up with Supreme Industry in progress	-	-

Sl	Utility	voltage levels	Number of ERS towers available	Location of ERS situated	Type of ERS (Suspension/ Tension/ any other)
8	CBPTCL		No ERS	PTC does not own any ERS, however, in case of any such requirement for deployment of ERS, CPTC has an existing agreement with POWERGRID for deployment of ERS.	-
9	PMTL	-	No ERS	-	-
10	PMJTL	765 kV	NO ERS	-	-
11	PTL	400 kV	07 towers set ERS structures suitable for Twin Moose Configuration 400 or 220 kV.	Siliguri (W.B.)	Lindsey Manufacturing Company Ltd USA Model 600
			07 towers set ERS structures suitable for Twin Moose Configuration 400 or 220 kV.	Muzaffarpur (Bihar)ER1	
12	Indigrid (ENICL, OGPTL & PKTCL)	400 KV & 765 KV Line	765 KV- 6 Sets / 400 KV- 8 Sets	Siliguri, WB.	For 765 KV- 4 Suspension & 2 Tension. For 400 KV- 6 Suspension & 2 Tension.
13	DMTCL	400 kV Lines	Arrangement of ERS with M/s Supreme Engineering at Kolkata.	Can be Dispatched in 2–3-weeks periods	-

Sl	Utility	voltage levels	Number of ERS towers available	Location of ERS situated	Type of ERS (Suspension/ Tension/ any other)
14	BSPTCL	220 kV & 132 kV	38 ERS which can be used for 220 and 132 kV	18 Towers in use for 132 kV Kishanganj-Barsoi ckt 4 towers for 220 kv BTPS-Hazipur ckt 4 towers for 220 kV Bodhgaya- Chandauti Purnea : 1 Dehri on sone: 2 Sultanganj: 2 Fatuah: 2 Muzaffarpur : 4	Can be used for both suspension and Tension
15	BGCL	-	No ERS	No ERS	-
16	JUSNL	220 kV	Total 8 ERS	Hatia: 3 Jamshedpur: 2 Dumka: 3	Details awaited
17	DVC	400 kV and 220 kV	400 kV: 7 (under procurement) 220 kV: 2 set Pilon structure	400 kV: **Under procurement** 220 kV: 1 at putki and 1 at Maithon	-
18	Sikkim Power Department		Details awaited	Details awaited	Details awaited

In the 193rd OCC meeting, TPTL representative submitted that they do not have any ERS towers of their own. In this regard, a MoU with PGCIL is there.

WBSETCL representative submitted that 10 nos. of ERS towers are available which could be used at all the voltage levels. Out of 10 nos., 6 nos. are used for Durgapur-Asansol line and 4 nos. are available. Procurement of additional 6 nos. of ERS towers (which could be used both under suspension and tension) is under planning stage.

Bihar representative submitted the status of ERS towers which is mentioned below.

Location	**Status**	**Usage**	**Type**	**Quantity**
Kishanganj-Barsoi Line	engaged	220/132 KV	Suspension/Tension	18
BTPS-Hajipur Line	engaged	220/132 KV	Suspension/Tension	4
Bodh Gaya-Chandauti	to be engaged	220/132 KV	Suspension/Tension	4
Purnea	Spare	220/132 KV	Suspension/Tension	1
Dehri	Spare	220/132 KV	Suspension/Tension	2
Fatuha	Spare	220/132 KV	Suspension/Tension	3
Mujaffarpur	Spare	220/132 KV	Suspension/Tension	4
Sultanganj	Spare	220/132 KV	Suspension/Tension	2
Total				38

OCC was of the view that many lines of BGCL and other new sub-stations like Mokama, Hajipur, etc. in Bihar fall under the coverage of river corridor and advised Bihar to keep provisions of ERS towers for those lines.

All concerned Transmission Utilities may please update.

3. PART-C: ITEMS FOR UPDATE/FOLLOW-UP

3.1. ER Grid performance during March 2024.

The average and maximum consumption of Eastern Region and Max/Min Demand (MW), Energy Export for the month March -2024 were as follows:

AVERAGE CONSUMPTION (MU)	MAXIMUM CONSUMPTION(MU)/ DATE	MAXIMUM DEMAND (MW)	MINIMUM DEMAND (MW)	SCHEDULE EXPORT	ACTUAL EXPORT
		DATE/TIME	DATE/TIME	(MU)	(MU)
493.1 MU	582 MU 30.03.2024	27079 MW, 30.03.2024 at 19:21 Hrs.	14940 MW, 04.03.2024 at 03:27 Hrs.	4501	4488

ERLDC/ERPC may highlight the performance of the ER grid.

4. PART-D: OPERATIONAL PLANNING

4.1. Anticipated power supply position during May-2024

The abstract of peak demand (MW) vis-à-vis availability and energy requirement vis-à-vis availability (MU) for the month of May 2024 were prepared by ERPC Secretariat (**Annexure D.1**) on the basis of LGBR for 2023-24 and feedback of constituents, keeping in view that the units are available for generation and expected load growth etc.

Members may update.

4.2. Major Thermal Generating Units/Transmission Element outages/shutdown in ER Grid (as on 16-04-2024)

a) Thermal Generating Stations outage report:

SL No	STATION	STATE	AGENCY	UNIT NO	CAPACITY (MW)	REASON(S)	OUTAGE DATE
1	BARAUNI TPS	BIHAR	NTPC	7	110	Poor condenser vacuum UNDER DECOMMISSIONING	19-Jul-2023
2	BARAUNI TPS	BIHAR	NTPC	6	110	Low vacuum UNDER DECOMMISSIONING	22-Jul-2023
3	RTPS	DVC	DVC	2	600	Initially Unit was taken out due to very low lube oil presssure, later unit was taken under annual overhauling w.e.f 00.00 hrs of 27/02/2024, now under forced outage wef 23/03/2024 due to damage in turbine bearing.	26-Feb-2024
6	DSTPS	DVC	DVC	1	500	Problem in Air Pre Heater	16-Apr-2024
8	JITPL	ODISHA	JITPL	1	600	Turbine shaft vibration high	26-Mar-2024

All Generating stations are requested to update expected restoration time and reason outage to ERLDC/ERPC on weekly basis in case of any change at their end.

b) Major Generating stations Out on Reserve Shutdown due to low system demand:

SL No	STATION	STATE	AGENCY	UNIT NO	CAPACITY (MW)	REASON(S)	OUTAGE DATE
NIL							

c) Hydro Unit Outage Report:

S. NO	STATION	STATE	AGENCY	UNIT NO	CAPACITY (MW)	REASON(S)	OUTAGE DATE
1	TEESTA STG III Hep	SIKKIM	TUL	1	200	Sudden cloudburst at glacier fed LOHNAK Lake followed by huge inrush of water in Teesta River and damage of Teesta III Dam & downstream Powerhouses	04-Oct-2023
2	TEESTA STG III Hep	SIKKIM	TUL	2	200		
3	TEESTA STG III Hep	SIKKIM	TUL	3	200		
4	TEESTA STG III Hep	SIKKIM	TUL	4	200		
5	TEESTA STG III Hep	SIKKIM	TUL	5	200		
6	TEESTA STG III Hep	SIKKIM	TUL	6	200		
7	DIKCHU Hep	SIKKIM	SKPPL	1	48	Sudden cloudburst at glacier fed LOHNAK Lake followed by huge inrush of water in Teesta River and damage of Teesta III Dam & downstream Powerhouses	04-Oct-2023
8	DIKCHU Hep	SIKKIM	SKPPL	2	48		
9	TEESTA HPS	SIKKIM	NHPC	1	170	Sudden cloudburst at glacier fed LOHNAK	04-Oct-2023
10	TEESTA HPS	SIKKIM	NHPC	2	170		

11	TEESTA HPS	SIKKIM	NHPC	3	170	Lake followed by huge inrush of water in Teesta River and damage of Teesta III Dam & downstream Powerhouses	
12	INDRAVATI	ODISHA	OHPC	2	150	Capital Maintenance	23-Nov-2023
13	CHIPLIMA HPS / HIRAKUD II	ODISHA	OHPC	1	24	Capital Overhauling	15-Dec-2023
14	BURLA HPS/HIRAKUD I	ODISHA	OHPC	7	37.5	Annual maintenance	13-Feb-2024
15	RANGIT HPS	SIKKIM	NHPC	2	20	Annual Maintenance	12-Mar-2024
16	BALIMELA HPS	ODISHA	OHPC	2	60	High Turbine Vibration	14-Mar-2024
17	RENGALI HPS	ODISHA	OHPC	1	50	Stator Earth Fault	22-Mar-2024

d) **Long outage report of transmission lines (As on 15.04.2024):**

Transmission Element / ICT	Outage From	Reasons for Outage
220/132KV 100 MVA ICT II AT LALMATIA	22.01.2019	Commissioning work of 220/132KV, 100MVA Transformer and its associated control Panel under progress.
220 KV PANDIABILI - SAMANGARA D/C	03.05.2019	Tower Collapsed during Cyclone FANI (Restoration project is entrusted upon PGCIL & 220kV Samangara-Pandiabili ckt-I&II are anti-theft charged from Pandiabili end from loc no.01 to loc no.74)
220/132KV 100 MVA ICT 3 AT CHANDIL	30.04.2020	Due to Fire hazard ICT damaged and burnt.
220KV-FSTPP-LALMATIA-I	21.04.2021	Conductor stringing 12.965 km has been completed and Stringing between Tower Loc. no. 152 to 159 is under progress. Transmission line is idle charged between Lalmatia GSS

		end to Tower Loc.no.169
220KV-WARIA-BIDHANNAGAR-1 & 2	08.06.2022	To control overloading of 220 kV Waria-DSTPS (Andal) D/C line
220KV-MUZAFFARPUR(PG)-GORAUL(BH)-1	11.06.2022	Main Bay is under breakdown due to flashing in GIS module
400/220KV 315 MVA ICT 2 AT PATRATU	27.09.2022	ICT tripped on few occasions due to Buchholz later DGA violation found, internal fault in transformer to be rectified. (DGA violation)
132KV-BARHI-RAJGIR-1	25.03.2023	Dismantling of tower no. 227, 228, and 229 crossing the premises of Mahabodhi Cultural centre along with Destringing of conductor of both circuits and Earth wire between tension tower no. 218-237 in same line.
132KV-NALANDA-BARHI(DVC)-1	25.03.2023	
220KV-TSTPP-MEERAMUNDALI-2	10.06.2023	Tower collapse at loc no 41, 42 (from Meramundali end). Ckt1 charged through ERS.
400KV-RANGPO-TEESTA-V-1 & 2	04.10.2023	Tower near gantry of Teesta V powerhouse collapsed due to sudden cloudburst at glacier fed LOHNAK Lake followed by huge inrush of water in TEESTA river and damage of Teesta III Dam & downstream Powerhouses
400KV-TEESTA-III-RANGPO-1	04.10.2023	Hand tripped from Teesta-III end due to sudden cloudburst at glacier fed LOHNAK Lake followed by huge inrush of water in TEESTA river and damage of Teesta III Dam & downstream Powerhouses
400KV-TEESTA-III-DIKCHU-1	04.10.2023	
400KV-RANGPO-DIKCHU-1	04.10.2023	Hand tripped from Rangpo end due to sudden cloudburst at glacier fed LOHNAK Lake followed by huge inrush of water in TEESTA river and damage of Teesta III Dam & downstream Powerhouses
400KV/220KV 315 MVA ICT 1 AT FARAKKA	21.02.2024	Replacement of 220kV circuit breaker of 315 MVA ICT-1 bay under ADDCAP.
400KV-KHSTPP-BANKA (PG)-1	24.02.2024	Switchyard bay updation work
132KV-RIHAND-NAGARUNTARI-1	08.03.2024	Height raising of 132 KV Rihand-Nagaruntari & 132 KV Rihand-Garhwa

		Rd. T/L
220KV-KATAPALLI-BOLANGIR(PG)-1	24.03.2024	To control the Loading of 220KV-ROURKELA-TARKERA-1&2; Anti-Theft charged from Katapalli end w.e.f 22:19 Hrs of 08-04-2024
400KV-ALIPURDUAR (PG)-PUNASANGCHUN-JIGMELING-1	27.03.2024	To carry out installation of Jumper-wire, Earth wire & OPGW
220KV-DALTONGUNJ-GARWAH (NEW)-2	30.03.2024	Tripped on Tower damage
220KV-KHAGARIA-NEW PURNEA-1&2	31.03.2024	Rectification of deformed tower no. 372 of 220kV Purnea PG-Khagaria (NEW) D/C
220KV-DALTONGUNJ-GARWAH (NEW)-1	31.03.2024	Tripped on Tower damage
400KV-JHARSUGUDA-ROURKELA-3	01.04.2024	Reconductoring work
220KV-ALIPURDUAR (PG)-SALAKATI-2	02.04.2024	CT, CVT, LA and Wave trap replacement in 204 bay and replacement of interconnecting jumper under NERSS-XII.
400KV-BIHARSARIFF(PG)-VARANASI-1	02.04.2024	LILO of existing 400 kV Varanasi-Biharsharif CKT-I (PGCIL)line at tower No. 702 at Sahupuri ,Chandauli (UPPTCL)
220KV-SAHARSA(PMTL)-BEGUSARAI-1	04.04.2024	To control loading on Begusarai-BTPS line
132KV-MADHEPURA (BH)-SAHARSA(PMTL)-1	04.04.2024	To control loading on 132kV Madhepura-Saharsa line
220KV-BUDHIPADAR-KORBA-2&3	05.04.2024	Tripped from Korba end only

Transmission licensees/ Utilities are requested to update expected restoration date & work progress regarding restoration regularly to ERLDC/ERPC on monthly basis by 5th of each month so that status of restoration can be reviewed in OCC. Utilities are also requested to update outage of any elements within their substation premises like isolator/breaker to ERLDC/ERPC regularly. (Reported as per Clause 5.2(e) of IEGC)

4.3. Commissioning of new units and transmission elements in Eastern Grid in the month of March -2024.

The details of new units/transmission elements commissioned in the month of February-2024 based on the inputs received from beneficiaries:

NEW ELEMENTS COMMISSIONED DURING MARCH, 2024

GENERATING UNITS

SL. NO.	Location	Owner/ Unit name	Unit No / Source	Capacity added (MW)	Total/Installed Capacity (MW)	DATE	Remarks
NIL							

ICTs/ GTs / STs

SL. NO.	Agency/ Owner	SUB-STATION	ICT NO	Voltage Level (kV)	CAPACITY (MVA)	DATE	Remarks
1	WBSETCL	NEW CHANDITALA	4	400KV/220KV	315	23-03-2024	
2	WBSETCL	JEERAT	4	400KV/220KV	315	15-03-2024	

TRANSMISSION LINES

SL. NO.	Agency/ Owner	Line Name	Length (KM)	Conductor Type	DATE	Remarks
NIL						

LILO/RE-ARRANGEMENT OF TRANSMISSION LINES

SL. NO.	Agency/ Owner	Line Name/LILO at	Length (KM)	Conductor Type	DATE	Remarks
1	PGCIL	400KV-BINAGURI-BONGAIGAON-1	216	GAP TYPE HTLS	30-03-2024	RECONDUCTORING DONE FROM BAY TO BAY WITH UPRATED CAPACITY OF 2800 AMPERES
2	PGCIL	400KV-BINAGURI-BONGAIGAON-2	216	GAP TYPE HTLS	28-03-2024	
3	BSPTCL	220kV Darbhanga (BSPTCL)- Darbhanga (DMTCL) ckt-2.	2.98	HTLS TYPE	22-03-2024	RECONDUCTORING DONE FROM BAY TO BAY WITH UPRATED CAPACITY OF 1593 AMPERES

BUS/LINE REACTORS

SL. NO.	Agency/ Owner	Element Name	SUB-STATION	Voltage Level (kV)	DATE	Remarks
1	PGCIL	125MVAR 400KV B/R-5 AT BIHARSARIFF(PG)	BIHARSARIFF(PG)	400	23-03-2024	

BUS

SL. NO.	Agency/ Owner	Element Name	SUB-STATION	Voltage Level (kV)	DATE	Remarks
NIL						

BAYS

SL. NO.	Agency/ Owner	Element Name	SUB-STATION	Voltage Level (kV)	DATE	Remarks
1	WBSETCL	400KV MAIN BAY (Bay No-410) OF 315 MVA ICT 4 AT NEW CHANDITALA	NEW CHANDITALA	400	23-03-2024	

2	PGCIL	132KV MAIN BAY OF MANIKCHAK-2 AT MALDA (PG)	MALDA (PG)	132	27-03-2024	
3	PGCIL	132KV MAIN BAY OF MANIKCHAK-1 AT MALDA (PG)	MALDA (PG)	132	27-03-2024	
4	PGCIL	400KV MAIN BAY OF 125MVAR B/R-5 AT BIHARSARIFF(PG)	BIHARSARIFF(PG)	400	23-03-2024	.

Members may note.

4.4. UFR operation during the month of March 2024.

Frequency profile for the month as follows:

MONTH	MAX (DATE/TIME)	MIN (DATE/TIME)	% LESS IEGC BAND	% WITHIN IEGC BAND	% MORE IEGC BAND
Mar, 2024	50.43 Hz on 17-03-2024 at 06:03 hrs	49.59 Hz on 28-03-2024 at 22:23 hrs	6.0	77.5	16.5

Hence, no report of operation of UFR has been received from any of the constituents.

Members may note.

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Annexure B.2.1.1

Government of India
Ministry of Power
Central Electricity Authority

Operating Procedure and Training Curriculum at 55% Minimum Technical Load of Thermal Generating Units

March 2023

Sewa Bhawan , Sector 1 , R K Puram , New Delhi -110066

Central Electricity Authority

Thermal Project Renovation and Modernization Division

घनश्याम प्रसाद
अध्यक्ष तथा पदेन सचिव भारत सरकार
GHANSHYAM PRASAD
Chairperson & Ex-officio Secretary
To the Government Of India

सत्यमेव जयते

आज़ादी का अमृत महोत्सव

केन्द्रीय विद्युत प्राधिकरण
भारत सरकार
विद्युत मंत्रालय
सेवा भवन, आर.के. पुरम
नई दिल्ली–110066
Central Electricity Authority
Ministry of Power
Sewa Bhawan, R. K. Puram
New Delhi-110066

FOREWORD

Availability of flexible power is essential for integration of increasingly renewables into the grid to achieve the goal of energy transition. Flexible operation of coal fired units are one of the cheapest source of flexible power presently in the country. Hence, it will be crucial to operate the existing thermal units in the new operating regime for integrating the renewables in the grid.

TPRM Division, CEA has brought out a comprehensive report on Standard Operating Procedure at 55% Technical Minimum Load of Thermal Generating Units. The report has highlighted prerequisites for reducing minimum stable load, operational issues of Ball and Tube mill based units and Long Term Concerns/Measures of low (55%) load operation. This document has listed in details the various standard operating procedure for the operation of coal fired power plants at 55% load. Training of Operators is another important aspects of low load operation which has also been discussed in the report. The committee with members from various organizations have put in their valuable efforts and time to bring out a comprehensive document covering important topics.

I would like to express my sincere appreciation to the chairman of the committee, Sh. B.C.Mallick, Chief Engineer and all committee members for bringing out the report which shall be useful in achieving country wide operation of thermal units at 55% minimum load.

(Ghanshyam Prasad)

दूरभाष / Telephone : 011-26732201, 26732222, ईमेल / Email : chair@nic.in, वेबसाईट / Website : www.cea.nic.in

दूरभाष (का०)
TELEPHONE (O) 011-26732901
TELEFAX (O)

सदस्य
तथा पदेन अपर सचिव भारत सरकार
केन्द्रीय विद्युत प्राधिकरण
सेवा भवन, रामाकृष्णा पुरम्

सत्यमेव जयते

PRAVEEN GUPTA

MEMBER (THERMAL)
& EX-OFFICIO ADDL. SECRETARY TO THE GOVERNMENT OF INDIA
CENTRAL ELECTRICITY AUTHORITY
SEWA BHAWAN, R.K. PURAM

नई दिल्ली - 110066
NEW DELHI-110066

PREFACE

Presently more than 70% of energy demand is being met from thermal generation. Flexible operation of coal-fired power plants is required to maximize absorption of generation from renewable energy sources into the grid. In this regard, CEA has recently notified a regulation on "Flexible Operation of Coal based Thermal Power Generating Units".

To facilitate power generating utilities, Central Electricity Authority has prepared Standard Operating Procedure/ manual for attaining / operating coal-based power plants at 55% technical minimum load including a training curriculum for technical personnel. A committee under chairmanship of Chief Engineer, TPRM Division, was constituted under the aegis of CEA with members from NTPC, DVC, BHEL, SEIMENS, L&T, STEAG, TATA Power, NPTI and CPRI for preparation of the Standard operating procedure (SOP) and training curriculum for power plants operators. The report also discusses the prerequisites for reducing minimum operating stable load and also suggested close monitoring of unit operational parameters like combustion, flame stability, turbine casing top bottom differential temperature etc.

I would like to appreciate the efforts of team of officers under able guidance of Shri B.C. Mallick for timely preparing the SOPs and training curriculum. I am confident that the document shall help the utilities to prepare themselves for 55% load operation and impart required training to the operating personnel for safe 55% load operation.

Gupta

(Praveen Gupta)

फैक्स/Fax : 011-26197267

भारत सरकार
GOVERNMENT OF INDIA
केन्द्रीय विद्युत प्राधिकरण
CENTRAL ELECTRICITY AUTHORITY
विद्युत मंत्रालय
MINISTRY OF POWER
सेवा भवन, रामकृष्ण पुरम्
SEWA BHAWAN, RAMAKRISHNA PURAM

नई दिल्ली-110066, दिनांक :
NEW DELHI-110066, Dated :

Bikash Chandra Mallick
Chief Engineer

ACKNOWLEDGEMENT

The flexible power can be made available from various resources like Hydro Power Plants, Pump Storage System, Gas Power Plants, Coal based Power Plant and Battery Storage System. Our first preference should be to utilize cheapest flexible power available in the system like Hydro Power Plants and Pump Storage System. Coal based plants have the capability to operate at lower loads, provide more than one percent ramp rate and it has also been found to be cheaper flexible resource.

Many coal fired generating units have been operating at 55% load as and when need arises in the grid. However, many other units are yet to achieve this operating milestone to support the grid. Reasons cited are the concerns regarding safety, security, availability and lack of support from original equipment suppliers. To tackle the issue, a committee was constituted by CEA to prepare a **Standard Operating Procedures (SOPs)** for operating coal fired generating unit at 55% load. A comprehensive SOP has been prepared which includes prerequisites of Boilers and Turbine parameters. Also discussed various issues which may be faced by generating utilities in long term. A training curriculum for developing trained power plant personnel is also included in the report for safe and efficient plant operation at 55% load. The SOPs prepared shall help coal based generating utilities in understanding the issues/ the up gradations required in the plants, if any and in the skills of the operators.

I express my sincere thanks to all the committee members from NTPC, DVC, MAHAGENCO, TANGEDCO, BHEL, Tata Power, L&T, Siemens, STEAG, NPTI, CPRI for their active participation during deliberations and providing valuable inputs. I am thankful to Chairperson, CEA and Member (Thermal), CEA for valuable guidance. Finally, I appreciate the efforts of TPRM Division and their support in bringing out the SOP.

(B.C.Mallick)
Chief Engineer and
Chairman of the Committee

CONTENTS

ABBREVIATIONS

MOP	Ministry of Power
CEA	Central Electricity Authority
NTPC	National Thermal Power Corporation
DVC	Damodar Valley Corporation
BHEL	Bharat Heavy Electricals Limited
L&T	Larson & Toubro
CPRI	Central Power Research Institute
NPTI	National Power Training Institute
NDC	Nationally determined contribution
RES	Renewable Energy Sources
NRE	New & Renewable Energy
MTL	Minimum Technical Load
SOP	Standard Operating Procedures
TML	Technical Minimum Load
TPP	Thermal Power Plant
MS	Main Steam
HRH	Hot Reheat Line
TG	Turbine Governor
SH	Superheat
RH	Reheat
VM	Volatile Matter
PA	Primary Air
TDBFP	Turbine Driven Boiler Feed Pump
MDBFP	Motor Driven Boiler Feed Pump
CRH	Cold Reheat
SCAPH	Steam Coil Air Preheater
TMCR	Turbine Maximum Continuous Rating
DP	Differential Pressure
BFP	Boiler Feed Pump

ID	Induced Draught
FD	Forced Draught
SWAS	Steam & water Analysis
mmWCL	Millimetres per Water Column Length
SADC	Secondary Air Damper Control
HP	High Pressure
HPT	High Pressure Turbine
IPT	Intermediate Pressure Turbine
LPT	Low Pressure Turbine
MW	Megawatts
OEM	Original Equipment Manufacturer
O&M	Operation and Maintenance
PM	Preventive Maintenance
APC	Auxiliary Power Consumption
FG	Flue Gas
AVT	All volatile treatment
PF	Pulverised Flow
SPM	Suspended Particulate Matter
APH	Air Preheater
FEGT	Furnace Exit Gas Temperature
DCS	Distributed Control Systems
FDS	Functional Design Specification
P&ID	Piping and instrumentation Diagram
ESV	Emergency Shutdown Valve
IVSV	Idle Vacuuming Switching Valve
HHV	Higher Heating Value
EHTC	Electro Hydraulic Turbine Control
CMC	Coordinated Master Control
HFO	Heavy fuel Oil
LFO	Light Fuel Oil
EBD	Emergency Blow Down

FRS	Feed Regulating Station
WW	Water Wall
DMCW	De Mineralized Cooling Water
GSC	Gland Steam Condenser
HPCV	High Pressure Check Valve
ECO	Economiser
RGMO	Restrictive Governor mode operation

1. BACKGROUND

1.1 Flexibilisation of Thermal Power Plant

India is moving ahead to achieve nationally determined contribution (NDC) of 40% of installed renewable capacity by 2030. The introduction of large scale renewable generation in the grid is bringing a new set of challenges in the power sector.
The inconsistency and intermittency of solar & wind power has to be managed by other sources of generation in order to ensure the grid stability. Flexible operation of existing coal-fired power plants is very much required to ensure security, reliability of power supply and stability of electricity grids while maximizing generation from renewable energy sources (RES) & integration of the same into grid, because thermal generation capacity of 209 GW constituting 54% of total installed capacity is the dominant part of power generation in the country and more than 70% of country's energy demand is being met from thermal generation. Thus, Flexible operation of thermal power plant is essential for handling the instability & intermittency of renewable generation.

1.2 Committee Formation

A meeting was held under the chairmanship of Hon'ble Minister of Power and NRE on 06.05.2022 to discuss the technical issues related to flexible operation/Technical Minimum of Thermal Power Plant for smooth integration of renewable generation. In the meeting it was decided that a operating manual for attaining/operating at 55% technical minimum load (TML) of thermal power plant and a training curriculum for technical personnel for the same was to be prepared by CEA.

In this regard a committee was constituted under the aegis of CEA with member from NTPC , DVC , BHEL , SEIMENS , L&T , STEAG , TATA Power for preparation of the operating manual and training curriculum .The composition of committee is as under :-

1. Sh. B.C. Mallick , Chief Engineer	CEA	Chairman of committee
2. Sh. Pravir Kumar , Director	CEA	Convener
3. Sh. Om Kant Shukla, Director	CEA	Member
4. Sh. Rohit Yadav, Deputy Director	CEA	Member
5. Sh, Vikalp Saini, Assistant Director	CEA	Member
6. Sh. Srinivasa Rao Gaddamanugu, GM	NTPC	Member
7. Sh. Dipankar Biswas, GM	NTPC	Member
8. Sh. Vijaya Nand Sharma, DCE	DVC	Member
9. Sh. Vijay V Namjoshi, Chief (Generation)	Tata Power	Member
10. Sh. P S Kumar, CEO	Steag	Member
11. Sh. Ian Rebello	Siemens	Member

12. Sh. Dhiman Chattopadhyay, GM	BHEL	Member
13. Sh. Akram Ansari, Sr. Manager	BHEL	Member
14. Sh. Rajneesh Kumar, Head	L&T	Member
15. Sh. Durgasankar Sahu	NPTI	Member
16. Sh. N. Rajkumar, Joint Director	CPRI	Member

Following officers were also invited as Special Invitees in the subsequent meetings of the committee:

1. Sh. Eknath Moze , CE	Mahagenco	Member
2. Sh. S. Parmeswaran , SE	Tangedco	Member

The main objective of this committee are as under:

i. To prepare the Standard Operating Procedures (SOPs) to address the challenges of Flexibilisation and achieve the target of TML (Technical Minimum Load).

ii. To prepare a training curriculum for technical personnel of TPPs(Thermal Power Plants) for the above purpose.

2. STANDARD OPERATING PROCEDURE FOR 55% MINIMUM TECHNICAL LOAD OPERATION

2.1. Objective

To enable coal based thermal Generating Units to run at a Technical Minimum Load of 55% of Rated capacity.

2.2. Scope

This document covers the operating procedure for reducing Unit load from peak load to the current Technical Minimum Load i.e. 55% of Unit rating and for sustaining at 55% Load for coal based Thermal Power Plants.

2.3. Introduction

With rapid rise in renewable energy addition, operation regime of coal-based power plants in India, which is primarily designed as base load power plants has changed over the past few years. This has warranted higher load ramp rates, lower minimum loads, and frequent unit start-ups. Minimum load operation is crucial for coal-based plants during the periods of low demand and high renewable energy injection into the grid, as they are expected to operate in follow up mode.

As coal-based power plants were not designed for prolonged operation at minimum load, reducing to minimum sustainable load imposes many challenges with respect to reliability, efficiency, and equipment health.

Currently Indian coal based thermal Units are being operated at a Technical Minimum Load of 55% to 70% of their rated capacity. If all the Units operate at the lowest possible Technical Minimum Load, then the excessive load cycling, start-ups and shutdowns can be reduced. The target TML of 55% can be reached in a single step (from 70% to 55%) or in two steps (70% to 60% and then to 55%). In each of the steps, ensure that all the Combustion equipment, monitoring equipment and control loops are healthy before starting to reduce the Unit load. Slowly reduce the load watching for any stumbling blocks and address them. Closely monitor Unit operation with respect to the required operational parameters and evolve the practices to be followed at 55% TML for safe and efficiency Unit operation.

2.4. Prerequisites for reducing minimum operating stable load to 55%:

2.4.1 Boiler

(i) Ensure that basic auto control loops such as feed water flow, airflow, and steam (MS/HRH) temp control, furnace draft control, etc. are healthy and in operation.

(ii) Ensure Fuel Air Dampers, Auxiliary Air dampers, Over Fire Air dampers, Burner tilt, Flame scanners and Pulveriser controls are in proper working condition.

(iii) The healthiness of Flame Scanner is to be checked regularly and necessary action to be taken as required to capture flame at TML. Ensure Furnace Cameras, if available, are in place and showing clear picture of Furnace.

(iv) Spray control for SH and RH should be re-tuned for meeting the requirement during load changes in the entire load range. Generally, auto loops are tuned for response in the range of 60% to 100% load range.

(v) Burner Tilt is to be in Synchronism in all the corners and elevations.

(vi) Requirement of Minimum Volatile Matter content and moisture content in coal being fired is to be ensured nearer to the design value. In case of low VM, blending may be considered.

(vii) Review Boiler Load Index Vs Oxygen curve for maintaining sufficient wind box to furnace differential pressure at low loads as low differential pressure causes flame to come closer to the burner resulting in damage to the burner. This will also ensure proper turbulence at low load operation and helps in avoiding the fire ball to become less intense and dilated.

(viii) Ensure Uniform coal flow through all coal pipes with preferably high coal fineness by conducting dirty air pitot test at minimum mill loading.

(ix) Optimize mill PA flow while ensuring no coal settles in coal pipes (Air Fuel velocity in the mill discharge pipe should not be below 20 m/s) and velocity at burner nozzle is more than speed of flame propagation. Modify PA Vs Coal flow curve accordingly (constant PA for 0 to 50% coal flow range).

(x) It is suggested to implement online monitoring of coal discharge pipe temperature to capture coal settling tendency due to low optimised PA flows.

(xi) Ensure no air ingress into furnace and flue gas ducts. Continuous CO monitoring is suggested to validate excess O_2 as CO is unaffected by air-in-leakages. Hence reducing zones in furnace can be eliminated.

(xii) It is suggested to ensure Coal mill steam inerting system charged and in auto with high CO value.

(xiii) In case of TDBFP, steam source from CRH should be available. Steam source changeover from Extraction to CRH and vice versa should be smooth to avoid disturbance in the Feed water flow.

(xiv) Superheater and Reheater metal temperature during load reduction and low load operation should be kept under limit.

(xv) Mill outlet temperature should be maintained minimum 70°C for Indian coals if required, SCAPH to be charged.

(xvi) Ensure Furnace to Wind box delta P are in Auto Mode of operation. For ensuring stability at 55% TMCR load, non-firing coal dampers' opening (coal dampers of mill which are not in service) should be optimized (typically < 30%) to increase Furnace-Wind Box DP and to ensure combustion quality.

(xvii) Unburnt Carbon in Ash is to be analysed frequently to assess combustion quality.

(xviii) To avoid drum level disturbances due to opening of BFP recirculation valves during disturbances at low loads, replacing ON/OFF recirculation valve with Control valve may be considered for better control.

(xix) Sliding pressure curve to be reviewed for lower load operation wherever applicable.

(xx) Developing online PA fan operating point display and installation of reliable stall sensing mechanism for better monitoring and control. It is suggested to install stall Protection Measures in PA Fans and ID/FD fans. In case, no. of Mills is to be reduced to ensure minimum feeder loading, PA header pressure is to be suitably modified to prevent PA Fan stalling.

(xxi) In once through supercritical boiler, Feed Water flow control is of utmost importance. Feed water flow is dependent on function based on boiler load index. The implementation of this function must be ensured with fair amount of accuracy.

(xxii) For once through boiler, steps are to be taken to ensure that water level at Water Separator Storage tank does not increase by ensuring appropriate degree of superheat at water separator inlet.

2.4.2 Turbine

(i) TG governor characteristics to be checked periodically during shutdown.

(ii) Turbine casing top bottom differential temperature during load reduction and low load operation should be kept under limit.

2.4.3 General

(i) Calibration of all the critical parameters measuring instruments is highly essential.

(ii) For 55% minimum load operation the ramp rates (up/down) shall be about 2%. However, in future the proposed new regulation shall have to be followed regarding the ramp rates.

(iii) All steam & water analysis system (SWAS) is charged and available for online monitoring.

(iv) RGMO (Restrictive Governor mode operation) may have to be bypassed.

2.5. Procedure:

2.5.1 Gradually reduce the Unit load by reducing load set point till loading comes to 80%.

2.5.2 To further reduce the Unit load, take out one feeder (either bottom or top) from auto and gradually reduce the coal feeding and stop the Milling system. Mill combination plays an important role in flame stability and to maintain rated main steam and reheat steam temperatures. Select the Milling system to be stopped according to the behaviour of the Boiler.

2.5.3 Mill cut-out procedure:

i. Gradually reduce feeder speed / coal flow through feeder to minimum either manually or by reducing the feeder bias set point
ii. Ensure that the Mill outlet temperature does not increase by modulating the hot air and cold air dampers
iii. Reduce PA flow through the Mill as per the reduced coal flow.
iv. Open mill inerting steam (If available) valve, if the coal fired is having high volatile matter, to avoid mill explosions during lean mixture conditions.
v. Stop the feeder
vi. Close hot air damper and gate
vii. Keep minimum cold PA through the Mill, till the Mill outlet temperature comes down
viii. Close the cold air damper and cold air gate.
ix. Stop the Mill after ensuring no coal is left in the Mill.

2.5.4 Following the above step reduce the coal feeding and stop one more Milling system at about 60% of unit load. Ensure that minimum 3 consecutive Mills are in service or a gap of not more than one elevation. For a safer side ensure each of the running mill is loaded more than 50%.

2.5.5 Running fewer mills at higher loading over running more mills at lower loading increases the combustion stability; hence restrict the number of mills according to individual mill loading >60%. (This may create a situation where in case of one running mill trips Unit tripping on flame failure has a very high probability. Reliability of feeders and Mills to be very high. Mill unloading due to foreign material in Feeder or Mill need to be avoided).

2.5.6 Air Preheater cold end corrosion due to low flue gas temperature at low loads and low average cold end temperatures in winter season. SCAPH to kept in charged condition as per the requirement.

2.5.7 Ensure wind box pressure is maintained around 50 to 60 mmWCL by proper operation of SADC and excess air adjustment during load reduction.

2.5.8 Deviation in Super heater and Reheater temperatures from rated values at low load operation can be reduced by adjusting mill combination, burner tilts or biasing fuel to upper burner levels, increasing O2, and Optimising wall soot blower operation frequency. All these actions result in balancing heat transfer in the first pass and convective pass.

2.5.9 Ensure SH & RH temperature variation is within +/- 15 ^{0}C. Check for any transients in differential expansion of turbine rotor and casing. Ensure HP turbine exhaust temperature is within limit.

2.5.10 Rate of saturation temperature change in boiler drum is to be monitored and limited while reducing the load. Drum top/bottom temperature difference to be maintained within limits during load reduction.

2.5.11 Soot blowing is not possible at low loads as it causes further disturbance in boiler flame. Unit load needs to be increased for carrying out soot blowing as and when required.

2.5.12 To gain confidence, after reducing the load to 60% of rated load, for initial load reducing trials, wait for 1 hr and observe all the parameters like flame intensity, MS/HRH temperatures, SH/RH spray levels, etc. for their stability.

2.5.13 Keep reducing the Unit load further to reduce the Unit load to 55% of rated capacity.

2.5.14 Open on BFP recirculation valve depending upon the requirement based on design flow Vs speed curve at low load.

2.5.15 Operate unit on modified sliding pressure (wherever available) mode to avoid possible steaming in economizer during load reduction.

2.5.16 Diligently monitor system chemistry during load reduction.

2.6. Operational Issues faced in Low load operation in case of Ball and Tube mill:

2.6.1 Difficulty in operating at low load conditions for units using Ball and Tube mills due to inherent limitations.

2.6.2 During single mill operation at 2 elevation may be explored at 55% operation without oil support.

2.6.3 During 1 ½ mill operation (ball tube mill) there may be a chance of explosion of mill when it operates with one side continuously. It is good practice to run the mill with both sides in service to avoid unwanted happenings.

2.6.4 During 2 mills low load operation, the constraint of ignition energy permissive in the adjacent elevation has to take into consideration and forced to run the mills with unequal loadings results in fluctuations of boiler load/stability of unit and which leads to chances of tripping of unit.

Total 18 units of 4310 MW capacity are running on Ball and Tube Mill. After extensive deliberation by the Committee, it has been suggested to Conduct a pilot test in association with OEM for Low Load operation (55%) at a 210 MW size Unit of DVC running on Ball and tube mill so that the operational issues being faced by such units can be studied in detailed and resolved accordingly.

2.7. Long Term Concerns/Measures:

2.7.1 Increased stresses in thick components of boiler and turbine due to cycling and higher equipment life consumption. Life time monitoring systems may be considered for thick wall components for better control and monitoring.

2.7.2 Increased Equipment failures and non-availability. Usage of Predictive Analytics for early detection of equipment anomalies with subsequent actions may be considered. Since all equipment shall have cyclic loading due to ramp up and down, proper Condition Monitoring is to be taken up with a predetermined schedule – in consultation with OEM, for assessment of equipment health. Further Capex allocation is to be ensured for through overhauling of all lead bearing equipment during annual shutdown

2.7.3 Increased O&M cost and decreased reliability. PM schedule to be reviewed for equipment and additional points may be included in checklist in consultation with OEM to minimise equipment failure.

2.7.4 Overall unit efficiency, heat rate and APC deterioration will increase financial burden.

2.7.5 Usage of Performance Optimisation tools for minimising losses due to deteriorated heat rate and APC at low loads.

2.7.6 With lowering load, amount of steam entering the feed water heater decreases, and the amount of drain also decreases, therefore it becomes difficult to control the drain level.

2.7.7 Steam pressure decreases with lowering load. At the economizer, the feed water temperature may approach saturated liquid temperature, and evaporation may occur. If evaporation occurs, the feed water flow may be interrupted, and the metal temperature of the water-cooling wall may rise.

2.7.8 In imported coal-based plant, Fuel flow and air flow decrease, and balance of fuel and air sometimes collapses at some space in furnace of boiler, and combustion becomes unstable.

2.7.9 The methodology of Biomass firing and impact of biomass firing on flame stability at 55% MCR to be explored.

2.7.10 Mill Centre pipe may be cleared periodically as a precaution.

2.7.11 Plant specific practices based on the design and equipment condition to be followed at 55% TML for safe and efficient Unit operation.

2.7.12 Higher ash accumulation is observed in flue gas path due low flue gas velocity endangering structural stability. To be monitored and suitable action to be taken. At any point do not allow water to enter into FG ducts.

2.7.13 Low Primary air flows may lead to Primary Air fans operating in stalling zone, especially in case of a coal mill trip at lower loads.

2.7.14 High Super heater and Reheater sprays at low loads lead to increased tendency of deposits in super heaters, reheaters and turbine blades. Ensure that the Station adheres to Water chemistry guidelines. Consider changing the chemical treatment regime to AVT(O) from AVT(R) to mitigate the adverse effects at low load operations.

2.7.15 Mill Centre pipe may be cleared periodically as a precaution.

2.7.16 Ensuring equalisation in PF flow in coal pipe by periodic mill maintenance and orifice adjustments.

2.7.17 Installation of vibration monitoring instruments in critical rotating equipment, if not available.

2.7.18 Monitoring of emissions parameters like SPM, NOx and SOx, and performance parameters like Boiler efficiency, unit heat rate, APC may be done periodically.

2.7.19 Critical parameters like Unburnt carbon, APH exit temperature, FEGT, coal fineness, APH pressure drop should be monitored closely.

3. TRAINING OF OPERATORS AND TRAINERS

3.1. Objective

The purpose of operator training is to train and assess operators in plant operation such as start-up and shut-down, supervision, monitoring and control during normal, emergency situations and in safety procedures. For safe and efficient plant operation at 55% minimum load, there is a need for developing trained plant personnel.

In a highly automated plant and to suit the changing needs of the thermal power plant training, Simulator is helpful to maintain a high level of proficiency of operators. Simulator is highly flexible, can be used in different ways to run a thermal unit.

3.2. Requirement

55% operation of Thermal plant requires highly efficient and skill manpower to ramp down the load and ramp up the load with desired parametric operation particularly for 210 MW and 500 MW Thermal generating units. Adequate training is required on Simulator for developing the confidence in operators to run the power plant at 55% load without oil support. Many simultaneous parameters monitoring are required for all critical equipments for stable and efficient operation at 55% load without oil support.

3.3. Training Programme

The simulators are capable to train the operators at 55% operation without oil firing.

1. Simulator Calibration: "The simulator training to be imparted shall cover the load cycling from maximum continuous load to 70% minimum load at a ramp rate of about 3% and then from 70% to 55% load at a ramp rate of about 2% without oil firing. It shall also include continuous operation at 55% minimum load". During this operation, all critical parameters are to be monitored and unit operation stability to be checked. Monitoring of Critical Parameters are to be recorded during 55% Operation without oil support. Operators need to record and monitor the parameters and must adopt the process of this operation with more skilled training. With proper training only operator can do successful operation and handle the emergency if any during this operation.
2. The training institutes providing training related to 55% Technical Minimum Load of thermal power plants should be recognised by CEA/MoP or the state governments.
3. Duration & Batch size: The training institute shall impart training as per the modules developed specifically for the above operation regime. The training duration shall be of 2 weeks for Operators, 1 week for trainers and at a time 12-15 operators can be trained. No of trainers per batch should be 2-3. Focus areas

in the Simulator training will be cold and warm start up conditions, 55% Operation (Manual) –Ramp Up with ramp rate, 55% Operation (Manual) -Ramp down with ramp rate, 55% Operation (Auto) –Ramp Up with ramp rate, 55% Operation (Auto) -Ramp down with ramp rate, Emergencies & Malfunctions, Unit Stable Operation, Critical Equipment Changeover etc.

The capability of simulators needs to be assessed and fine-tuned as per the requirement of 55% load operation at Institute of NPTI, Central, State and Private power training centres where Simulators are available. The details of available Simulators for Thermal Power Plants at NPTI and various Utilities is attached as Annexure II.

The 210 MW and 500MW Simulator Training material of NPTI has been attached as Annexure I.

3.4. Recommendation

Plant Operators/Trainers must train on the simulator for 55% Load operation with 3% ramp rate above 70% load and 2% ramp rate below 70% load and without oil support. Simulator Training to the power Plant operators will enhance their skills and make them ready for low load operation without oil support and help in making the plant stable during ramp up and ramp down at lower load.

The operators of Central, state and private utilities can also be trained at the training centres of NPTI or the training centres of major utilities to gain confidence. Further, utilities which have achieved 55% load operation without oil support in their units can extend the support for achieving the 55% operation at other utilities which are facing difficulties. In this regard the list of NTPC's units operating at 55% load along with their location is attached as Annexure III.

As far as possible the simulator training pertaining to the 55% Technical Minimum Load of thermal power plants shall be plant specific.

ANNEXURE I

National Power Training Institute

(Under Ministry of Power, Govt of India)

500 MW SIMULATOR TRAINING MATERIAL

For Lower Load Operation (55% Operation)

NPTI Complex, Sector-33,

Faridabad – 121003 (Haryana)

Introduction

For safe, efficient and economical thermal power plant operation, there are a significant numbers of thermal power plants around the world and new plants based on coal firing are also added into operation regularly. This creates an increasing need for trained thermal power plant personnel.

The thermal power plant simulator model is used for both the training of newly-hired employees and refresher courses of personnel with earlier experience. The main purpose of the Thermal Power Plant simulator is to train and assess operators in the operation of Distributed Control Systems (DCS) and in plant operation, including training in plant start-up and shut-down, emergency situations and safety procedures.

Utilizing thermal power plant operation as the basis for simulation provides our student and employee with a strong foundation, ensuring that their operational procedures and practices will enhance the plant economic efficiency and safety measures.

Objectives/ Purpose

The main purpose of the Thermal Power Plant simulator is to train and assess operators in general plant operation, including training in plant start-up and shut-down, supervision, monitoring and control during normal, emergency situations and in safety procedures. In addition, the simulator can be used as a powerful tool for engineers and plant management to verify process design and control strategies prior to start-up of a plant as well as investigation and testing of operational problems that are normally not allowable under real plant normal operating conditions.

Our simulator is highly fidelity and can be used in a number of different ways to suit the changing needs of the thermal power plant.

Power plant simulator is an effective training tool, with which the actual characteristics of a power plant can be generated through real time execution of mathematical models of various systems on a computer. The trainee operator quickly gains experience in normal, abnormal and emergency operation of power plant through Simulator Training. Operator confidence is increased, resulting in improved efficiency of power plant operating personnel, better equipped to respond to problems and emergencies. The hands-on training in a highly realistic environment provided by the training Simulator cannot be substituted by any other form of training. A well-trained operator runs a plant safely and expensive downtime caused by operator error is significantly reduced. In a highly automated plant, refresher training on Simulator also helps experienced operators to maintain a high level of proficiency.

General

High-Fidelity Simulator for the NPTI 500 MW Unit consist of Functional Design Specification (FDS) is an expansion of the proposal to include information and details not available at the time of proposal. The simulator will realistically represent the systems, processes, and controls, including startups, shutdowns, normal and abnormal operations, and malfunctions, subject to the scope outlined in the signed specification.

The simulator will provide dynamic simulation of a 500MW TPP unit. This 500 MW unit includes, coal Fired, balanced draft and controlled circulation Drum type Boiler.

The simulator will also be a tool for initial training and retraining of control room operators, operation supervisors, and other plant equipment operators in:

- Various plant systems, equipment and their functions
- Following specific plant operating procedures
- Abnormal and emergency events, including malfunctions

The process model consists of the following major systems:

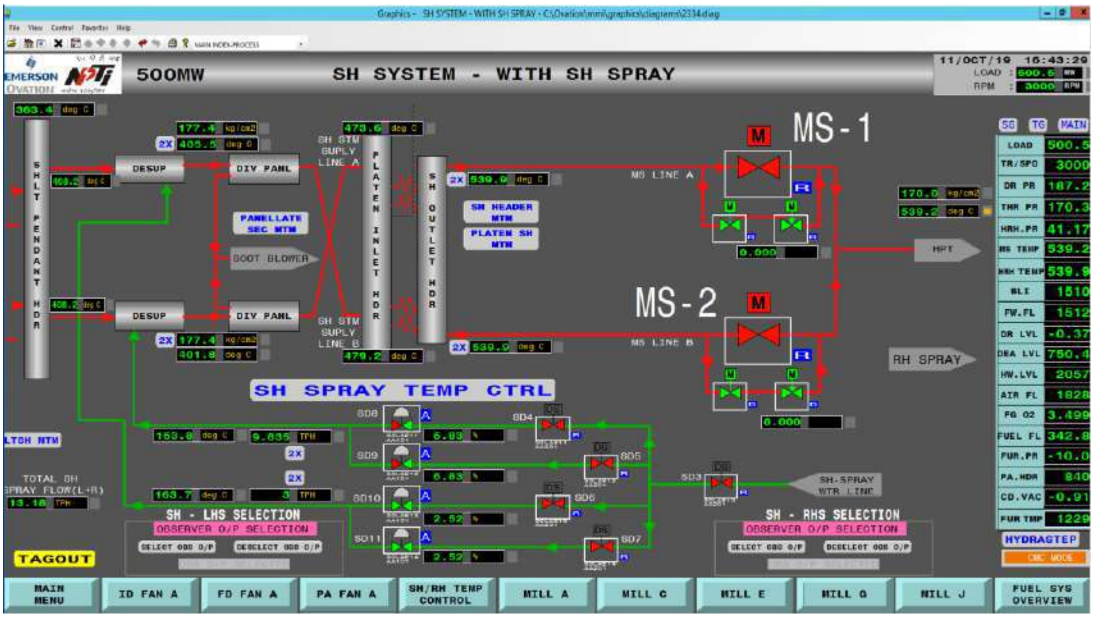
- Turbine
- Boiler
- Balance of Plant
- Electrical
- Miscellaneous Systems

Boiler Model

The boiler section of the process model will be defined in the following sections. The model schematics are based on 500MW design information, system descriptions, P&ID's, verbal and written information from NPTI personnel and will include the following major systems:

Steam from the Drum is directed to the series of Six (6) nodes of Steam cooled walls. It is then passed through the Low Temp SH, SH divisional Panel & Final SH. The superheated steam from the Final SH outlet header node is directed to MS1 network by means of two (2) flow boundaries, feeding inlet steam to the high-pressure section of the turbine.

The Superheaters are Physically Modelled.



Steam at high pressure & temperature from the outlet node of the HP turbine is directed to the RH inlet header node through two (2) cold RH flow paths. Reheater arrangement consist of two (2) headers, one is for inlet & other for outlet and twelve (12) nodes for tube section with six (6) nodes in each parallel flow path. Steam flows through the nodes and gains heat from the heat slabs corresponding to each node.

Turbine Model

The Turbine and its related system of the process model will be represented on the MS1 network (Main Steam & Extraction Steam Network No.1), and will include the following major systems:

- Turbine System
- Boiler Feed Pump Turbine
- Governing Valves System
- Gland Steam Sealing System
- Turbine Drain System

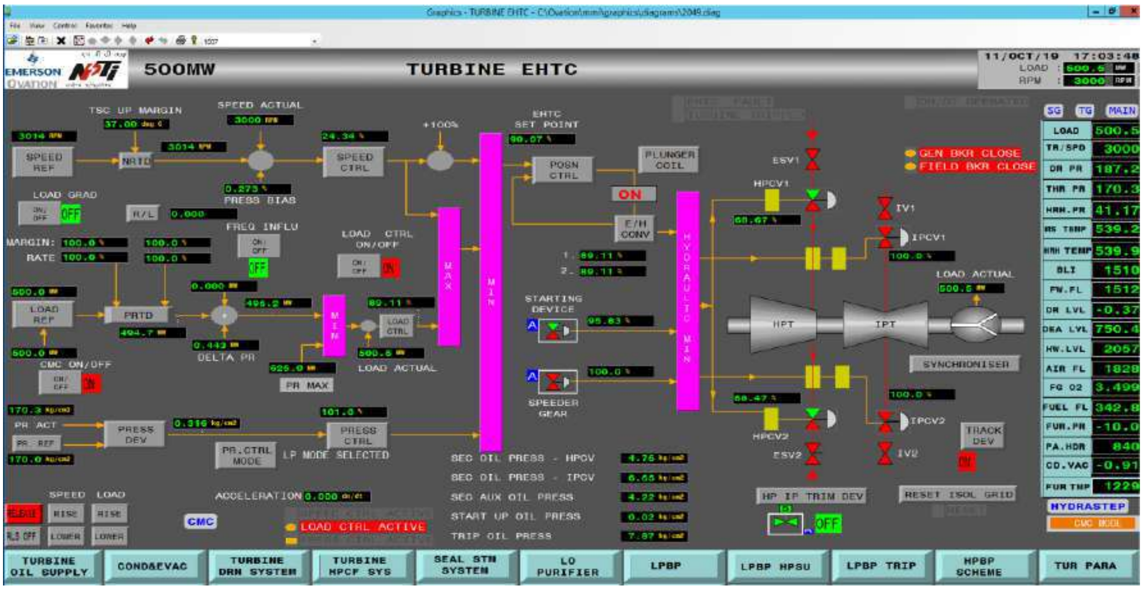
The turbine unit consists of a 500 MW Three Cylinder Single Reheat Condensing Turbine designed for high operating efficiencies and maximum reliability. Turbine icons are used in the model as per the number of extractions. High Pressure (HP) and Intermediate Pressure (IP) and Low Pressure (LP) turbines are taken on a single shaft. High pressure and high temperature steam from the BR1 network is directed through flow & pressure boundaries to the HP turbine inlet node in the MS1 network through two (2) HPT stop valves (ESV) and two (2) HPT control valves.

Steam is directed from the HP turbine exit node to the reheater inlet node, which is then passed through the reheater. The hot reheated steam is then fed to the IP turbine in the MS1 network through two (2) IPT Stop Valves (IVSV) and two (2) IPT Control Valves (IVCV). Steam from the IP turbine exit node is directed to the LP turbine inlet node through a crossover flow path. By opening the HP bypass valve, steam is fed into the cold reheat line.

The de-superheating station is represented as a node in the model to reduce the temperature and pressure. By opening the LP bypass valve, steam is fed into the condenser from the hot reheat.

Steam is extracted from the nodes in the turbine icon and flows through the feed water heaters shells. There are six (3) extractions on the LP Turbine, two (2) on IP Turbine and one (1) on the Cold Reheat (CRH) Line. Extraction #1 is located on the cold reheat line and supplies to HP feed water heater #6A and HP feed water heater #6B. Extraction #2 is from the IP turbine and supplies to HP feed water heater #5A and HP feed water heater #5B. Extraction #3 is from IP turbine to Deaerator and BFPT. Extractions #4, #5, #6 from the LP turbine and supplies steam to LP heaters #3, #2, #1 respectively.

Turbine system section is Physically Modeled. The electro-hydraulic system and governing system are Physically Modeled.



Critical parameters of the 500 MW Thermal Simulator Graphics Representation

NPTI 500 MW Unit Simulator Critical Parameters

Parameter	%Accuracy	Normal	Unit
Main Steam mass flow rate	±2	1498.5	t/h
Main Steam Pressure	±2	176.7	kg/cm2 (g)
Main Steam Temperature	±2	540	°C
Fuel flow	±2	344	t/h
Fuel Heating Value	±2	3300 (HHV)	kcal/kg
Hot Reheat Steam mass flow rate	±2	1335.1	t/h
Hot Reheat Pressure	±2	41	kg/cm2 (g)
Hot Reheat Temperature	±2	540	°C
Combustion Air Flow	±2	1847	t/h
Combustion Air temperature	±2	312	°C
Condensate flow	±2	1177.64	t/h
Feedwater Flow	±2	1481.5	t/h
Feedwater Temperature	±2	253	°C
Economizer Gas Exit Temperature	±2	335	°C
Furnace Pressure	±2	-5	mmwc
Condenser Vacuum	±2	77	mmhg(abs)
Steam Turbine Generator Net Power	±2	500	MW

Coordinated Master Control in Service (CMC)

Coordinated Master Control interfaces the turbine and boiler control together by generating boiler demand with Turbine Target Load point and Coordinated -Master Control point and M.S. pressure set point. Coordinated Master Control can be put in service generally after turbine is loaded to 60% loads.

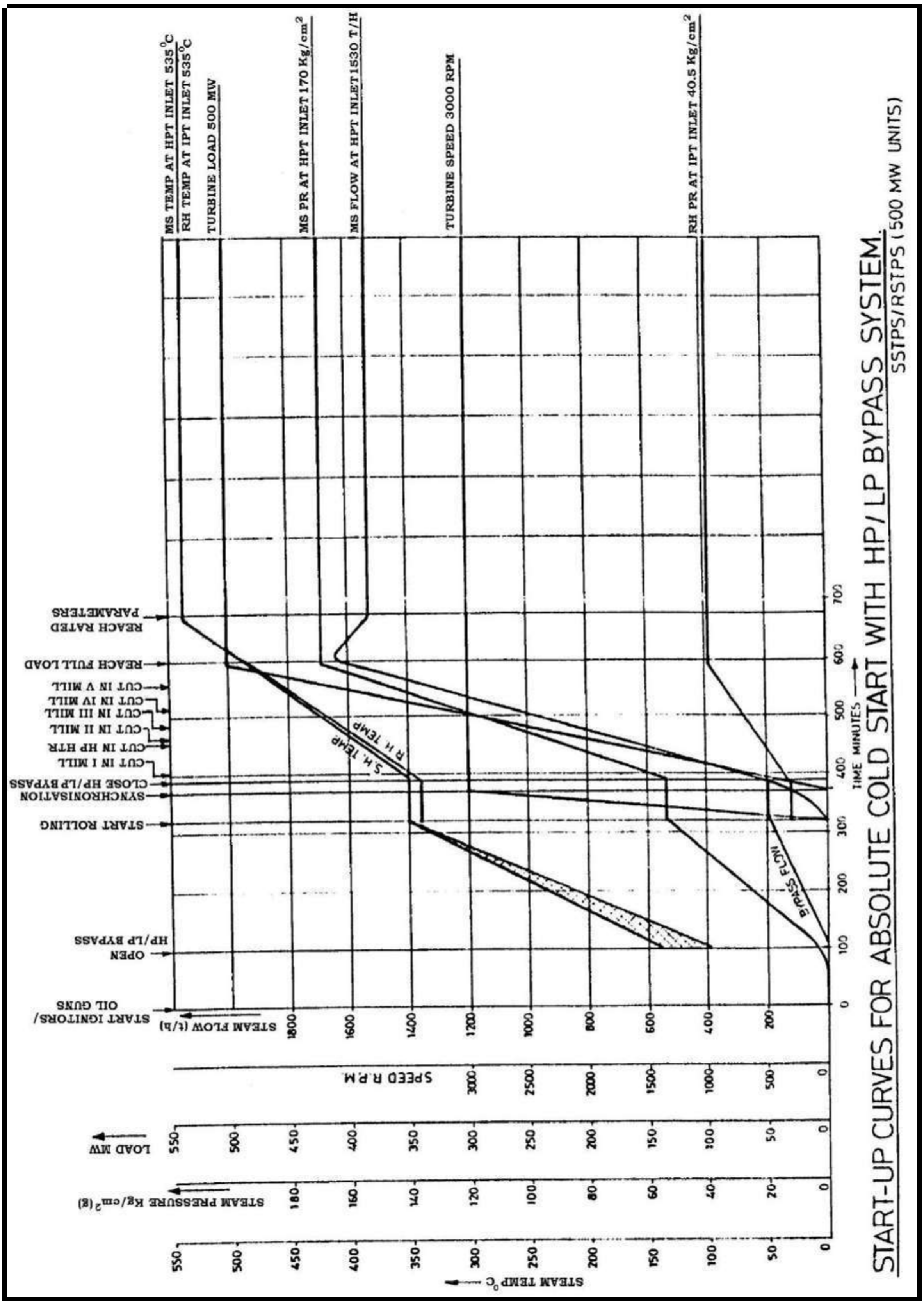
Ensure the following:

1. From the Turbine EHTC Graphic, check the following: -
   a) Load control – ON
   b) Pressure Control Mode – LP Mode Selection
2. Coordinate Master Control- Put the Throttle Pressure Set point same as the running pressure (Ensure Operator mode selection: Constant pressure mode

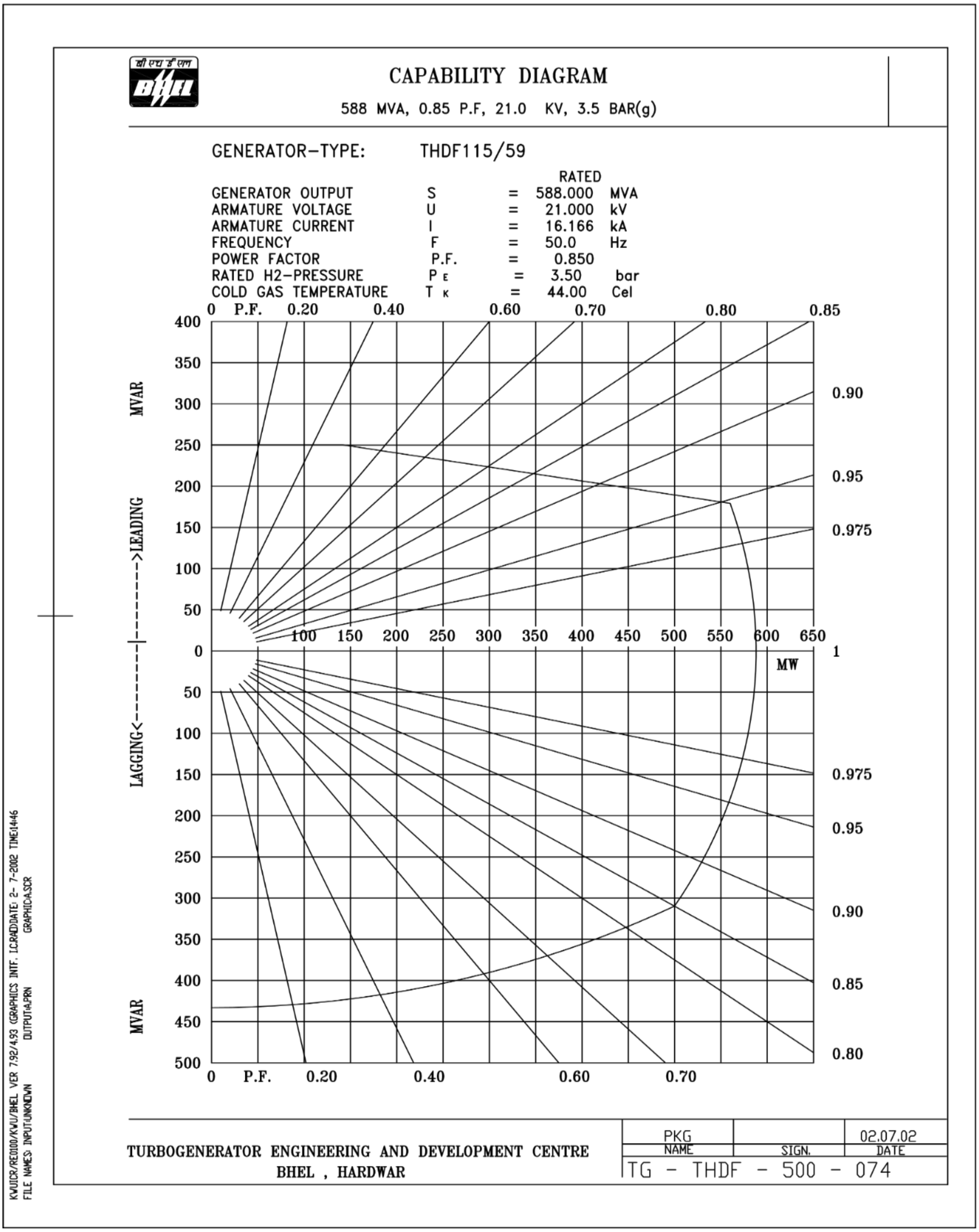
graphics. The pressure set point on EHTC graphic and CMC graphic should be same).

3. Put all the mills in Auto and then put the 'fuel master' in Auto from Graphic of Fuel Flow Control.
4. Put the 'Boiler Master Control' in Auto
5. Put the Turbine in CMC mode from Graphic
6. Click on "CMC" tab in graphic
7. Ensure "Co-ordinated" is flashing in Red colour.
8. Unit Load will be maintained as per operator set point.

Start-up Curve



Generator Capability Curve



Lowering Load –Thermal Backing Operation (55 % Operation Training)

State of Plant - Ensure

- M/C on Load.
- SH/RH spray control on auto.
- Drum level control on auto.
- Furnace pressure control on auto.
- Aux. Steam pressure/temp. Control on auto.
- Ensure igniters and oil guns are in position to be operated in case of requirement
- Mill temp. On auto.
- PA control on auto.
- Burner Tilt system are in alignment with all corners
- SADC on auto.
- HFO temp is adequate.
- Six mills are in service.
- AB, CD, EF elevation oil guns are available.
- Burner Tilt operation OK.
- HP /LP bypass on auto.
- EBD is available for operation.
- FRS high range in service and low range is available.
- Fire fighting equipment's are available.
- WW & APH Soot blowing system is available.
- Feed water flow management in lined condition with TDBFP.
- SH/RH Spray Control in auth with Set points.
- TG Governor & LL setting should be proper.

1. Check HP / LP bypass operation is O.K. and again ensure furnace to wind box dP in Auto Mode. Mills outlet Temperature should be in the range of 65 to 80 Deg C for Indian and Imported Coal.
2. Machine is still in CMC mode; reduce the load gradually from graphics from "OPR LOAD SP" Tab.
3. Steam flow will be reduced, Allow the pressure to drop with the reduction in load.
4. Observe the reduction rate of temperature prescribed by the manufacturer for turbine but never exceeding the forced cooling rate of boiler if required to regulate load to maintain MS and HRH temperature constant.
5. Check Throttle Pressure and Actual Pressure for any wide variation difference.
6. Adjust air flow for required O2 % and Monitor CO.
7. Again reduce the load gradually and check the conditions of Boiler and Turbine, Machine is still in CMC operation.

8. Reduce the up to from 500 MW to 300 MW in the step manner with time stamping of load 5 to 10 MW per minute and observe the Critical parameters. Ramp Down rate up to 55% should be such that it should be in the range of 1.0 to 2.0 % (5 to 10 MW per minute) to make stable parameters. In case of wide variation in parameters, lets parameter to be made stable and observe the position of different parameters and let them to stabilize. Boiler flame stability is very important during ramp down or ramp up process. Every moment of time availability and reliability of mills and feeder needs to be ensured.
9. If Machine is old age More than 12-15 years, please ensure
    - Feed flow
    - Air Flow
    - PA Header Flow
    - Furnace Pressure Control
    - Fuel Flow control
    - Check also bypasses operations.
10. Bring out machine from CMC mode around 270-300 MW and manually reduce the load from the CMC graphics from Tab "LOAD REF/LOAD SP.
11. Close the extraction of HP heaters and bring out HP heaters charging and observe the HP heaters.
12. Further reduce the load and reduce the coal firing and gradually bring out one coal mill from service and if required take two mills but support with oil if unit is old.
13. Reduce Coal demand further and still coal master in auto and check further all critical parameters. Change over from TDBFP to MDBFP, if required.
14. Load Operation need fine control for drum level, drum pressure. If at any moments of time, flame disturbed wide fluctuation may be observed in drum. If required support of oil guns to be taken immediately and ensure pair mode and elevation mode should be available at respective elevation.
15. Density difference at lower load with respect to water and steam is very important for stable operation and balanced load profile.
16. Soot blowing at lower load is to be avoided as it make disturbance in the Flame and Furnace draft.
17. Reduction in Turbine load also reflect disturbance in Condenser vacuum, which need to be monitored perfectly.
18. Metal Temperature and Air Pre-heater, SCAPH Temperature needs to be monitored.
19. In case of Disturbance in Load, Control the MS Pressure and Feed water to avoid tripping & Ensure flame stability.
20. For Older Units, Control System and Control Loops Tuning are required. Some Loops and Sub-loops Control Response are slow, which need to be retuned for ramp up and ramp down as per unit operation and Design Specification, Technical documents.

Critical Set Point Parameters of 500 MW Thermal Power Plant

Sr.No	Equipment	Set Point
1	DMCW(SG)	LONG RECIRCULATION VALVE = 3kg/cm2
2	DMCW(TG)	LONG RECIRCULATION VALVE = 3kg/cm2
3	HOTWELL FILLING	NORMAL VALVE = 1800MMWC EMERGENCY VALVE = 1740MMWC
4	GSC	RECIRCULATION VALVE = 400T/HR
5	DEAERATOR	LEVEL CONTROL VALVE = 750MM
6	HP BYPASS	BP-1 = 35kg/cm2 BPE-1 = 350 DEG C BP-2 = 35kg/cm2 BPE-2 = 350 DEG C
7	LP BYPASS	CV = 5 kg/cm2 CV-1 = 100T/HR CV-2 = 100T/HR
8	FURNACE DRAFT	PRESSURE = - (8 TO 10 MMWC)
9	PA FAN HEADER	PRESSURE = 850 MMWC
10	LFO PUMP DISCHARGE	HEADER PRESSURE = 20 kg/cm2
11	LFO HEADER	PRESSURE = 10 kg/cm2
12	HFO PUMP DISCHARGE	HEADER PRESSURE = 20 kg/cm2
13	HFO HEADER	PRESSURE= 10 kg/cm2
14	HFO HEATER	TEMPERATURE SET POINT = 125 DEG C
15	HFO HEADER	FLOW CONTROL MAIN VALVE = 10 kg/cm2
16	TURBINE DRAIN HPCV	TEMPERATURE SET POINT = 300 DEG C
17	GENERATOR COOLING WATER	TEMPERATURE SET POINT = 45 DEG C

National Power Training Institute

(Under Ministry of Power, Govt.Of.India)

210 MW SIMULATOR TRAINING MATERIAL

For Lower Load Operation (55% Operation)

NPTI Complex, Sector-33,

Faridabad – 121003 (Haryana)

Introduction

For safe, efficient and economical thermal power plant operation, there are a significant numbers of thermal power plants around the world and new plants based on coal firing are also added into operation regularly. This creates an increasing need for trained thermal power plant personnel.

The thermal power plant simulator model is used for both the training of newly-hired employees and refresher courses of personnel with earlier experience. The main purpose of the Thermal Power Plant simulator is to train and assess operators in the operation of Distributed Control Systems (DCS) and in plant operation, including training in plant start-up and shut-down, emergency situations and safety procedures.

Utilizing thermal power plant operation as the basis for simulation provides our student and employee with a strong foundation, ensuring that their operational procedures and practices will enhance the plant economic efficiency and safety measures.

Objectives/ Purpose

The main purpose of the Thermal Power Plant simulator is to train and assess operators in general plant operation, including training in plant start-up and shut-down, supervision, monitoring and control during normal, emergency situations and in safety procedures. In addition, the simulator can be used as a powerful tool for engineers and plant management to verify process design and control strategies prior to start-up of a plant as well as investigation and testing of operational problems that are normally not allowable under real plant normal operating conditions.

Our simulator is highly fidelity and can be used in a number of different ways to suit the changing needs of the thermal power plant.

Power plant simulator is an effective training tool, with which the actual characteristics of a power plant can be generated through real time execution of mathematical models of various systems on a computer. The trainee operator quickly gains experience in normal, abnormal and emergency operation of power plant through Simulator Training. Operator confidence is increased, resulting in improved efficiency of power plant operating personnel, better equipped to respond to problems and emergencies. The hands-on training in a highly realistic environment provided by the training Simulator cannot be substituted by any other form of training. A well-trained operator runs a plant safely and expensive downtime caused by operator error is significantly reduced. In a highly automated plant, refresher training on Simulator also helps experienced operators to maintain a high level of proficiency.

General

High-Fidelity Simulator for the NPTI 500 MW Unit consist of Functional Design Specification (FDS) is an expansion of the proposal to include information and details not available at the time of proposal. The simulator will realistically represent the systems, processes, and controls, including startups, shutdowns, normal and abnormal operations, and malfunctions, subject to the scope outlined in the signed specification.

The simulator will provide dynamic simulation of a 500MW TPP unit. This 500 MW unit includes, coal Fired, balanced draft and controlled circulation Drum type Boiler.

The simulator will also be a tool for initial training and retraining of control room operators, operation supervisors, and other plant equipment operators in:

- Various plant systems, equipment and their functions
- Following specific plant operating procedures
- Abnormal and emergency events, including malfunctions

The process model consists of the following major systems:

- Turbine
- Boiler
- Balance of Plant
- Electrical
- Miscellaneous Systems

Boiler Model

The boiler section of the process model will be defined in the following sections. The model schematics are based on 210 MW design information, system descriptions, P&ID's, verbal and will include the major systems:

- Combustion Air & Gas System
- Fuel Oil & Coal Firing System
- Boiler Water Side System
- Economizer
- Superheater
- Reheater

Turbine Model

The Turbine and its related system of the process model will be represented on the JTOPSOFTWARE MS1 network, and will include the following major systems:

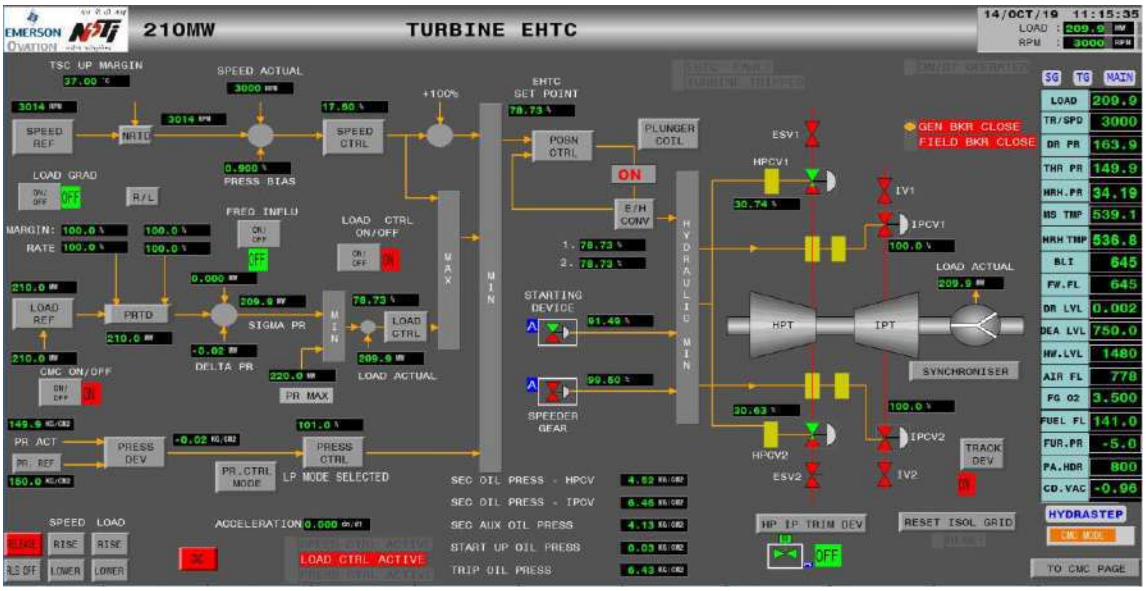
- Turbine System
- Governing Valves System
- Gland Steam Sealing System
- Turbine Drain System

- Turbine lube oil system
- Turbine evacuation system

The turbine unit consists of a 210 MW Three Cylinder Single Reheat Condensing Turbine designed for high operating efficiencies and maximum reliability. Turbine icons are used in the model as per the number of extractions. High Pressure (HP) and intermediate pressure (IP) and Low Pressure (LP) turbines are taken on a single shaft. High pressure and high temperature steam from the BR1 network is directed through flow & pressure boundaries to the HP turbine inlet node in the MS1 network through two (2) HPT Stop Valves (ESV) and two (2) HPT Control Valves. Steam is directed from the HP turbine exit node to the re-heater inlet node, which is then passed through the re-heater. The hot reheated steam is then fed to the IP turbine in the MS1 network through two (2) IPT Stop Valves (IVSV) and two (2) IPT Control Valves (IVCV). Steam from the IP turbine exit node is directed to the LP turbine inlet node through a crossover flow path. By opening the HP bypass valve, steam is fed into the cold reheat line. The de-superheating station is represented as a node in the model to reduce the temperature and pressure. By opening the LP bypass valve, steam is fed into the condenser from the hot reheat.

Steam is extracted from the nodes in the turbine icon and flows through the feed water heaters shells. There are three (3) extractions on the LP Turbine, two (2) on IP Turbine and one (1) on the Cold Reheat (CRH) Line. Extraction #6 is located on the cold reheat line and supplies to HP feed water heater#6. Extraction #5 is from the IP turbine and supplies to HP feed water heater #5. Extraction #4 is from IP turbine to Deaerator. Extractions #3, #2, #1 the LP turbine and supplies steam to LP heaters #3, #2, #1 respectively.

Turbine system section is Physically Modeled.



Critical parameters of the 210 MW Thermal Simulator Graphics Representations

Balance of Plant System Model

The balance of plant (BOP) section of the process model will be represented on the Main Steam (MS1) network, and will include the following major systems:

- Condensate System
- Auxiliary Steam System
- Heater Bypass
- Heater Drain & Vent System
- Condensate Water Makeup System
- Steam Coil Air Pre-Heaters (SCAPH)
- Circulating Water System
- Auxiliaries Cooling Water System
- Equipment Cooling Water System

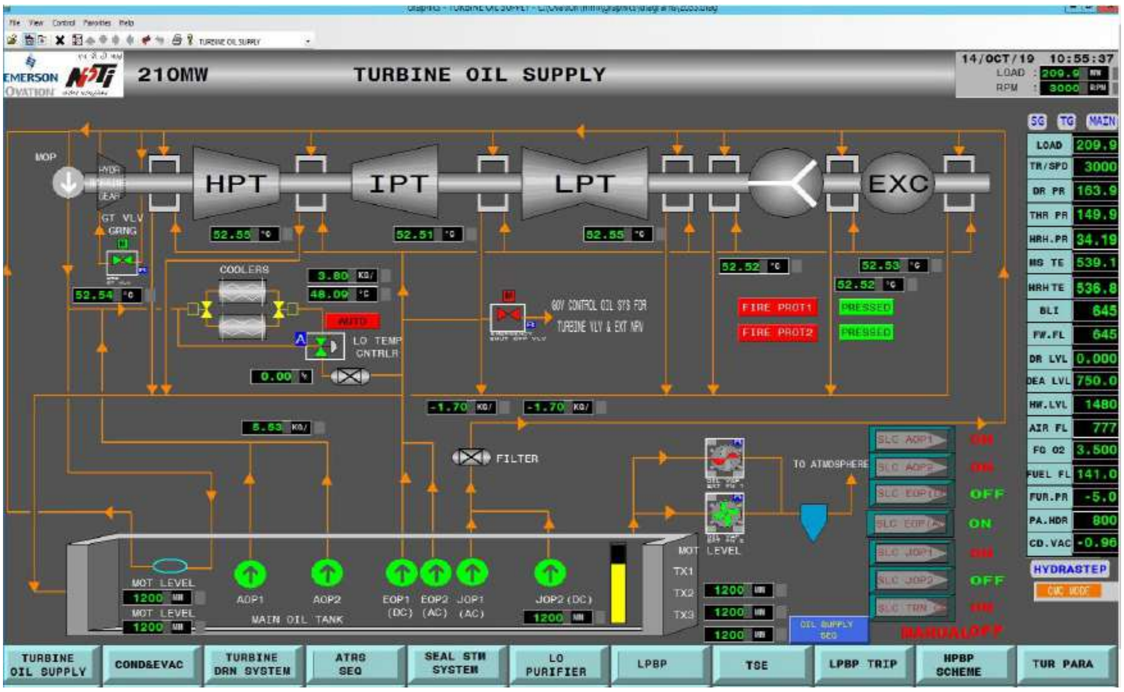
Turbine Lube Oil System

The turbine lube oil system supplies oil to the turbine bearings, generator and exciter bearings. The lube oil system also acts as source of control oil which is being used for operation of Control valves, Stop valves, mechanical protections devices and NRV's etc.

This system consists of several major components listed below:

- Turbine Main Oil Tank
- Main Shaft Oil Pump
- Auxiliary Oil Pump
- Jacking Oil Pump
- Emergency Oil Pump
- Injectors
- Lube Oil Coolers
- Filters/Strainers

Main oil tank is represented by a node which is always assumed to have certain mass of oil available during plant operation. AC auxiliary oil pumps, Emergency oil pump, jacking oil pumps take suction from the main oil tank through respective flow paths.



NPTI 210 MW Unit Simulator Critical Parameters

S. No.	Parameter	Units	Design Value
1	Main Steam Flow	Tons/Hr	700.00
2	Main Steam Pressure L	Bar	155.98
3	Main Steam Pressure R	Bar	155.98
4	Feedwater Flow	Tons/Hr	700.00
5	Feedwater Temperature	DEG C	294.00
6	Feedwater Pressure	Bar	172
7	Furnace Pressure	mmwc	-4.00
8	Generator Gross MW	MW	210.00
9	Turbine Speed	RPM	3000.00
10	Cold Reheat Temperature L	DEG C	352.00

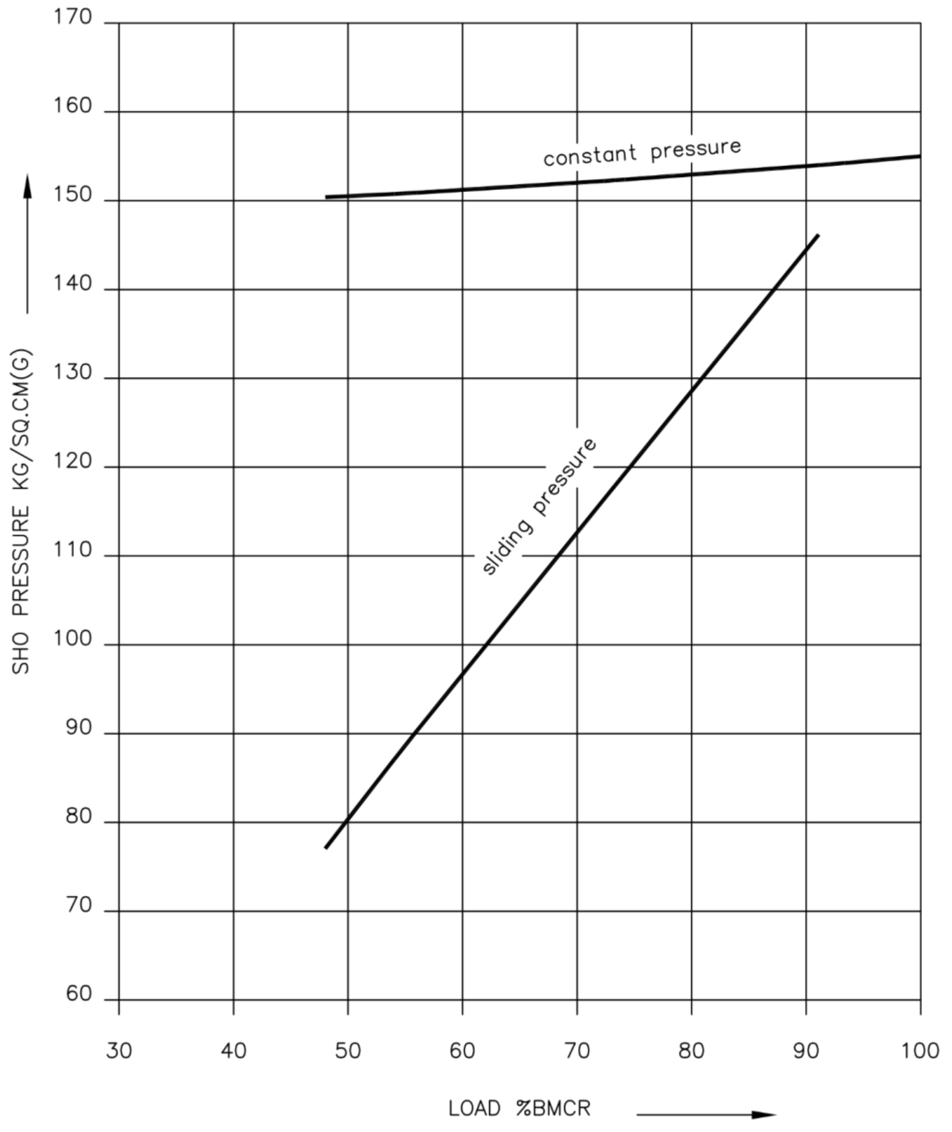
S. No.	Parameter	Units	Design Value
11	Cold Reheat Temperature R	DEG C	352.00
12	Cold Reheat Pressure L	Bar	40.4
13	Cold Reheat Pressure R	Bar	40.4
14	Hot Reheat Temperature	DEG C	540.00
15	Hot Reheat Pressure	Bar	38.8
16	Superheat Outlet Temperature	DEG C	537.00
17	Superheat Outlet Pressure	Bar	156.00
18	Condenser Pressure (Vacuum)	KG/CM2	-0.94
19	ECO out gas Temperature	DEG C	356.00
20	Fuel (Coal) Flow	Tons/Hr	148.00

Coordinated Master Control in Service (CMC)

Coordinated Master Control interfaces the turbine and boiler control together by generating boiler demand with Turbine Target Load point and Coordinated -Master Control point and M.S. pressure set point. Coordinated Master Control can be put in service generally after turbine is loaded to 60% loads.
Ensure the following

1. From the Turbine EHTC Graphic, check the following: -
   a) Load control – ON
   b) Pressure Control Mode – LP Mode Selection
2. Coordinate Master Control- Put the Throttle Pressure Set point same as the running pressure (Ensure Operator mode selection: Constant pressure mode graphics. The pressure set point on EHTC graphic and CMC graphic should be same).
3. Put all the mills in Auto and then put the 'fuel master' in Auto from Graphic of Fuel Flow Control.
4. Put the 'Boiler Master Control' in Auto
5. Put the Turbine in CMC mode from Graphic
6. Click on "CMC" tab in graphic
7. Ensure "Co-ordinated" is flashing in Red colour.
8. Unit Load will be maintained as per operator set point.

SHO PRESSURE Vs LOAD



Project : NTPC/Bongaigaon TPP – 3x250MW							Sheet 3 of 11	
Cont No: 0397–0399			Rev.1		Rev.2		Rev.3	
	Sign.	Date	Sign.	Date	Sign.	Date	Sign.	Date
Engineer: JLJ								
Reviewer: MA								
Approver: MA/SCS								

CPT –1801

Lowering Load –Thermal Backing Operation (55 % Operation Training)

State of Plant - Ensure

- M/C on Load.
- SH/RH spray control on auto.
- Drum level control on auto.
- Furnace pressure control on auto.
- Aux. Steam pressure/temp. Control on auto.
- Ensure igniters and oil guns are in position to be operated in case of requirement
- Mill temp. On auto.
- PA control on auto.
- Burner Tilt system are in alignment with all corners
- SADC on auto.
- HFO temp is adequate.
- Six mills are in service.
- AB, CD, EF elevation oil guns are available.
- Burner Tilt operation OK.
- HP /LP bypass on auto.
- EBD is available for operation.
- FRS high range in service and low range is available.
- Fire fighting equipment's are available.
- WW & APH Soot blowing system is available.
- Feed water flow management in lined condition with TDBFP.
- SH/RH Spray Control in auth with Set points.
- TG Governor & LL setting should be proper.

1. Check HP / LP bypass operation is O.K. and again ensure furnace to wind box dP in Auto Mode. Mills outlet Temperature should be in the range of 65 to 80 Deg C for Indian and Imported Coal.
2. Machine is still in CMC mode; reduce the load gradually from graphics from "OPR LOAD SP" Tab.
3. Steam flow will be reduced, Allow the pressure to drop with the reduction in load.
4. Observe the reduction rate of temperature prescribed by the manufacturer for turbine but never exceeding the forced cooling rate of boiler if required to regulate load to maintain MS and HRH temperature constant.
5. Check Throttle Pressure and Actual Pressure for any wide variation difference.
6. Adjust air flow for required O2 % and Monitor CO.
7. Again reduce the load gradually and check the conditions of Boiler and Turbine, Machine is still in CMC operation.

8. Reduce the up to from 210 MW to 125 MW in the step manner with time stamping of load 2 to 5 MW per minute and observe the Critical parameters. Ramp Down rate up to 55% should be such that it should be in the range of 1.0 to 2.0 % (2 to 5 MW per minute) to make stable parameters. In case of wide variation in parameters, lets parameter to be made stable and observe the position of different parameters and let them to stabilize. Boiler flame stability is very important during ramp down or ramp up process. Every moment of time availability and reliability of mills and feeder needs to be ensured.
9. If Machine is old age More than 12-15 years, please ensure
    - Feed flow
    - Air Flow
    - PA Header Flow
    - Furnace Pressure Control
    - Fuel Flow control
    - Check also bypasses operations.
10. Bring out machine from CMC mode around 135-150 MW and manually reduce the load from the CMC graphics from Tab "LOAD REF/LOAD SP.
11. Close the extraction of HP heaters and bring out HP heaters charging and observe the HP heaters.
12. Further reduce the load and reduce the coal firing and gradually bring out one coal mill from service and if required take two mills but support with oil if unit is old.
13. Reduce Coal demand further and still coal master in auto and check further all critical parameters. Change over from TDBFP to MDBFP, if required.
14. Load Operation need fine control for drum level, drum pressure. If at any moments of time, flame disturbed wide fluctuation may be observed in drum. If required support of oil guns to be taken immediately and ensure pair mode and elevation mode should be available at respective elevation.
15. Density difference at lower load with respect to water and steam is very important for stable operation and balanced load profile.
16. Soot blowing at lower load is to be avoided as it make disturbance in the Flame and Furnace draft.
17. Reduction in Turbine load also reflect disturbance in Condenser vacuum, which need to be monitored perfectly.
18. Metal Temperature and Air Pre-heater, SCAPH Temperature needs to be monitored.
19. In case of Disturbance in Load, Control the MS Pressure and Feed water to avoid tripping & Ensure flame stability.
20. For Older Units, Control System and Control Loops Tuning are required. Some Loops and Sub-loops Control Response are slow, which need to be retuned for ramp up and ramp down as per unit operation and Design Specification, Technical documents.

ANNEXURE II

Details of Available Simulators of Thermal Power Plants:

S.No	Name of the Utility	No. of Simulators with Capacity	Location	Supplier
1	NPTI	210/500 MW	Faridabad, Durgapur, Nagpur, Banglore, Shivpuri, Alapuzzha	M/s Emerson
2	KSTPS , KOTA	01 – 195MW	Kota Super Thermal Power Station (KSTPS), Kota	STEAG ENERGY Pvt. Ltd., Noida, New Delhi
3	SSTPS, Suratgarh	01 – 250 MW	Suratgarh Super Thermal Power Station (SSTPS), Suratgarh, Baran	STEAG ENERGY Pvt. Ltd., Noida, New Delhi
4	Jindal Power Limited , Tamnar ,Raigarh	01 – 600 MW	Jindal Institute of Power Technology, Jindal Power Limited , Tamnar, Raigarh,	BHEL Make Plant – Supplier M/S Honeywell
5	Jindal Power Limited , Tamnar ,Raigarh	01 – 250 MW	Jindal Institute of Power Technology, Jindal Power Limited , Tamnar, Raigarh,	BHEL Make Plant – Supplier M/S Honeywell
6	Jindal Power Limited , Tamnar ,Raigarh	01 – 135 MW	Jindal Institute of Power Technology, Jindal Power Limited , Tamnar, Raigarh,	CFBC boiler – Supplier M/S Emerson
7	Guru Gobind Singh Super Thermal Plant Ropar (PSPCL)	06 – 210MW	Guru Gobind Singh Super Thermal Plant Ropar (PSPCL)	Tri-Angle Simulation Pvt. Ltd. Mumbai.
8	WBPDCL	01- 210MW	Bakreshwar Thermal Plant	GSE Solution
9	TANGEDCO	01 – 800 MW (under 37stablishment)	North Chennai Thermal Power project – III	M/s.- BHEL
10	TANGEDCO	Establishment of Simulators at Thermal Training Institute & Research Centre for 210 MW and 600 MW is under process		

11	CESC Limited	01 – 250MW	Budge Budge Generating Station, Pujali	STEAG Energy Services (India) Pvt. Ltd.
12	GSECL	01 – 500 , 660 , 800MW	Wanakbori Thermal Power Station	BHEL
13	MAHAGENCO	02 – 210MW	Nashik Training Centre	M/s Traingle Simulation Pvt. Ltd , Mumbai
14	MAHAGENCO	01 – 500MW	Nashik Training Centre	BHEL Max DNA Based
15	MAHAGENCO	02 – 660MW	Koradi Training Centre , Nagpur	Steag Energy Services (India) Pvt. Ltd.
16	MAHAGENCO	01 – 500MW	Training Sub Centre , CSTPS	M/s Traingle Simulation Pvt. Ltd , Mumbai
17	APGENCO	04 – 210MW	Traning institute, Dr. NTTPS, APGENCO	M/s BHEL, EDN, Banglore
18	APGENCO	01 – 500 MW	Traning institute, Dr. NTTPS, APGENCO	M/s BHEL, EDN, Banglore
19	APGENCO	01 – 600 MW	Traning institute, Dr. NTTPS, APGENCO	M/s BHEL, EDN, Banglore
20	NTPC LTD	01-500MW 01-250MW	Korba	Emerson Process Management
21	NTPC LTD	01-660MW	Sipat	Yokogawa Ltd
22	NTPC LTD	01-660MW 01-800 MW	Solapur	M/s Steag Ltd
23	TSGENCO	01-500 MW 01-800MW (Installation of LVS Pending in 800 MW Simulator)	CETD, Adm. Building, KTPS-VI, Paloncha, Kothagudem	M/s BHEL, EDN, Banglore

ANNEXURE III

NTPC Group Coal Station Details: Operating at 55% MTL

S.No	NTPC Coal Stations	State	Installed Capacity (MW)
1	Singrauli	Uttar Pradesh	2000
2	Rihand	Uttar Pradesh	3000
3	Unchahar	Uttar Pradesh	1550
4	Tanda	Uttar Pradesh	1760
5	Dadri coal	Uttar Pradesh	1820
6	Mouda	Maharashtra	2320
7	Korba	Chhattisgarh	2600
8	Vindhyachal	Madhya Pradesh	4760
9	Sipat	Chhattisgarh	2980
10	Ramagundam	Telangana	2600
11	Simhadri	Andhra Pradesh	2000
12	Farakka	West Bengal	2100
13	Kahalgaon	Bihar	2340
14	Barh	Bihar	1980
15	Talcher kaniha	Odisha	3000
16	Bongaigaon	Assam	750
17	Kudgi	Karnataka	2400
18	Solapur	Maharashtra	1320
19	Gadarwara	Madhya Pradesh	1600
20	Lara	Chhattisgarh	1600
21	Barauni	Bihar	720
22	Darlipalli	Odisha	1600
23	Khargone	Madhya Pradesh	1320
	NTPC COAL		**48120**

JV and Subsidiaries

1	Bhilai PP III	Chhattisgarh	500
2	Kanti	Bihar	390
3	Jhajjar	Haryana	1500
4	Vallur	Tamilnadu	1500
5	BRBCL	Bihar	1000
6	NPGCL	Bihar	1980
7	Meja	Uttar Pradesh	1320
			8190
	TOTAL NTPC GROUP		**56310**

Annexure B.2.1.2

			डी सी							
2030	दिसम्बर	राज्य	टी ए एन जी ई डी सी ओ	उत्तरी चेन्नई टी पी एस	3	210	2/24/1996	नहीं	33.9	द. क्षे.
2030	दिसम्बर	राज्य	ए पी जी ई एन सी ओ	रायलसीमा टी पी एस	1	210	3/31/1994	नहीं	35.8	द. क्षे.
2030	दिसम्बर	राज्य	के पी सी एल	रायचूर टी पी एस	3	210	3/30/1991	नहीं	38.8	द. क्षे.
2030	दिसम्बर	केन्द्रीय	एन टी पी सी	रामागुंडेम एस टी पी एस	4	500	6/26/1988	हाँ	41.5	द. क्षे.
2030	दिसम्बर	राज्य	के पी सी एल	रायचूर टी पी एस	1	210	3/29/1985	नहीं	44.8	द. क्षे.
2030	दिसम्बर	राज्य	ए पी जी ई एन सी ओ	डॉ. एन. टाटा राव टी पी एस	1	210	11/1/1979	नहीं	50.2	द. क्षे.
2030	दिसम्बर	निजी	एस पी एल	सासन यू एम टी पी पी	1	660	5/30/2013	हाँ	16.6	प. क्षे.
2030	दिसम्बर	केन्द्रीय	एन टी पी सी	कोरबा एस टी पी एस	7	500	11/25/2010	हाँ	19.1	प. क्षे.
2030	दिसम्बर	राज्य	एम पी पी जी सी एल	संजय प्रौद्योगिकी टी पी एस	4	210	11/23/1999	नहीं	30.1	प. क्षे.
2030	दिसम्बर	राज्य	एम पी पी जी सी एल	संजय प्रौद्योगिकी टी पी एस	2	210	3/27/1994	नहीं	35.8	प. क्षे.
2030	दिसम्बर	राज्य	जी एस ई सी एल	गांधी नगर टी पी एस	3	210	3/20/1990	नहीं	39.8	प. क्षे.
2030	दिसम्बर	केन्द्रीय	एन टी पी सी	विंध्याचल एस टी पी एस	2	210	7/23/1988	हाँ	41.5	प. क्षे.
2030	दिसम्बर	राज्य	जी एस ई सी एल	वानकबोरी टी पी एस	4	210	3/9/1986	नहीं	43.8	प. क्षे.
2030	दिसम्बर	केन्द्रीय	एन टी पी सी	कोरबा एस टी पी एस	3	200	3/17/1984	हाँ	45.8	प. क्षे.
2030	दिसम्बर	राज्य	महा जेनको	भुसावल टी पी एस	3	210	9/18/1982	नहीं	47.3	प. क्षे.
2030	दिसम्बर	राज्य	जी एस ई सी एल	उकाई टी पी एस	3	200	1/21/1979	नहीं	51.0	प. क्षे.
	दिसम्बर कुल				**26**	**7910**				
	कुल इकाईयाँ एवं क्षमता (चरण IV)				**191**	**55767**				

राकेश कुमार, सचिव

[विज्ञापन-III/4/असा./617/2023-24]

CENTRAL ELECTRICITY AUTHORITY

NOTIFICATION

New Delhi, the 15th December, 2023

CEA-TH-14-21/5/2023-TRM Division.—Whereas the Central Electricity Authority (Flexible Operation of Coal based Thermal Generating Units) Regulations, 2023 was notified by the Central Electricity Authority vide notification no. CEA-TH-17-13/4/2022-TETD Division dated 30th January, 2023;

And whereas the sub-regulation (2) of regulation 5 of the said regulations requires that the implementation of the flexible operation of the Coal based thermal generating Units shall be as per the Phasing Plan specified by the Authority from time to time;

And whereas the phasing plan has been finalized after incorporating the comments from the stakeholders. The final phasing plan approved by the Authority is attached herein under at **Annexure.**

Annexure

(PHASING PLAN)

1. The utilities shall modify the units strictly within the duration stipulated under various phases in the Phasing Plan mentioned herein under.
2. The utilities shall avail the maximum shutdown period of one month as mentioned against each unit in the Phasing Plan.
3. As far as possible, the utilities shall match the shutdown period of upgradation/retrofits works for flexible operation with Annual Over Haul (AOH) period.
4. The utilities shall plan shutdown period of the units for upgradation/retrofits works for flexible operation in coordination with the respective Regional Power Committee (RPC).
5. The following five phases have been identified under the Phasing Plan including a Pilot Phase:

I. PHASE- PILOT

Duration: To be completed by March, 2024

Under this phase, the following 10 nos. of units of capacity 5850 MegaWatt (MW) in aggregate of various thermal power plants have been planned and identified for which the study, field tests, retrofits etc. have already been initiated for flexible operation. The upgradation/retrofitting for flexible operation to be completed before 31st March, 2024.

PILOT PHASE (May, 2023 - March, 2024)

Phase	Sector	Organisation	Name of Project	Unit No.	Capacity (MW)	Region
Pilot	Central	NTPC	MAUDA TPS	1	500	WR
Pilot	Central	NTPC	SIMHADRI	3	500	SR
Pilot	Central	NTPC	DADRI	6	490	NR
Pilot	Central	DVC	MEJIA TPS	8	500	ER
Pilot	Central	NEYVELI LIGNITE	NEYVELI NEW TPP	2	500	SR
Pilot	State	KPCL	YERMARUS TPS	1	800	SR
Pilot	State	GSECL	WANAKBORI TPP	6	800	WR
Pilot	State	RRVUNL	SURATGARH SCTPP	8	660	NR
Pilot	State	WBPDC	SAGARDIGHI TPS	3	500	ER
Pilot	Private	CEPL	MUTHIARA	2	600	SR
Pilot Phase Total				**10**	**5850**	

II. PHASE-I

Duration: July, 2024 to June, 2026

Under this phase, the following 91 Nos. of units of capacity 51080 MW in aggregate of various thermal power plants have been planned and identified for the upgradation/retrofitting for flexible operation including the study and field tests. This phase to be completed within 2 years i.e. from July, 2024 to June, 2026.

PHASE 1 (JULY , 2024 - JUNE , 2026)

Year	Month	Phase	Sector	Organisation	Name of Project	Unit No.	Capacity (MW)	Date of Commissioning	Pit head	Region
2024	November	Phase 1	State	UPRVUNL	HARDUAGANJ TPS	10	660	1/29/2022	N	NR
2024	November	Phase 1	Private	GPGSL (GVK)	GOINDWAL SAHIB	2	270	3/15/2016	N	NR
2024	November	Phase 1	State	APPDCL	DAMODARAM SANJEEVAIAH TPS	3	800	3/9/2023	N	SR
2024	November	Phase 1	State	TSGENCO	BHADRADRI TPP	4	270	1/9/2022	N	SR
2024	November	Phase 1	State	TANGEDCO	METTUR TPS-II	1	600	10/11/2012	N	SR
2024	November	Phase 1	Central	NTPC	GADARWARA TPP	2	800	2/16/2021	N	WR
2024	November	Phase 1	Private	RKMPPL	UCHPINDA TPP	3	360	9/12/2017	N	WR
2024	November	Phase 1	Central	NTPC	MAUDA TPS	3	660	3/28/2016	N	WR
2024	November	Phase 1	Private	APL	MUNDRA TPS	8	660	3/3/2012	N	WR
2024	November	Phase 1	Central	DVC	BOKARO TPS `A` EXP	1	500	3/22/2016	N	ER
	November Total					**10**	**5580**			
2024	December	Phase 1	Central	NTPC	TANDA TPS	6	660	3/31/2021	N	NR
2024	December	Phase 1	Private	GPGSL (GVK)	GOINDWAL SAHIB	1	270	2/14/2016	N	NR
2024	December	Phase 1	Private	ITPCL	ITPCL TPP	2	600	4/18/2016	N	SR
2024	December	Phase 1	Private	HNPC	VIZAG TPP	2	520	3/30/2016	N	SR
2024	December	Phase 1	Central	NTPC	SIMHADRI	4	500	3/30/2012	N	SR
2024	December	Phase 1	Central	NTPC	LARA TPP	2	800	7/12/2020	N	WR
2024	December	Phase 1	Private	RATTANINDIA	NASIK (P) TPS	5	270	5/30/2017	N	WR
2024	December	Phase 1	Private	APL	RAIKHEDA TPP	2	685	3/28/2016	N	WR
2024	December	Phase 1	Private	CGPL	MUNDRA UMTPP	1	800	2/25/2012	N	WR
2024	December	Phase 1	Private	IBPIL	UTKAL TPP (IND BARATH)	1	350	2/25/2016	N	ER
	December Total					**10**	**5455**			
2025	January	Phase 1	Central	NTPC	MEJA STPP	2	660	1/12/2021	N	NR
2025	January	Phase 1	Private	SPPL	Thoothukudi St IV	1	525	11/30/2021	N	SR
2025	January	Phase 1	State	SCCL	SINGARENI TPP	1	600	3/13/2016	N	SR
2025	January	Phase 1	Central	NTECL	VALLUR TPP	1	500	3/28/2012	N	SR
2025	January	Phase 1	Central	NTPC	KHARGONE STPP	2	660	3/24/2020	N	WR
2025	January	Phase 1	Private	RATTANINDIA	NASIK (P) TPS	4	270	5/19/2017	N	WR
2025	January	Phase 1	Private	BALCO	BALCO TPS	2	300	3/24/2016	N	WR
2025	January	Phase 1	Central	DVC	RAGHUNATHPUR TPP	2	600	1/18/2016	N	ER
	January Total					**8**	**4115**			

2025	Februrary	Phase 1	State	RRVUNL	Suratgarh SCTPP	7	660	3/15/2020	N	NR
2025	Februrary	Phase 1	Central	NTPC	UNCHAHAR TPS	5	210	9/28/2006	N	NR
2025	Februrary	Phase 1	State	TSGENCO	BHADRADRI TPP	3	270	3/26/2021	N	SR
2025	Februrary	Phase 1	State	KPCL	BELLARY TPS	3	700	3/1/2016	N	SR
2025	Februrary	Phase 1	Central	NTPC	KHARGONE STPP	1	660	9/29/2019	N	WR
2025	Februrary	Phase 1	Private	SKS	BINJKOTE TPP	2	300	4/25/2017	N	WR
2025	Februrary	Phase 1	Private	JHAPL	SEIONI TPP	1	600	3/22/2016	N	WR
2025	Februrary	Phase 1	Central	NTPC	KUDGI STPP	1	800	12/25/2016	N	SR
	February Total					**8**	**4200**			
2025	March	Phase 1	Central	NTPC	TANDA TPS	5	660	9/28/2019	N	NR
2025	March	Phase 1	State	TSGENCO	BHADRADRI TPP	2	270	12/7/2020	N	SR
2025	March	Phase 1	Private	SEIL	PAINAMPURAM TPP	2	660	9/3/2015	N	SR
2025	March	Phase 1	Private	TRNE	NAWAPARA TPP	2	300	4/18/2017	N	WR
2025	March	Phase 1	State	MAHAGENCO	CHANDRAPUR(MAHARASHTRA) STPS	9	500	3/21/2016	N	WR
2025	March	Phase 1	Private	TSPL	TALWANDI SABO TPP	3	660	3/29/2016	N	NR
2025	March	Phase 1	State	CSPGCL	MARWA TPS	2	500	7/15/2016	N	WR
2025	March	Phase 1	Private	CGPL	MUNDRA UMTPP	3	800	10/16/2012	N	WR
2025	March	Phase 1	State	SCCL	SINGARENI TPP	2	600	11/25/2016	N	SR
	March Total					**9**	**4950**			
2025	July	Phase 1	State	RRVUNL	CHHABRA TPP	6	660	3/29/2019	N	NR
2025	July	Phase 1	State	TSGENCO	BHADRADRI TPP	1	270	6/5/2020	N	SR
2025	July	Phase 1	Central	NTPL	Thoothukudi (JV) TPP	2	500	7/9/2015	N	SR
2025	July	Phase 1	Central	NTPC	GADARWARA TPP	1	800	3/29/2019	N	WR
2025	July	Phase 1	Private	RATTANINDIA	NASIK (P) TPS	3	270	4/14/2017	N	WR
2025	July	Phase 1	Private	SEIL	SGPL TPP	1	660	11/12/2016	N	SR
2025	July	Phase 1	State	MAHAGENCO	KORADI TPS	9	660	3/15/2016	N	WR
	July Total					**7**	**3820**			
2025	November	Phase 1	Central	NTPC	MEJA STPP	1	660	3/31/2018	N	NR
2025	November	Phase 1	State	TSGENCO	KOTHAGUDEM TPS (STAGE-7)	12	800	12/26/2018	N	SR
2025	November	Phase 1	State	APPDCL	DAMODARAM SANJEEVAIAH TPS	2	800	3/17/2015	N	SR
2025	November	Phase 1	State	MPPGCL	SHREE SINGAJI TPP	4	660	3/27/2019	N	WR
2025	November	Phase 1	Central	NTPC	SOLAPUR STPS	1	660	4/7/2017	N	WR
2025	November	Phase 1	Private	RKMPPL	UCHPINDA TPP	2	360	1/28/2016	N	WR
2025	November	Phase 1	Central	NTECL	VALLUR TPP	2	500	2/28/2013	N	SR
2025	November	Phase 1	Private	CGPL	MUNDRA UMTPP	2	800	7/17/2012	N	WR
2025	November	Phase 1	Private	SPPL	SHIRPUR TPP	1	150	9/28/2017	N	WR
	November Total					**9**	**5390**			
2025	December	Phase 1	Central	NTPC	KUDGI STPP	3	800	3/12/2018	N	SR
2025	December	Phase 1	Central	NTPL	Thoothukudi (JV) TPP	1	500	3/10/2015	N	SR
2025	December	Phase 1	Private	RKMPPL	UCHPINDA TPP	4	360	3/20/2019	N	WR
2025	December	Phase 1	Central	NTPC	MAUDA TPS	4	660	3/18/2017	N	WR
2025	December	Phase 1	State	TANGEDCO	NORTH CHENNAI TPS	4	600	9/13/2013	N	SR
2025	December	Phase 1	Central	NTPC	LARA TPP	1	800	3/23/2018	N	WR
2025	December	Phase 1	Private	RATTANINDIA	AMARAVATI	5	270	3/12/2015	N	WR
	December Total					**7**	**3990**			
2026	January	Phase 1	State	RRVUNL	CHHABRA TPP	5	660	4/4/2017	N	NR
2026	January	Phase 1	State	APGENCO	RAYALASEEMA TPS	6	600	3/12/2018	N	SR
2026	January	Phase 1	Private	SEIL	PAINAMPURAM TPP	1	660	2/7/2015	N	SR
2026	January	Phase 1	State	MPPGCL	SHREE SINGAJI TPP	3	660	11/18/2018	N	WR
2026	January	Phase 1	Private	RATTANINDIA	NASIK (P) TPS	2	270	2/15/2017	N	WR
2026	January	Phase 1	State	TANGEDCO	NORTH CHENNAI TPS	5	600	3/9/2013	N	SR
2026	January	Phase 1	Private	APL	MUNDRA TPS	9	660	3/9/2012	N	WR
2026	January	Phase 1	Private	WPCL	AKALTARA TPS	2	600	1/18/2018	N	WR
2026	January	Phase 1	Central	NTPC	MAUDA TPS	2	500	3/29/2013	N	WR
	January Total					**9**	**5210**			
2026	Februrary	Phase 1	Central	NTPC	UNCHAHAR TPS	6	500	3/31/2017	N	NR
2026	Februrary	Phase 1	State	KPCL	YERMARUS TPP	2	800	3/29/2017	N	SR
2026	Februrary	Phase 1	State	APPDCL	DAMODARAM SANJEEVAIAH TPS	1	800	8/28/2014	N	SR
2026	Februrary	Phase 1	Private	APL	MAHAN TPP	2	600	10/7/2018	N	WR
2026	Februrary	Phase 1	State	MAHAGENCO	KORADI TPS	10	660	12/28/2016	N	WR
2026	Februrary	Phase 1	Central	NTPC	SOLAPUR STPS	2	660	3/30/2019	N	WR
2026	Februrary	Phase 1	Private	CGPL	MUNDRA UMTPP	5	800	3/18/2013	N	WR
	February Total					**7**	**4820**			
2026	March	Phase 1	Central	NTPC	KUDGI STPP	2	800	3/23/2017	N	SR
2026	March	Phase 1	Central	NTECL	VALLUR TPP	3	500	2/28/2014	N	SR
2026	March	Phase 1	Private	SKS	BINJKOTE TPP	1	300	3/28/2018	N	WR
2026	March	Phase 1	Private	TRNE	NAWAPARA TPP	1	300	8/14/2016	N	WR
2026	March	Phase 1	State	MAHAGENCO	PARLI TPS	8	250	3/30/2016	N	WR
2026	March	Phase 1	Private	MBPMPL	ANUPPUR TPP	2	600	3/30/2016	N	WR
2026	March	Phase 1	Private	CGPL	MUNDRA UMTPP	4	800	1/16/2013	N	WR
	March Total					**7**	**3550**			
	TOTAL UNITS AND CAPACITY (Phase I)					**91**	**51080**			

III. PHASE-II

Duration: July, 2026 to June, 2028

Under this phase, the following 100 Nos. of units of capacity 46825 MW in aggregate of various thermal power plants have been planned and identified for the upgradation/retrofitting for flexible operation including the study and field tests. This phase to be completed within 2 years i.e. from July, 2026 to June, 2028.

			PHASE II (JULY,2026 - JUNE ,2028)						
Year	**Month**	**Sector**	**Organisation**	**Name of Project**	**Unit No.**	**Capacity (MW)**	**Date of Commissioning**	**Pit head**	**Region**
2026	July	Private	RKMPPL	UCHPINDA TPP	1	360	10/28/2015	N	WR
2026	July	Private	JPL	TAMNAR TPP	1	600	1/7/2015	N	WR
2026	July	Private	DBPCL	BARADARHA TPS	1	600	2/23/2014	N	WR
2026	July	Private	APL	MAHAN TPP	1	600	2/24/2013	N	WR
2026	July	Private	SEIL	SGPL TPP	2	660	2/15/2017	N	SR
2026	July	Central	NTPC	NORTH KARANPURA STPP	1	660	1/18/2023	N	ER
2026	July	Private	ADHUNIK	MAHADEV PRASAD STPP	2	270	3/29/2013	N	ER
2026	July	Central	NTPC	BONGAIGAON TPP	3	250	3/23/2019	N	NER
	July Total				**8**	**4000**			
2026	August	State	GSECL	SIKKA REP. TPS	4	250	9/25/2015	N	WR
2026	August	State	MPPGCL	SHREE SINGAJI TPP	2	600	10/15/2014	N	WR
2026	August	Private	RATTANINDIA	AMARAVATI TPS	2	270	2/17/2014	N	WR
2026	August	Private	GMR ENERG	GMR WARORA TPS	1	300	2/7/2013	N	WR
2026	August	State	TSGENCO	KAKATIYA TPS	2	600	12/31/2015	N	SR
2026	August	Central	NPGCL	NABINAGAR STPP	3	660	3/6/2022	N	ER
2026	August	Central	NTPC	MUZAFFARPUR TPS	4	195	3/24/2016	N	ER
2026	August	Private	GMR ENERG	KAMALANGA TPS	1	350	3/29/2013	N	ER
	August Total				**8**	**3225**			
2026	November	Private	MCCPL	BANDAKHAR TPP	1	300	6/19/2015	N	WR
2026	November	Private	APL	TIRORA TPS	5	660	9/25/2014	N	WR
2026	November	State	MPPGCL	SATPURA TPS	11	250	12/25/2013	N	WR
2026	November	Private	HNPC	VIZAG TPP	1	520	12/27/2015	N	SR
2026	November	Central	NTPC	NABI NAGAR TPP	4	250	11/10/2021	N	ER
2026	November	Central	DVC	KODARMA TPP	2	500	2/15/2013	N	ER
2026	November	Central	NTPC	BONGAIGAON TPP	1	250	6/22/2015	N	NER
2026	November	State	RRVUNL	KALISINDH TPS	2	600	6/6/2015	N	NR
	November Total				**8**	**3330**			
2026	December	Private	BALCO	BALCO TPS	1	300	6/4/2015	N	WR
2026	December	Private	JPPVL	NIGRI TPP	1	660	8/29/2014	N	WR
2026	December	State	MPPGCL	SHREE SINGAJI TPP	1	600	11/18/2013	N	WR
2026	December	Private	ITPCL	ITPCL TPP	1	600	9/19/2015	N	SR
2026	December	Central	NTPC	BARH I	1	660	10/30/2021	N	ER
2026	December	Central	NTPC	MUZAFFARPUR TPS	3	195	3/31/2015	N	ER
2026	December	Private	ADHUNIK	MAHADEV PRASAD STPP	1	270	11/19/2012	N	ER
2026	December	Private	NPL	RAJPURA TPP	2	700	7/6/2014	N	NR
	December Total				**8**	**3985**			
2027	January	Private	MBPMPL	ANUPPUR TPP	1	600	4/20/2015	N	WR
2027	January	Private	WPCL	AKALTARA TPS	4	600	8/22/2014	N	WR
2027	January	Private	DIPL	DHARIWAL TPP	1	300	11/3/2013	N	WR
2027	January	Private	CEPL	MUTHIARA TPP	1	600	12/2/2014	N	SR
2027	January	Central	NTPC	NEW NABI NAGAR TPP	2	660	3/31/2021	N	ER
2027	January	Central	NTPC	BARH II	5	660	3/4/2015	N	ER
2027	January	Private	MPL	MAITHON RB TPP	2	525	3/31/2012	N	ER
2027	January	Private	TSPL	TALWANDI SABO TPP	1	660	6/17/2014	N	NR
	January Total				**8**	**4605**			
2027	February	State	MAHAGENCO	KORADI TPS	8	660	3/30/2015	N	WR
2027	February	Private	DIPL	DHARIWAL TPP	2	300	5/28/2014	N	WR
2027	February	Private	GMR ENERG	GMR WARORA TPS	2	300	8/27/2013	N	WR

2027	February	Central	NTPC	NEW NABI NAGAR TPP	1	660	7/12/2019	N	ER
2027	February	Private	HEL	HALDIA TPP	2	300	2/16/2015	N	ER
2027	February	Central	DVC	DURGAPUR STEEL TPS	2	500	3/23/2012	N	ER
2027	February	State	RRVUNL	KALISINDH TPS	1	600	5/2/2014	N	NR
	February Total				**7**	**3320**			
2027	March	State	GSECL	SIKKA REP. TPS	3	250	3/29/2015	N	WR
2027	March	Private	VVL	SALORA TPP	1	135	4/10/2014	N	WR
2027	March	Private	WPCL	AKALTARA TPS	3	600	8/13/2013	N	WR
2027	March	State	MAHAGENCO	BHUSAWAL TPS	5	500	3/30/2012	N	WR
2027	March	Private	JITPL	DERANG TPP	2	600	1/24/2015	N	ER
2027	March	Private	LPGCL	LALITPUR TPS	1	660	3/26/2016	N	NR
2027	March	Private	NPL	RAJPURA TPP	1	700	1/24/2014	N	NR
	March Total				**7**	**3445**			
2027	July	State	MAHAGENCO	CHANDRAPUR(MAHA RASHTRA) STPS	8	500	3/29/2015	N	WR
2027	July	Private	APL	AVANTHA BHANDAR	1	600	3/31/2014	N	WR
2027	July	Private	APL	TIRORA TPS	3	660	6/10/2013	N	WR
2027	July	Private	HEL	HALDIA TPP	1	300	1/14/2015	N	ER
2027	July	State	WBPDC	SAGARDIGHI TPS	4	500	12/15/2016	N	ER
2027	July	Private	TSPL	TALWANDI SABO TPP	2	660	10/25/2015	N	NR
2027	July	Private	APL	KAWAI TPS	2	660	12/24/2013	N	NR
	July Total				**7**	**3880**			
2027	August	Private	JPL	TAMNAR TPP	4	600	3/28/2015	N	WR
2027	August	Private	VIP	BUTIBORI TPP	1	300	3/31/2014	N	WR
2027	August	Private	JPPVL	BINA TPS	2	250	3/31/2013	N	WR
2027	August	Central	NTPC	NABI NAGAR TPP	3	250	2/26/2019	N	ER
2027	August	Central	DVC	RAGHUNATHPUR TPP	1	600	8/24/2014	N	ER
2027	August	Private	LPGCL	LALITPUR TPS	2	660	1/8/2016	N	NR
2027	August	Private	APL	KAWAI TPS	1	660	5/28/2013	N	NR
	August Total				**7**	**3320**			
2027	November	Private	DBPCL	BARADARHA TPS	2	600	3/24/2015	N	WR
2027	November	State	CSPGCL	MARWA TPS	1	500	3/30/2014	N	WR
2027	November	Private	APL	TIRORA TPS	2	660	3/25/2013	N	WR
2027	November	Central	NTPC	BARAUNI TPS	9	250	3/31/2018	N	ER
2027	November	Private	JITPL	DERANG TPP	1	600	4/10/2014	N	ER
2027	November	Private	PPGCL	PRAYAGRAJ TPP	2	660	9/6/2016	N	NR
2027	November	State	UPRVUNL	PARICHHA TPS	6	250	3/11/2013	N	NR
	November Total				**7**	**3520**			
2027	December	Private	RATTANINDIA	AMARAVATI TPS	4	270	3/4/2015	N	WR
2027	December	Private	JPL	TAMNAR TPP	3	600	3/30/2014	N	WR
2027	December	Central	NTPC	BARAUNI TPS	8	250	1/11/2018	N	ER
2027	December	State	DPL	D.P.L. TPS	8	250	3/31/2014	N	ER
2027	December	Central	NTPC	NABI NAGAR TPP	1	250	3/20/2016	N	ER
2027	December	Private	PPGCL (Tata)	PRAYAGRAJ TPP	3	660	5/22/2017	N	NR
	December total				**6**	**2280**			
2028	January	Private	JPPVL	NIGRI TPP	2	660	2/27/2015	N	WR
2028	January	Private	APL	TIRORA TPS	4	660	3/23/2014	N	WR
2028	January	State	MPPGCL	SATPURA TPS	10	250	3/22/2013	N	WR
2028	January	Private	HMEL	Hiranmaye TPP	2	150	12/31/2017	N	ER
2028	January	Private	GMR ENERG	KAMALANGA TPS	3	350	3/21/2014	N	ER
2028	January	Private	LPGCL	LALITPUR TPS	3	660	4/1/2016	N	NR
	January Total				**6**	**2730**			
2028	February	Private	APL	RAIKHEDA TPP	1	685	2/24/2015	N	WR
2028	February	Private	JPL	TAMNAR TPP	2	600	3/10/2014	N	WR
2028	February	Private	IEPL	BELA TPS	1	270	3/20/2013	N	WR
2028	February	Private	HMEL	Hiranmaye TPP	1	150	6/7/2017	N	ER
2028	February	Central	NTPC	BONGAIGAON TPP	2	250	3/22/2017	N	NER
2028	February	Private	RATTANINDIA	AMARAVATI TPS	1	270	3/25/2013	N	WR

2028	February	Central	NTPC	BARH II	4	660	11/20/2013	N	ER
	February Total				**7**	**2885**			
2028	March	Private	RATTANINDIA	AMARAVATI TPS	3	270	1/29/2015	N	WR
2028	March	Private	RATTANINDIA	NASIK (P) TPS	1	270	2/25/2014	N	WR
2028	March	State	GSECL	UKAI TPS	6	500	3/5/2013	N	WR
2028	March	Central	NTPC	NABI NAGAR TPP	2	250	4/3/2017	N	ER
2028	March	Private	PPGCL (Tata)	PRAYAGRAJ TPP	1	660	12/25/2015	N	NR
2028	March	Private	GMR ENERG	KAMALANGA TPS	2	350	9/28/2013	N	ER
	March Total				**6**	**2300**			
				TOTAL UNITS AND CAPACITY (Phase II)	**100**	**46825**			

IV. PHASE-III

Duration: July, 2028 to December, 2029

Under this phase, the following 101 Nos. of units of capacity 37215 MW in aggregate of various thermal power plants have been planned and identified for the upgradation/retrofitting for flexible operation including the study and field tests. This phase to be completed within a period of 18 months i.e. from July, 2028 to December, 2029.

			PHASE III (JULY , 2028 - DEC, 2029)						
Year	**Month**	**Sector**	**Organisation**	**Name of Project**	**Unit No.**	**Capacity (MW)**	**Date of Commissioning**	**Pithead**	**Region**
2028	July	Private	RPSCL	ROSA TPP Ph-II	3	300	12/28/2011	N	NR
2028	July	State	UPRVUNL	PARICHHA TPS	3	210	3/29/2006	N	NR
2028	July	Central	NEYVELI LIGNITE	NEYVELI NEW TPP	1	500	12/20/2019	Y	SR
2028	July	State	APGENCO	RAYALASEEMA TPS	4	210	11/20/2007	N	SR
2028	July	Private	APL	MUNDRA TPS	7	660	11/7/2011	N	WR
2028	July	Private	JSWEL	JSW RATNAGIRI TPP	1	300	8/24/2010	N	WR
2028	July	Private	JPL	OP JINDAL TPS	4	250	6/17/2008	N	WR
2028	July	Central	NTPC	DARLIPALI STPS	2	800	7/21/2021	Y	ER
2028	July	State	WBPDC	BAKRESWAR TPS	5	210	12/24/2007	N	ER
	July Total				**9**	**3440**			
2028	August	State	UPRVUNL	HARDUAGANJ TPS	8	250	9/27/2011	N	NR
2028	August	State	TSGENCO	KOTHAGUDEM TPS (NEW)	11	500	6/26/2011	N	SR
2028	August	State	APGENCO	RAYALASEEMA TPS	3	210	1/25/2007	N	SR
2028	August	Private	JSWEL	JSW RATNAGIRI TPP	4	300	10/8/2011	N	WR
2028	August	Private	APL	MUNDRA TPS	3	330	8/2/2010	N	WR
2028	August	Central	NSPCL	BHILAI TPS	1	250	4/20/2008	N	WR
2028	August	Central	NTPC	DARLIPALI STPS	1	800	12/30/2019	Y	ER
2028	August	Private	APL	TIRORA TPS	1	660	9/11/2012	N	WR
2028	August	Central	NTPC	INDIRA GANDHI STPP	3	500	11/7/2012	N	NR
2028	August	State	WBPDC	SAGARDIGHI TPS	2	300	12/21/2007	N	ER
	August Total				**10**	**4100**			
2028	November	State	HPGCL	RAJIV GANDHI TPS	2	600	10/1/2010	N	NR
2028	November	Private	APL	UDUPI TPP	2	600	4/16/2011	N	SR
2028	November	Central	NEYVELI LIGNITE	NEYVELI (EXT) TPS	2	210	7/22/2003	Y	SR
2028	November	State	MAHAGENCO	KHAPARKHEDA TPS	5	500	8/5/2011	N	WR
2028	November	Private	WPCL	WARDHA WARORA TPP	1	135	6/5/2010	N	WR
2028	November	Private	JPL	OP JINDAL TPS	3	250	3/6/2008	N	WR
2028	November	Central	DVC	DURGAPUR STEEL TPS	1	500	7/29/2011	N	ER
2028	November	Private	JPPVL	BINA TPS	1	250	8/12/2012	N	WR
2028	November	State	DPL	D.P.L. TPS	7	300	11/24/2007	N	ER
	November Total				**9**	**3345**			
2028	December	Private	RPSCL	ROSA TPP Ph-I	2	300	6/26/2010	N	NR
2028	December	State	APGENCO	RAYALASEEMA TPS	5	210	12/31/2010	N	SR
2028	December	State	KPCL	RAICHUR TPS	7	210	12/11/2002	N	SR
2028	December	Private	APL	MUNDRA TPS	6	660	7/20/2011	N	WR

2028	December	State	MAHAGENCO	PARAS TPS	2	250	3/27/2010	N	WR
2028	December	Private	JPL	OP JINDAL TPS	2	250	2/10/2008	N	WR
2028	December	Central	DVC	KODARMA TPP	1	500	7/20/2011	N	ER
2028	December	Private	JhPL(HR)	MAHATMA GANDHI TPS	1	660	1/12/2012	N	NR
2028	December	State	WBPDC	SANTALDIH TPS	5	250	11/7/2007	N	ER
	December Total				**9**	**3290**			
2029	January	State	HPGCL	RAJIV GANDHI TPS	1	600	3/31/2010	N	NR
2029	January	Private	APL	UDUPI TPP	1	600	7/23/2010	N	SR
2029	January	Central	NEYVELI LIGNITE	NEYVELI (EXT) TPS	1	210	10/21/2002	Y	SR
2029	January	Private	JSWEL	JSW RATNAGIRI TPP	3	300	5/6/2011	N	WR
2029	January	Private	LANCO	PATHADI TPP	2	300	3/25/2010	N	WR
2029	January	State	CSPGCL	DSPM TPS	2	250	12/11/2007	N	WR
2029	January	Private	MPL	MAITHON RB TPP	1	525	6/30/2011	N	ER
2029	January	Central	NTPC	SIMHADRI	2	500	8/24/2002	N	SR
2029	January	Central	DVC	MEJIA TPS	4	210	10/12/2004	N	ER
	January Total				**9**	**3495**			
2029	February	Private	RPSCL	ROSA TPP Ph-I	1	300	2/10/2010	N	NR
2029	February	State	KPCL	RAICHUR TPS	8	250	6/26/2010	N	SR
2029	February	Private	TAQA	NEYVELI TPS(Z)	1	250	10/21/2002	N	SR
2029	February	Private	WPCL	WARDHA WARORA TPP	4	135	4/30/2011	N	WR
2029	February	Private	APL	MUNDRA TPS	2	330	3/17/2010	N	WR
2029	February	Private	JPL	OP JINDAL TPS	1	250	9/2/2007	N	WR
2029	February	State	WBPDC	SANTALDIH TPS	6	250	6/29/2011	N	ER
2029	February	Private	RPSCL	ROSA TPP Ph-II	4	300	3/28/2012	N	NR
2029	February	Private	TATA PCL	JOJOBERA TPS	3	120	2/1/2002	N	ER
	February Total				**9**	**2185**			
2029	March	State	PSPCL	GH TPS (LEH.MOH.)	4	250	7/31/2008	N	NR
2029	March	State	TSGENCO	KAKATIYA TPS	1	500	5/27/2010	N	SR
2029	March	Private	WPCL	WARDHA WARORA TPP	3	135	1/21/2011	N	WR
2029	March	State	MAHAGENCO	PARLI TPS	7	250	2/10/2010	N	WR
2029	March	State	MPPGCL	SANJAY GANDHI TPS	5	500	6/18/2007	N	WR
2029	March	Private	SEL	STERLITE TPP	2	600	12/29/2010	N	ER
2029	March	Private	EPGL	SALAYA TPP	2	600	6/13/2012	N	WR
2029	March	State	MAHAGENCO	BHUSAWAL TPS	4	500	3/7/2012	N	WR
2029	March	State	WBPDC	BAKRESWAR TPS	4	210	3/21/2001	N	ER
	March Total				**9**	**3545**			
2029	July	State	HPGCL	YAMUNA NAGAR TPS	2	300	3/29/2008	N	NR
2029	July	State	APGENCO	Dr. N.TATA RAO TPS	7	500	10/8/2009	N	SR
2029	July	Private	APL	MUNDRA TPS	5	660	12/26/2010	N	WR
2029	July	Private	APL	MUNDRA TPS	1	330	8/4/2009	N	WR
2029	July	State	MAHAGENCO	PARAS TPS	1	250	5/31/2007	N	WR
2029	July	Private	SEL	STERLITE TPP	1	600	10/14/2010	N	ER
2029	July	Central	NTPC	INDIRA GANDHI STPP	1	500	10/31/2010	N	NR
2029	July	State	UPRVUNL	HARDUAGANJ TPS	9	250	5/25/2012	N	NR
2029	July	Private	TATA PCL	JOJOBERA TPS	2	120	2/1/2001	N	ER
	July Total				**9**	**3510**			
2029	August	State	PSPCL	GH TPS (LEH.MOH.)	3	250	1/3/2008	N	NR
2029	August	Private	JSWEL	TORANGALLU TPS(SBU-II)	2	300	8/24/2009	N	SR
2029	August	Private	APL	MUNDRA TPS	4	330	12/20/2010	N	WR
2029	August	Central	NSPCL	BHILAI TPS	2	250	7/12/2009	N	WR
2029	August	State	CSPGCL	DSPM TPS	1	250	3/30/2007	N	WR
2029	August	State	KPCL	BELLARY TPS	2	500	3/23/2012	N	SR
2029	August	Central	NTPC	INDIRA GANDHI STPP	2	500	11/5/2011	N	NR
2029	August	Private	EPGL	SALAYA TPP	1	600	2/22/2012	N	WR
2029	August	Central	DVC	MEJIA TPS	7	500	9/30/2010	N	ER
	August Total				**9**	**3480**			

2029	November	State	HPGCL	YAMUNA NAGAR TPS	1	300	11/1/2007	N	NR
2029	November	Private	JSWEL	TORANGALLU TPS(SBU-II)	1	300	4/23/2009	N	SR
2029	November	Private	JSWEL	JSW RATNAGIRI TPP	2	300	12/9/2010	N	WR
2029	November	Private	LANCO	PATHADI TPP	1	300	6/4/2009	N	WR
2029	November	State	MAHAGENCO	PARLI TPS	6	250	2/16/2007	N	WR
2029	November	State	OPGC	IB VALLEY TPS	4	660	7/2/2019	Y	ER
2029	November	Private	JhPL(HR)	MAHATMA GANDHI TPS	2	660	4/11/2012	N	NR
2029	November	Central	NTPC	DADRI (NCTPP)	5	490	1/25/2010	N	NR
2029	November	State	UPRVUNL	PARICHHA TPS	5	250	5/24/2012	N	NR
2029	November	Private	CESC	BUDGE BUDGE TPS	3	250	9/29/2009	N	ER
	November Total				**10**	**3760**			
2029	December	State	UPRVUNL	PARICHHA TPS	4	210	12/28/2006	N	NR
2029	December	State	KPCL	BELLARY TPS	1	500	12/3/2007	N	SR
2029	December	Private	WPCL	WARDHA WARORA TPP	2	135	10/10/2010	N	WR
2029	December	Private	TATA PCL	TROMBAY TPS	8	250	3/26/2009	N	WR
2029	December	State	MAHAGENCO	KHAPARKHEDA TPS	4	210	1/7/2001	N	WR
2029	December	State	OPGC	IB VALLEY TPS	3	660	7/2/2019	Y	ER
2029	December	Central	NTPC	SIMHADRI	1	500	2/22/2002	N	SR
2029	December	Private	VIP	BUTIBORI TPP	2	300	8/17/2012	N	WR
2029	December	State	WBPDC	SAGARDIGHI TPS	1	300	7/20/2008	N	ER
	December Total				**9**	**3065**			
	TOTAL UNITS AND CAPACITY (Phase III)				**101**	**37215**			

V. PHASE-IV

Duration: January, 2030 to December, 2030

Under this phase, the following 191 Nos. of units of capacity 55767 MW in aggregate of various thermal power plants have been planned and identified for the upgradation/retrofitting for flexible operation including the study and field tests. This phase to be completed within a period of 12 months i.e. from January, 2030 to December, 2030.

In case the utilities comprehend that 40% operation of units having age more than 40 years under this phase is not viable/possible, the utilities may opt for 2-shift operation by suitable retrofits/study/tests. However the duration for the retrofits including the study/test of this phase shall be the same.

		PHASE IV (JAN,2030 - DEC,2030)								
Year	**Month**	**Sector**	**Organisation**	**Name of Project**	**Unit No.**	**Capacity (MW)**	**Date of Commissioning**	**Pit head**	**Age as on 31.12.2029**	**Region**
2030	January	State	UPRVUNL	ANPARA TPS	7	500	3/6/2016	Y	13.8	NR
2030	January	Central	NTPC	RIHAND STPS	3	500	1/31/2005	Y	24.9	NR
2030	January	State	PSPCL	ROPAR TPS	6	210	3/30/1993	N	36.8	NR
2030	January	State	RRVUNL	KOTA TPS	4	210	5/1/1989	N	40.7	NR
2030	January	State	PSPCL	ROPAR TPS	3	210	3/31/1988	N	41.8	NR
2030	January	Central	NTPC	SINGRAULI STPS	5	200	2/26/1984	Y	45.9	NR
2030	January	Central	NTPC	SINGRAULI STPS	1	200	2/14/1982	Y	47.9	NR
2030	January	Central	NTPC	FARAKKA STPS	6	500	3/7/2011	Y	18.8	ER
2030	January	Central	NTPC	TALCHER STPS	3	500	2/21/2003	Y	26.9	ER
2030	January	State	OPGC	IB VALLEY TPS	1	210	6/2/1994	Y	35.6	ER
2030	January	State	WBPDC	KOLAGHAT TPS	6	210	3/17/1991	N	38.8	ER
2030	January	Central	NTPC	BARAUNI TPS	6	105	5/1/1983	N	46.7	ER

2030	January	Central	NTPC	RAMAGUNDE M STPS	7	500	9/26/2004	Y	25.3	SR
2030	January	State	TANGEDCO	NORTH CHENNAI TPS	2	210	3/27/1995	N	34.8	SR
2030	January	Central	NEYVELI LIGNITE	NEYVELI TPS-II	7	210	6/19/1993	Y	36.6	SR
2030	January	State	APGENCO	Dr. N.TATA RAO TPS	4	210	8/23/1990	N	39.4	SR
2030	January	Central	NEYVELI LIGNITE	NEYVELI TPS-II	1	210	1/17/1988	Y	42.0	SR
2030	January	Central	NTPC	RAMAGUNDE M STPS	3	200	12/13/1984	Y	45.1	SR
2030	January	State	TANGEDCO	Thoothukudi TPS	1	210	7/9/1979	N	50.5	SR
2030	January	Central	NTPC	VINDHYACHA L STPS	13	500	8/6/2015	Y	14.4	WR
2030	January	Central	NTPC	VINDHYACHA L STPS	12	500	3/22/2013	Y	16.8	WR
2030	January	Central	NTPC	SIPAT STPS	5	500	8/13/2008	Y	21.4	WR
2030	January	State	MPPGCL	SANJAY GANDHI TPS	3	210	2/28/1999	N	30.9	WR
2030	January	State	MPPGCL	SANJAY GANDHI TPS	1	210	3/26/1993	N	36.8	WR
2030	January	State	MAHAGENCO	KHAPARKHED A TPS	2	210	1/8/1990	N	40.0	WR
2030	January	Central	NTPC	KORBA STPS	5	500	3/25/1988	Y	41.8	WR
2030	January	State	MAHAGENCO	CHANDRAPUR (MAHARASHT RA) STPS	4	210	3/8/1986	N	43.8	WR
2030	January	State	GSECL	WANAKBORI TPS	3	210	3/15/1984	N	45.8	WR
2030	January	State	MAHAGENCO	KORADI TPS	6	210	3/30/1982	N	47.8	WR
2030	January	Private	TOR. POW. (UNOSUGEN)	SABARMATI (D-F STATIONS)	1	120	10/12/1978	N	51.3	WR
	January Total				**30**	**8685**				
2030	February	State	UPRVUNL	ANPARA TPS	6	500	6/8/2015	Y	14.6	NR
2030	February	State	PSPCL	GH TPS (LEH.MOH.)	2	210	10/16/1998	N	31.2	NR
2030	February	Central	NTPC	DADRI (NCTPP)	3	210	3/23/1993	N	36.8	NR
2030	February	Central	NTPC	UNCHAHAR TPS	2	210	3/22/1989	N	40.8	NR
2030	February	Central	NTPC	TANDA TPS	1	110	3/21/1988	N	41.8	NR
2030	February	Central	NTPC	SINGRAULI STPS	4	200	11/2/1983	Y	46.2	NR
2030	February	State	UPRVUNL	OBRA TPS	12	200	3/28/1981	N	48.8	NR
2030	February	Central	NTPC	KAHALGAON TPS	7	500	7/31/2009	Y	20.4	ER
2030	February	Private	CESC	BUDGE BUDGE TPS	2	250	3/6/1999	N	30.8	ER
2030	February	State	TVNL	TENUGHAT TPS	1	210	4/14/1994	N	35.7	ER
2030	February	Central	NTPC	FARAKKA STPS	3	200	8/6/1987	Y	42.4	ER
2030	February	State	KPCL	RAICHUR TPS	6	210	7/22/1999	N	30.5	SR
2030	February	State	APGENCO	RAYALASEEM A TPS	2	210	2/25/1995	N	34.9	SR
2030	February	Central	NEYVELI LIGNITE	NEYVELI TPS-II	6	210	10/30/1992	Y	37.2	SR

2030	February	State	TANGEDCO	METTUR TPS	4	210	3/27/1990	N	39.8	SR
2030	February	State	TANGEDCO	METTUR TPS	2	210	12/1/1987	N	42.1	SR
2030	February	Central	NTPC	RAMAGUNDE M STPS	2	200	5/29/1984	Y	45.6	SR
2030	February	Private	SPL	SASAN UMTPP	6	660	3/19/2015	Y	14.8	WR
2030	February	State	CSPGCL	KORBA-WEST TPS	5	500	3/22/2013	Y	16.8	WR
2030	February	State	MPPGCL	AMARKANTA K EXT TPS	3	210	6/15/2008	Y	21.6	WR
2030	February	State	GSECL	WANAKBORI TPS	7	210	12/31/1998	N	31.0	WR
2030	February	State	MAHAGENCO	CHANDRAPUR (MAHARASHT RA) STPS	6	500	3/11/1992	N	37.8	WR
2030	February	Central	NTPC	VINDHYACHA L STPS	4	210	12/26/1989	Y	40.0	WR
2030	February	State	GSECL	WANAKBORI TPS	6	210	11/18/1987	N	42.1	WR
2030	February	State	MAHAGENCO	CHANDRAPUR (MAHARASHT RA) STPS	3	210	5/3/1985	N	44.7	WR
2030	February	Private	TATA PCL	TROMBAY TPS	5	500	1/25/1984	N	46.0	WR
2030	February	State	GSECL	WANAKBORI TPS	1	210	3/23/1982	N	47.8	WR
	February Total				**27**	**7470**				
2030	March	Central	NTPC	RIHAND STPS	6	500	10/17/2013	Y	16.2	NR
2030	March	Central	NTPC	TANDA TPS	4	110	2/20/1998	N	31.9	NR
2030	March	Central	NTPC	DADRI (NCTPP)	2	210	12/18/1992	N	37.1	NR
2030	March	Central	NTPC	TANDA TPS	2	110	3/11/1989	N	40.8	NR
2030	March	State	UPRVUNL	ANPARA TPS	3	210	3/12/1988	Y	41.8	NR
2030	March	State	RRVUNL	KOTA TPS	2	110	7/13/1983	N	46.5	NR
2030	March	State	UPRVUNL	OBRA TPS	9	200	1/26/1980	N	50.0	NR
2030	March	Central	NTPC	KAHALGAON TPS	6	500	3/16/2008	Y	21.8	ER
2030	March	Private	CESC	BUDGE BUDGE TPS	1	250	9/16/1997	N	32.3	ER
2030	March	Central	NTPC	KAHALGAON TPS	2	210	3/17/1994	Y	35.8	ER
2030	March	Central	NTPC	FARAKKA STPS	2	200	12/24/1986	Y	43.0	ER
2030	March	Private	JSWEL	TORANGALLU TPS(SBU-I)	2	130	5/16/1999	N	30.6	SR
2030	March	State	APGENCO	Dr. N.TATA RAO TPS	6	210	2/24/1995	N	34.9	SR
2030	March	State	TANGEDCO	Thoothukudi TPS	4	210	2/11/1992	N	37.9	SR
2030	March	Central	NTPC	RAMAGUNDE M STPS	6	500	10/16/1989	Y	40.2	SR
2030	March	Central	NEYVELI LIGNITE	NEYVELI TPS-II	3	210	3/29/1987	Y	42.8	SR
2030	March	Central	NTPC	RAMAGUNDE M STPS	1	200	10/27/1983	Y	46.2	SR
2030	March	Private	SPL	SASAN UMTPP	5	660	8/24/2014	Y	15.4	WR
2030	March	Central	NTPC	VINDHYACHA L STPS	11	500	6/14/2012	Y	17.6	WR
2030	March	Central	NTPC	SIPAT STPS	4	500	5/27/2007	Y	22.6	WR

2030	March	State	GSECL	GANDHI NAGAR TPS	5	210	3/17/1998	N	31.8	WR
2030	March	State	GSECL	GANDHI NAGAR TPS	4	210	7/20/1991	N	38.5	WR
2030	March	State	MAHAGENCO	KHAPARKHED A TPS	1	210	3/26/1989	N	40.8	WR
2030	March	Central	NTPC	VINDHYACHA L STPS	1	210	10/10/1987	Y	42.3	WR
2030	March	State	CSPGCL	KORBA-WEST TPS	3	210	3/26/1985	Y	44.8	WR
2030	March	Central	NTPC	KORBA STPS	2	200	10/31/1983	Y	46.2	WR
2030	March	State	MAHAGENCO	NASIK TPS	5	210	1/30/1981	N	49.0	WR
	March Total				**27**	**7190**				
2030	July	Central	NTPC	RIHAND STPS	5	500	5/25/2012	Y	17.6	NR
2030	July	State	PSPCL	GH TPS (LEH.MOH.)	1	210	12/29/1997	N	32.0	NR
2030	July	State	PSPCL	ROPAR TPS	5	210	3/29/1992	N	37.8	NR
2030	July	State	PSPCL	ROPAR TPS	4	210	1/29/1989	N	40.9	NR
2030	July	Central	NTPC	SINGRAULI STPS	7	500	11/24/1987	Y	42.1	NR
2030	July	Central	NTPC	SINGRAULI STPS	3	200	3/28/1983	Y	46.8	NR
2030	July	State	UPRVUNL	OBRA TPS	10	200	1/14/1979	N	51.0	NR
2030	July	Central	NTPC	KAHALGAON TPS	5	500	3/31/2007	Y	22.8	ER
2030	July	State	TVNL	TENUGHAT TPS	2	210	10/10/1996	N	33.2	ER
2030	July	Central	NTPC	FARAKKA STPS	5	500	2/16/1994	Y	35.9	ER
2030	July	Central	NTPC	FARAKKA STPS	1	200	1/1/1986	Y	44.0	ER
2030	July	State	KPCL	RAICHUR TPS	5	210	1/31/1999	N	30.9	SR
2030	July	State	TANGEDCO	NORTH CHENNAI TPS	1	210	10/25/1994	N	35.2	SR
2030	July	Central	NEYVELI LIGNITE	NEYVELI TPS-II	5	210	12/31/1991	Y	38.0	SR
2030	July	State	APGENCO	Dr. N.TATA RAO TPS	3	210	10/5/1989	N	40.3	SR
2030	July	Central	NEYVELI LIGNITE	NEYVELI TPS-II	2	210	2/6/1987	Y	42.9	SR
2030	July	State	TANGEDCO	Thoothukudi TPS	3	210	4/16/1982	N	47.7	SR
2030	July	Private	SPL	SASAN UMTPP	3	660	5/21/2014	Y	15.6	WR
2030	July	Central	NTPC	SIPAT STPS	3	660	6/2/2012	Y	17.6	WR
2030	July	Central	NTPC	VINDHYACHA L STPS	10	500	3/8/2007	Y	22.8	WR
2030	July	State	MAHAGENCO	CHANDRAPUR (MAHARASHT RA) STPS	7	500	10/1/1997	N	32.3	WR
2030	July	State	MAHAGENCO	CHANDRAPUR (MAHARASHT RA) STPS	5	500	3/22/1991	N	38.8	WR
2030	July	Central	NTPC	KORBA STPS	6	500	2/26/1989	Y	40.9	WR
2030	July	Central	NTPC	KORBA STPS	4	500	5/31/1987	Y	42.6	WR
2030	July	State	GSECL	UKAI TPS	5	210	1/30/1985	N	44.9	WR
2030	July	State	CSPGCL	KORBA-WEST TPS	2	210	6/21/1983	Y	46.6	WR

2030	July	State	MAHAGENCO	NASIK TPS	4	210	7/10/1980	N	49.5	WR
	July Total				**27**	**9150**				
2030	August	Private	LAPPL	ANPARA C TPS	2	600	11/15/2011	Y	18.1	NR
2030	August	State	UPRVUNL	ANPARA TPS	5	500	7/4/1994	Y	35.5	NR
2030	August	Central	NTPC	DADRI (NCTPP)	1	210	12/21/1991	N	38.1	NR
2030	August	Central	NTPC	UNCHAHAR TPS	1	210	11/21/1988	N	41.1	NR
2030	August	State	UPRVUNL	ANPARA TPS	2	210	2/28/1987	Y	42.9	NR
2030	August	State	RRVUNL	KOTA TPS	1	110	1/17/1983	N	47.0	NR
2030	August	State	UPRVUNL	HARDUAGANJ TPS	7	105	3/31/1978	N	51.8	NR
2030	August	Central	NTPC	TALCHER STPS	6	500	2/6/2005	Y	24.9	ER
2030	August	Central	NTPC	KAHALGAON TPS	4	210	3/18/1996	Y	33.8	ER
2030	August	State	WBPDC	KOLAGHAT TPS	5	210	12/28/1993	N	36.0	ER
2030	August	State	WBPDC	KOLAGHAT TPS	3	210	12/16/1985	N	44.1	ER
2030	August	Private	JSWEL	TORANGALLU TPS(SBU-I)	1	130	1/15/1999	N	31.0	SR
2030	August	State	KPCL	RAICHUR TPS	4	210	9/29/1994	N	35.3	SR
2030	August	State	TANGEDCO	Thoothukudi TPS	5	210	3/31/1991	N	38.8	SR
2030	August	Central	NTPC	RAMAGUNDE M STPS	5	500	3/26/1989	Y	40.8	SR
2030	August	State	TANGEDCO	METTUR TPS	1	210	1/4/1987	N	43.0	SR
2030	August	State	TANGEDCO	Thoothukudi TPS	2	210	12/17/1980	N	49.1	SR
2030	August	Private	SPL	SASAN UMTPP	4	660	3/25/2014	Y	15.8	WR
2030	August	Central	NTPC	SIPAT STPS	2	660	12/24/2011	Y	18.0	WR
2030	August	Central	NTPC	VINDHYACHA L STPS	9	500	7/27/2006	Y	23.4	WR
2030	August	Private	APL	DAHANU TPS	2	250	3/29/1995	N	34.8	WR
2030	August	Central	NTPC	VINDHYACHA L STPS	6	210	2/1/1991	Y	38.9	WR
2030	August	Central	NTPC	VINDHYACHA L STPS	3	210	2/3/1989	Y	40.9	WR
2030	August	State	GSECL	WANAKBORI TPS	5	210	9/23/1986	N	43.3	WR
2030	August	Private	TOR. POW. (UNOSUGEN)	SABARMATI (D-F STATIONS)	2	121	12/31/1984	N	45.0	WR
2030	August	Central	NTPC	KORBA STPS	1	200	2/28/1983	Y	46.9	WR
2030	August	State	MAHAGENCO	NASIK TPS	3	210	4/26/1979	N	50.7	WR
	August Total				**27**	**7776**				
2030	Novembe r	Private	LAPPL	ANPARA C TPS	1	600	11/12/2011	Y	18.1	NR
2030	Novembe r	Central	NTPC	DADRI (NCTPP)	4	210	3/24/1994	N	35.8	NR
2030	Novembe r	Central	NTPC	TANDA TPS	3	110	3/28/1990	N	39.8	NR
2030	Novembe r	State	RRVUNL	KOTA TPS	3	210	9/25/1988	N	41.3	NR
2030	Novembe r	Central	NTPC	SINGRAULI STPS	6	500	12/23/1986	Y	43.1	NR

2030	November	Central	NTPC	SINGRAULI STPS	2	200	11/25/1982	Y	47.1	NR
2030	November	State	UPRVUNL	OBRA TPS	11	200	12/31/1977	N	52.0	NR
2030	November	Central	NTPC	TALCHER STPS	5	500	5/13/2004	Y	25.7	ER
2030	November	State	OPGC	IB VALLEY TPS	2	210	10/22/1995	Y	34.2	ER
2030	November	Central	NTPC	FARAKKA STPS	4	500	9/25/1992	Y	37.3	ER
2030	November	Central	NTPC	BARAUNI TPS	7	105	3/31/1985	N	44.8	ER
2030	November	State	TSGENCO	KOTHAGUDEM TPS (NEW)	10	250	2/28/1998	N	31.9	SR
2030	November	State	APGENCO	Dr. N.TATA RAO TPS	5	210	3/31/1994	N	35.8	SR
2030	November	Central	NEYVELI LIGNITE	NEYVELI TPS-II	4	210	3/30/1991	Y	38.8	SR
2030	November	State	TANGEDCO	METTUR TPS	3	210	3/22/1989	N	40.8	SR
2030	November	State	KPCL	RAICHUR TPS	2	210	3/2/1986	N	43.9	SR
2030	November	State	APGENCO	Dr. N.TATA RAO TPS	2	210	10/10/1980	N	49.3	SR
2030	November	Private	SPL	SASAN UMTPP	2	660	12/18/2013	Y	16.0	WR
2030	November	Central	NTPC	SIPAT STPS	1	660	6/27/2011	Y	18.5	WR
2030	November	State	MAHAGENCO	KHAPARKHEDA TPS	3	210	5/31/2000	N	29.6	WR
2030	November	Private	APL	DAHANU TPS	1	250	1/6/1995	N	35.0	WR
2030	November	Central	NTPC	VINDHYACHAL STPS	5	210	3/31/1990	Y	39.8	WR
2030	November	Private	TOR. POW. (UNOSUGEN)	SABARMATI (D-F STATIONS)	3	121	9/28/1988	N	41.3	WR
2030	November	State	CSPGCL	KORBA-WEST TPS	4	210	3/13/1986	Y	43.8	WR
2030	November	State	CSPGCL	KORBA-WEST TPS	1	210	3/30/1984	Y	45.8	WR
2030	November	State	GSECL	WANAKBORI TPS	2	210	1/15/1983	N	47.0	WR
2030	November	State	GSECL	UKAI TPS	4	200	3/28/1979	N	50.8	WR
	November Total				**27**	**7586**				
2030	December	Central	NTPC	RIHAND STPS	4	500	9/24/2005	Y	24.3	NR
2030	December	State	UPRVUNL	ANPARA TPS	4	500	7/19/1993	Y	36.5	NR
2030	December	Central	NTPC	RIHAND STPS	2	500	7/5/1989	Y	40.5	NR
2030	December	Central	NTPC	RIHAND STPS	1	500	3/31/1988	Y	41.8	NR
2030	December	State	UPRVUNL	ANPARA TPS	1	210	3/24/1986	Y	43.8	NR
2030	December	State	UPRVUNL	OBRA TPS	13	200	7/21/1982	N	47.5	NR
2030	December	Central	NTPC	TALCHER STPS	4	500	10/25/2003	Y	26.2	ER
2030	December	Central	NTPC	KAHALGAON TPS	3	210	3/24/1995	Y	34.8	ER
2030	December	Central	NTPC	KAHALGAON TPS	1	210	3/31/1992	Y	37.8	ER
2030	December	State	WBPDC	KOLAGHAT	4	210	1/24/1984	N	46.0	ER

				TPS						
2030	December	State	TANGEDCO	NORTH CHENNAI TPS	3	210	2/24/1996	N	33.9	SR
2030	December	State	APGENCO	RAYALASEEM A TPS	1	210	3/31/1994	N	35.8	SR
2030	December	State	KPCL	RAICHUR TPS	3	210	3/30/1991	N	38.8	SR
2030	December	Central	NTPC	RAMAGUNDE M STPS	4	500	6/26/1988	Y	41.5	SR
2030	December	State	KPCL	RAICHUR TPS	1	210	3/29/1985	N	44.8	SR
2030	December	State	APGENCO	Dr. N.TATA RAO TPS	1	210	11/1/1979	N	50.2	SR
2030	December	Private	SPL	SASAN UMTPP	1	660	5/30/2013	Y	16.6	WR
2030	December	Central	NTPC	KORBA STPS	7	500	11/25/2010	Y	19.1	WR
2030	December	State	MPPGCL	SANJAY GANDHI TPS	4	210	11/23/1999	N	30.1	WR
2030	December	State	MPPGCL	SANJAY GANDHI TPS	2	210	3/27/1994	N	35.8	WR
2030	December	State	GSECL	GANDHI NAGAR TPS	3	210	3/20/1990	N	39.8	WR
2030	December	Central	NTPC	VINDHYACHA L STPS	2	210	7/23/1988	Y	41.5	WR
2030	December	State	GSECL	WANAKBORI TPS	4	210	3/9/1986	N	43.8	WR
2030	December	Central	NTPC	KORBA STPS	3	200	3/17/1984	Y	45.8	WR
2030	December	State	MAHAGENCO	BHUSAWAL TPS	3	210	9/18/1982	N	47.3	WR
2030	December	State	GSECL	UKAI TPS	3	200	1/21/1979	N	51.0	WR
	December Total				**26**	**7910**				
	TOTAL UNITS AND CAPACITY (Phase IV)				**191**	**55767**				

RAKESH KUMAR, Secy.

[ADVT.-III/4/Exty./617/2023-24]

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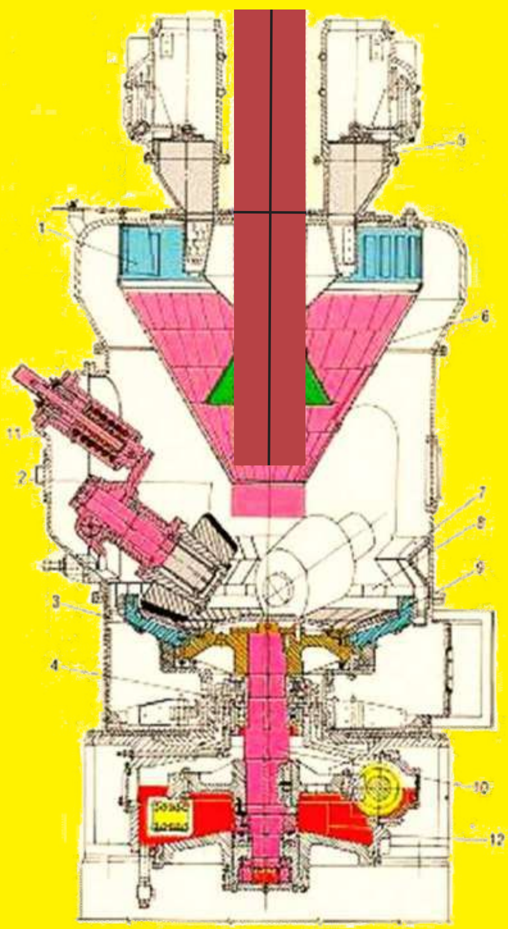
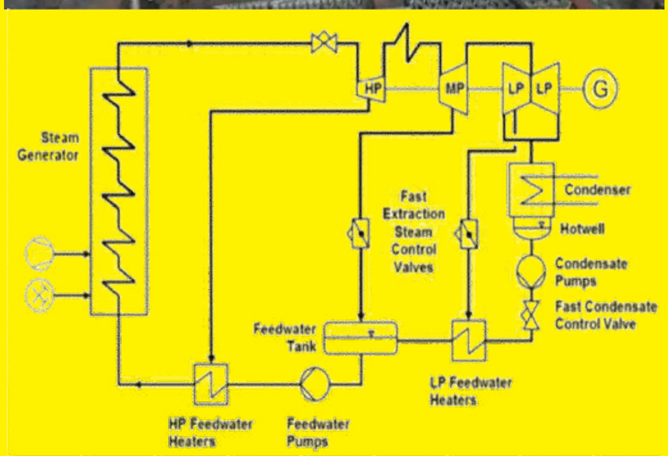
Annexure B.2.1.3

सत्यमेव जयते

Government of India
Ministry of Power
Central Electricity Authority

FLEXIBILISATION OF COAL FIRED POWER PLANT





A Roadmap for Achieving 40% Technical Minimum Load

February, 2023

Sewa Bhawan, Sector 1, R K Puram, New Delhi – 110066

घनश्याम प्रसाद
अध्यक्ष तथा पदेन सचिव भारत सरकार
GHANSHYAM PRASAD
Chairperson & Ex-officio Secretary
To the Government Of India

सत्यमेव जयते

केन्द्रीय विद्युत प्राधिकरण
भारत सरकार
विद्युत मंत्रालय
सेवा भवन, आर.के. पुरम
नई दिल्ली–110066
Central Electricity Authority
Ministry of Power
Sewa Bhawan, R. K. Puram
New Delhi-110066

आज़ादी का अमृत महोत्सव

FOREWORD

India has great potential for renewables which has been recognized and a goal for attaining 500GW has been set by year 2030. To achieve the goal of integration of such high level of renewables there are both technical and financial challenges. The thermal units so far has been operated as base load plants which require overhauling. I am happy that TPRM Division, CEA has brought out a comprehensive report on flexible operation of base load thermal plants including operating procedure, challenges, retrofit and roadmap for achieving 40% load operation. The committee which was headed by B.C. Mallick, Chief Engineer, TPRM Division with members from various organizations have put in their valuable efforts and time to bring out an comprehensive reports covering important topics which shall be useful for the thermal utilities. It has also touched the cost aspects for achieving the flexibility of thermal units considering the requirement of retrofits and heat rate deterioration, etc. The pilot tests conducted under the support of CEA at various thermal units have added to the knowledge base of utilities/OEMs and highlighted the issues involved in our thermal units. The guideline has also deliberated on the issues as how these need to be tackled in effective manner.

It needs to be highlighted that flexible thermal units are one of the cheapest source of flexible power presently in the country. Hence, it will be crucial to ready the existing thermal units for the new operating regime enforced by the renewables. It shall help to optimize the operation of thermal units and reduce the emission burden of power generation.

I commend the efforts of Shri B. C. Mallick, Chief Engineer TPRM and Chairman of the committee for formulation of the entire report which shall lay the foundation of the flexibilisation of thermal power in the country.

(Ghanshyam Prasad)

दूरभाष (का०)
TELEPHONE (O)
TELEFAX (O)

सदस्य
तथा पदेन अपर सचिव भारत सरकार
केन्द्रीय विद्युत प्राधिकरण
सेवा भवन, रामाकृष्णा पुरम्

MEMBER
& EX-OFFICIO ADDL. SECRETARY TO THE GOVERNMENT OF INDIA
CENTRAL ELECTRICITY AUTHORITY
SEWA BHAWAN, R. K. PURAM

नई दिल्ली - 110066

NEW DELHI-110066

Preface

Flexibilisation of coal fired plants has become inevitable for integration of power generated from renewable energy sources into the grid. The report "Flexibilisation of Coal-fired Power plants - A Roadmap for Achieving 40% Technical Minimum Load" prepared under the Chairmanship of Shri B. C. Mallick, Chief Engineer (TPRM), CEA shall guide the thermal power utilities, regulators and professionals for better understanding of the issues linked to flexibilisation and help them in formulating their future course of action.

I have gone through the report and found it to be very useful. The report is very exhaustive covering important topics like details of the various pilot tests conducted under the direction of CEA, procedure for flexible tests, the control modifications required, impact on the tariff and the future roadmap. In addition report is suggesting to explore the future possibility of two shift operation of thermal units based on the grid requirement.

I congratulate Shri B. C. Mallick, Chief Engineer & Chairman of the committee and other committee members for their valuable efforts in preparing the report.

(A. Balan)
Member (Thermal)

Bikash Chandra Mallick
Chief Engineer

आज़ादी का अमृत महोत्सव

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विद्युत मंत्रालय
MINISTRY OF POWER
सेवा भवन, रामाकृष्ण पुरम्
SEWA BHAWAN, RAMAKRISHNA PURAM

सत्यमेव जयते

नई दिल्ली–110066, दिनांक :
NEW DELHI-110066, Dated : 14 July 2022

ACKNOWLEDGEMENT

The power sector is going through transformational changes due to the environmental concerns. There shall be increased share of renewables in the grid in future which shall impose new operational requirement on the large existing thermal fleet. Thermal power utilities are going to find themselves at the receiving end in future, hence thermal units would have to modernize to remain in the business of power generation. The present report shall help thermal utilities in understanding the issues/ up gradations required in the plants and in the skills of the operators. The contents of the report are very comprehensive, incorporates the learnings from the low load tests conducted at various thermal units.

The flexible power is available from Hydro Power Plants, Pump Storage System, Thermal Power Plant and Battery Storage System. The cheapest flexible power may be available from hydro plants/ pump storage system, costlier from thermal power plants and costliest power from Battery storage system. Therefore our first preference to utilize or develop flexible power shall be from hydro/pump storage, second from thermal power plants and lastly from battery storage system.

The committee has considered heat balance study report of BHEL, SIEMENS, GE and actual test report of Dadri TPS, Maithon RBTPS, DSTPS, Sagardighi TPS, WBPDL, Ukai TPS, GESCL, Mouda TPS of NTPC. Accordingly suggested a Road Map for preparing thermal power plants flexible including operating procedure, identification of measure and cost of flexible power.

I would like to thank all the committee members from NTPC, BHEL, POSOCO, Tata Power, Siemens, GE, GESCL, independent consultants, and divisions of thermal wing who have contributed in preparing the report. I am thankful to Chairperson, CEA, Member (Thermal), CEA for their valuable guidance. Finally, I appreciate the efforts of TPRM Div. for their support.

Bmallik

(B.C. Mallick)
Chief Engineer (TPRM) &
Chairman of the Committee

CONTENTS

EXECUTIVE SUMMARY

GOI has set an ambitious target of 500 GW renewable generation by 2029-30 and 175GW by end 2022. There is a delay in capacity addition of 175GW RES due to covid-19 pandemic and the same may be achieved by end 2023. In near future thermal power plants fleet is expected to operate at an average minimum load of 40%. It shall drastically impact the schedule of most of the conventional generating plants and shall lead to operating thermal power plants at part load. Hence, thermal generating units shall haveto be tuned such that they can meet the new load demands in a very effective and efficient manner. And if any gaps are found, the same needs to be fixed.

A committee was constituted under the chairmanship of Sh. B. C. Mallick, Chief Engineer, TPRM Division, CEA with the members from various organizations. The committee would guide the central, state & private utilities in selecting thermal generating units and conducting low load test. The committee would also prepare a guideline for low load operation of TTPs, on the basis of experience gained from the pilot test, to help generating utilities in achieving flexibility in their units.

A comprehensive report has been prepared with the contribution of committee members from various organizations, consultants which are at the forefront for steering this new demand. The report comprises of eleven chapters which tries to covers the various important issues in details. The chapter-1 **"Need for Flexibilisation",** which gives the back ground for the new requirement which has arisen and the challenge faced by the thermal power sector. Chapert-2 "**Key Requirement of Flexibilisation"** elaborates the new regime of operation of power plants, i.e. minimum load, ramp rates requirement. For implementation of flexibilisation, the tests/studies are required to be conducted, the chapter-3, "**Studies Conducted"** describes the tests conducted so far and their major findings. The operation of thermal power plant in flexibilisation mode has lot of impact on the plant life, operation and maintenance, efficiency which has been briefly discussed in the chapter-4 "**Challenges of Flexibilisation".** The paradigm of operation of the plant changes due to the flexibilisation, hence new operating procedure which require changes and training of personnel is required to be upgraded (operating procedures). Based on the tests/ studies, there will be a clear picture obtained of the existing capabilities of the plant which shall require to be upgraded. The chapter-5 "**Procedures for low load tests"** describes the procedures in details for attaining the 40% low load operation without oil support and various parameters to be observed carefully during the test tofind the measures to be implemented in the generating unit. The chapter-6 "**Modification Required"** discusses in details the various options available for modification for the performance improvement. The flexibilisation has impact on the fixed and operating cost of the thermal power plant. The committee members have compiled costs for adopting measures for the improvement of flexible performance of thermal power plant as discussed in the chapter-7 "**Cost of Flexible power".** However, the capital costs for retrofit, given in the report, are only indicative in nature actual costs need to be ascertained by conducting a detailed feasibility study as the modifications are plant specific. Further, increased O&M cost form part of fixed tariff and efficiency degradation & increased oil consumption due to EFOR forms part of variable tariff. It has been found that impact of 40% low load operation on tariff (fixed + variable) is maximum about 7 to 8% which may increaseto some extent for old units. "**Two-shift operation"** of thermal power plants has been discussed in the chapter-8. The comparison of flexible power from the various sources is elaborated in the chapter -9 "**Flexible Power from Different Sources".** To refurbish the fleet of thermal units for flexibilisation, the time required for making them equipped forcycling has been presented in the chapter-10 "**Roadmap"**. Finally, in the last chapter-11 "**Conclusion and Way Forward"** the findings of the report have been summarized andsteps for implementation have been recommended.

Looking at the addition of renewables in future, the thermal power utilities will be required to play a very important role. The report prepared by thecommittee shall be beneficial for the utilities for understanding the need and implication of flexible operation of coal fired units.

BACKGROUND

India is moving ahead to achieve nationally determined contribution (NDC) of 40% of installed renewable capacity by 2030. The introduction of large scale renewable generation in the grid is bringing a new set of challenges in the power sector.

The inconsistency and intermittency of solar & wind power has to be managed by other sources of generation in order to ensure the grid stability. Flexible operation of existing coal-fired power plants is very much required to ensure security, reliability of power supply and stability of electricity grids while maximizing generation from renewable energies sources (RES) & integration of the same into grid. Because thermal generation capacity of 209 MW constituting 54% of total installed capacity is the dominant part of power generation in the country and more than 70% of country's energy demand is being met from thermal generation. Thus, flexible operation of thermal power plant is essential for handling the instability & intermittency of renewable generation.

The CEA report "Flexible operation of thermal power plants for integration of renewable generation" was finalized considering 175 GW RES by the committee constituted under chairmanship of Sh. B. C. Mallick, Chief Engineer (TPRM), CEA in January 2019. On the basis of net heat rate increase due to minimum thermal load (MTL) operation,thermal generating units are categorized under very flexible (40% MTL), flexible (45%MTL) and low flexible (50% MTL) group. In a particular day (with 175 GW RES) about 90 very flexible units (24 GW), 78 flexible units (42 GW) & 75 low flexible units (52 GW)from 243 grid synchronized thermal generating units (118 GW) are required for safe &secured grid operation.

In this regard, a committee was constituted under the aegis of CEA for implementation of findings of the above CEA's report and guide utilities for assessing their capabilities & identification of measures to be implemented to enhance flexibility with the following members.

1. Sh. B. C. Mallick, Chief Engineer, TPRM, CEA - Chairman
2. Sh. Rajeev Kumar, Dir./Sh. Pravir Kumar, Dir., TPRM, CEA - Convener
3. Sh. C.P. Jain, Director, TETD, CEA - Member
4. Sh. Y. M. Babu, GM /Sh P Mukherjee, GM /Sh. BVN Kishore, AGM BHEL - Member
5. Sh. N. Nallarasan, ED /Sh. Surajit Banerjee, GM POSOCO - Member
6. Sh. Snehesh Banerjee, AGM, NTPC - Member
7. Sh. A. K. Sinha, Technical Director , Intertek - Member
8. Sh. B.A. Gandhi, Executive Engineer, GSECL - Member
9. Sh. C.P. Tiwari, Head of technology & Process /Sh. Ashok Panda, Chief O&M, Tata Power - Member
10. Sh. Mahesh Kendhe, Head of Product Management, GE – Member

The Chairman of the committee coopted the following members:
1. Sh. Sandeep Chittora, Chief Manager, Siemens
2. Sh. Deepak Tiku, AGM, TPRM, CEA
3. Sh. Rohit Yadav, Dy. Director, TPRM, CEA

The committee shall guide the central, state & private utilities to conduct pilot test for flexible operation and prepare a report as per the following terms of reference -

i. Identify thermal units for pilot test and guide state/central private utilities to conduct pilot test of flexible operation.
ii. Prepare a guideline for pilot test of flexible operation of thermal unit.
iii. Identify measure for flexible operation and monitor implementation of measures at plant level.

OBJECTIVE

The majority of the power generation in the country is thermal, it has to be made flexible in its output for supporting the greening of grid. It would require identifying the thermal units which are technically and economical feasible for flexibilisation. The technical feasibility shall be decided by detailed studies/tests. The studies shall also explore the possibility of carrying out the required retrofits. The flexibilisation of thermal units involve capital expenditure depending upon the modifications required and the operating costs in terms of deteriorating performance, higher maintenance costs and loss of life. The main objectives of the committee are as follows-

- Explore the new technical minimum load of thermal generating units without oil support
- Assessment of thermal flexible power and ramp rate available for integration of renewable generation.
- Identify measures to be implemented thus Capex.
- Identify increase of net heat rate, O&M cost and consumption of life thus Opex.
- Targeting grid security and stability, less impact on tariff.
- Explore cost implication of flexible operation of thermal unit.
- Preparation of Roadmap for achieving new technical minimum load

ABBREVIATIONS

APH	Air Pre Heater
APRDS	Auxiliary steam Pressure Reducing and Desuperheating Station
AVT	All Volatile Treatment
BFP	Boiler Feed Pump
BMCR	Boiler Maximum Continuous Rating
C&I	Control & Instrumentation
CEP	Condensate Extraction Pump
CMC	Coordinated Master Control
CPU	Condensate Polishing Unit
CRH	Cold Reheat
DC	Declared Capacity
DCS	Distributed Control System
DM	De Mineralized
DNB	Departure from Nucleate Boiling
DO	Dissolved Oxygen
EFOR	Equivalent Forced Outage Rate
EHS	Equivalent Hot Start
EOH	Equivalent Operating Hours
ESP	Electro Static Precipitators
FAC	Flow Accelerated Corrosion
FD	Forced Draught
FEGT	Flue Exit Gas Temperature
FGD	Flue Gas Desulphurization
FRS	Feed Regulating Station
GCV	Gross Calorific Value
GW	Giga Watt
HBD	Heat Balance Diagram
HRH	Hot ReHeat
ID	Induced Draft
LRSB	Long Retractable Soot Blower
LTSH	Low Temperature Super Heater
MDBFP	Motor Driven Boiler Feed Pump
MS	Main Steam
MTL	Minimum Technical Load
PA	Primary Air
PC	Pulverised Coal
RAPH	Regenerative Air Preheater
RH	Re Heater
SCAPH	Steam Coil Air Pre Heater
SECD	Security Constrained Economic Dispatch
SH	Super Heater
TDBFP	Turbine Driven Boiler Feed Pump
TMCR	Turbine Maximum Continuous Rating
VM	Volatile matter
WWSB	Water Wall Soot Blower

1. NEED FOR FLEXIBILISATION

1.1 Global Commitments

The focus of power generation in the country had been on thermal power generation in the past as it was cheaper, having lower gestation time compared to hydro power and there are plenty of coal reserves for its sustenance. In recent times, there has been global environmental concerns regarding power generation from fossil fuel and steps are being taken in the country to make the power generation less carbon dependent. In October 2015, India submitted its Intended Nationally Determined Contribution (INDC) to UNFCCC. It aims is to achieve about 40 percent cumulative electric power installed capacity from non-fossil fuel based energy resources by 2030 with the help of transfer of technology and low cost international finance. It also aims to reduce the emission intensity of its GDP by 33% to 35% by 2030 from the 2005 level. Further, to create an additional carbon sink of 2.5 to 3 billion tons of CO_2 equivalent by resorting to additional forest and tree cover by 2030. The above national commitments have made it obligatory for the government to put greater emphasis on the renewables energy resources.

1.2 Thrust on Renewables

Renewable energy sources have the environmental advantages over fossil fuel fired plants, they are emission free, and however, the renewable alternative for bulk power generation was very costly earlier. The reduction in cost of renewable energy sources has given a push to the solar and wind based power generation. In fact, as per the recent cost trends, RE generation sources have become competitive with the conventional electricity generation. One of the major advantages is that India has vast renewable energy potential of around 1050GW which is largely untapped. It is estimated that the solar potential is around 748GWp and the wind potential is greater than 302GW* (MNRE Report 2019-20).

1.2.1 Target 2022

Considering the vast renewable potential, GOI has set an ambitious target of setting up of 175GW installed capacity from renewables (RE) by December 2022. Out of which, 100GW is planned through solar energy, 60GW through wind energy, 10GW through small hydro power, and balance 5GW through biomass-based power projects. The target for solar capacity is to be achieved through 40GW rooftop projects and balance through utility-scale solar plants and ultra-mega solar parks. The Covid-19 pandemic has slowed down the progress of Solar and Wind capacity addition in last 2 years.

1.2.2 Target 2030

To meet the INDC target by 2030, the installed capacity of renewables shall have to be increased. The recent CEA study indicates that the likely total installed capacity by the end of 2029-30 shall be 838.8GW which would include 454.4GW of renewables. With this renewable proposed capacity, the INDC target set for the country shall be easily met.

*at 100m agl.

1.2.3 Present Status

There is already a significant wind power capacity in operation and various initiatives have made solar PV more widespread. A significant growth has been experienced in past few years. The installed capacity of solar and wind is 94 GW as on 31st March, 2022 and total generation is 142 billion units for the period April to March, 2022 which is almost 9.5% of the total energy generation in the country.

1.3 Why stress on thermal generating unit?

Renewable power output has three major key limitations: *variability* varies from moment to moment, *uncertainty* cannot be predicted with any certainty in advance and *concentration,* is concentrated during a limited number of hours of the year. Thus creatinga need for the balancing the demand on various time scales for proper functioning, stability and security of the grid. The inconsistency and intermittency of solar & wind power has to be managed by other sources of generation in order to ensure the gridstability. Flexible operation of existing coal-fired power plants is very much required to ensure security, reliability of power supply and stability of electricity grids while maximizing generation from renewable energies sources (RES) & integration of the same
into grid, because thermal generation capacity of 209 MW constituting 54% of total installed capacity is the dominant part of power generation in the country and more than 70% of country's energy demand is being met from thermal generation. Thus, Flexible operation of thermal power plant is essential for handling the instability of renewable generation.

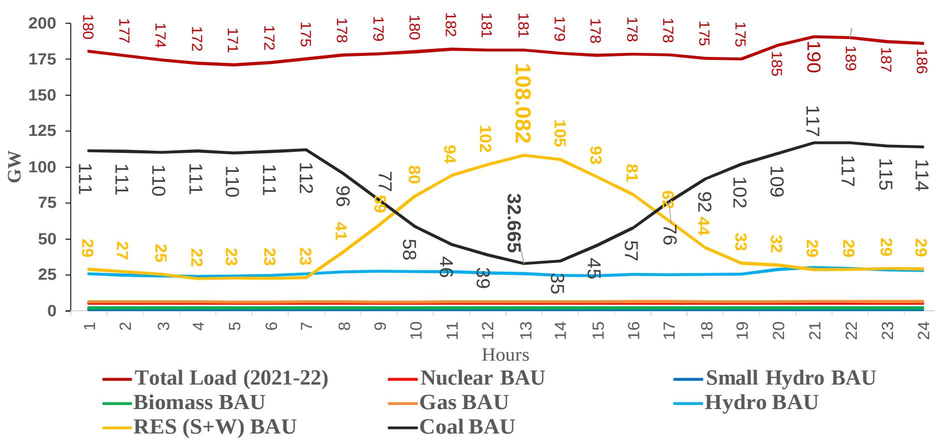


Figure 1.1 Demand & Generation on a critical day
(Source: CEA's report "flexible operation of thermal power plants for integration of renewable generation")

1.4 Load and Generation as predicted in CEA's Report (Jan 2019)

The above figure-1 shows the impact of the renewable generation on the daily net load demand of the grid. The top red curve is the forecasted load demand. The yellow curve is the power output considering the proposed installed capacity of solar and wind. The net load demand (black) is to be met by the fleet of thermal power units in the grid which is very steep. It creates demand of large flexible power from the base load thermal plants, reducing their minimum operating load and requiring steep ramp rates.

A significant proportion of the older coal-fired plants, are based on conventional sub-critical technology which were originally designed and built with steady base load operation. The major change like operating cyclically daily has major impact on coal-fired plant in several areas: operation and maintenance, plant life and economics. Hence, in a scenario of high penetration of renewables (175 GW) by 2023 (expected) there is an urgent requirement of developing the flexible capability of existing thermal power plants.

Further due to part load operation, the utilities will be forced to operate units at lower efficiency. It may therefore be required to undergo modernization of these plants with target of improving heat rate at lower minimum loads. The report presents various solutions that are available to be implemented in thermal power plants to have better operation and maintenance under flexible operation. These related issues are examinedin the following chapters.

2. KEY REQUIREMENT OF FLEXIBILISATION

2.1 Management of grid

The coal-based thermal generation is responsible for meeting more than 74% of India's electricity energy demand and this share is expected to stay near 50% by 2030. Thermal units would experience lower minimum loads and higher ramp rates as the share of variable renewable resources in the energy mix increases. Many studies performed to assess the impact of large scale renewable integration into the Indian power system have captured the aspect of increased flexibility demands on thermal power plants. As per CEA's report "*Flexible operation of thermal power plants for integration of renewable generation*", peak thermal flexible capacity (gross) required on the most critical day in year 2022 was found to be 140 GW considering 175 GW renewable installed capacity and the coordinated efforts from hydro, gas capacity and pumped storage system (PSS), the requirement of thermal capacity could be reduced to 117 GW. Further, the requirement of thermal flexible power is also reduced from 84 GW to 64 GW. Thus, coordinated efforts of hydro, PSS, gas is important for reduction of stress on thermal units and followings have been recommended for balancing the grid:

I. Final Balancing shall be done at national level which will minimize the requirement of balancing power.
II. Hydro power plants are especially suitable for quick supply of flexible power. Coordination with state hydro power plant for reallocation of generation and provision of separate (higher) tariff for flexible hydro power are suggested. If the tariff is increased, hydro rich states (those are continuously operating due to very low cost) will draw power from grid during day time and operate during peaking hours. Tariff (minimum) of flexible hydro power should be higher than the off-peak grid power.
III. Flexible operation of coal-fired plant (up to 40% minimum load).
IV. Study on demand side management (implement TOD metering) including measure targeted at domestic, industrial and e-mobility sector would enable more rational consumption pattern of electricity which will improve the off-peak to peak generation ratio of thermal power plants. Thus reduction of regional as well as national peak demand.
V. Study or land survey to avail the geographically advantage for establishment of pump storage.
VI. Two shift operation of smaller size thermal units.
VII. Shifting of Agricultural load from night hours to day during solar peak generation period
VIII. Battery Storage: One of the important source of flexible power is battery storage. This capacity should be as low as possible for the following reason:
    a) Lithium reserves are not available in India.
    b) High cost

c) Service life is about 10 years
d) Disposal issue

In the Indian power system, role of thermal generation has evolved from being operated as base load till recently to be used as the major source of flexible power. With increase in all-India ramping requirements over the years, most of the additional ramping is being met by thermal generation, with maximum thermal ramp touching 250 MW/ minute in 2018-22, as seen in figure 1. The maximum ramp up and ramp down rate as projected in CEA's "*Flexible operation of thermal power plants for integration of renewable generation*" report were 379 MW/min and 422 MW/min. considering 175 GW RES. The increasing need for flexibility is driven by change in demand pattern with round-the-clock power supply, and increasing penetration of RE resources.

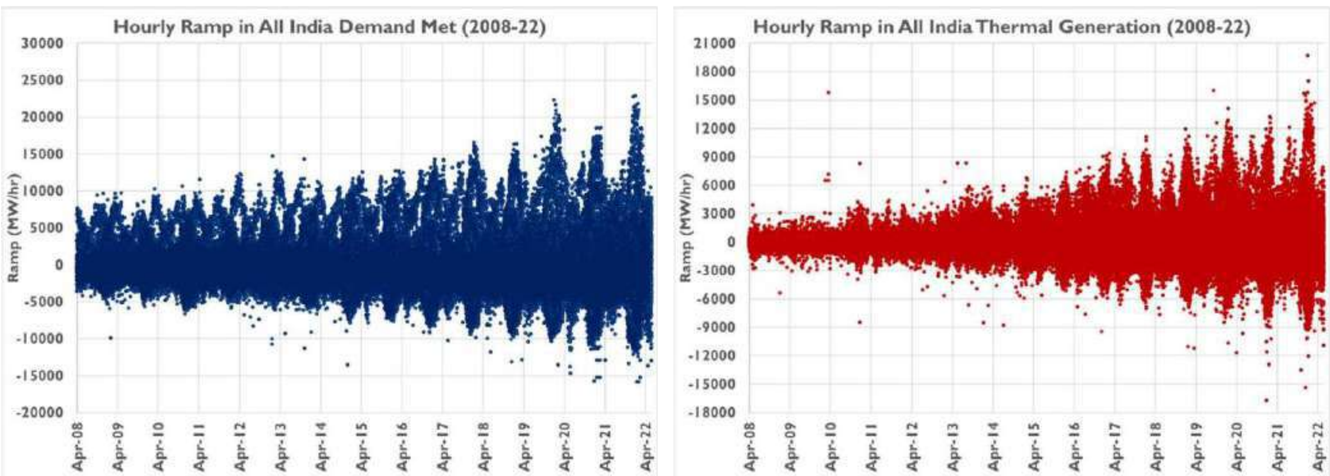


Figure 2.1 Hourly Ramp Rates of Demand and Thermal Generation in India - 2008 to 2022 (Source: POSOCO)

POSOCO report on Flexibility Analysis of Thermal Generation for RE integration utilized time series data of 438 thermal units to quantify flexibility across different units. Here flexibility is expressed as percentage of *(Daily Maximum Generation – Daily Minimum Generation)/Installed Capacity*. The day-wise flexibility requirement of the Indian power system demand is increasing at 8-9 GW/annum, and it reached a maximum of 72GW during winter of 2021-22 (Figure 2.2). On all India basis, thermal flexibility is on increasing trend, approaching 30-35% during 2021-22 (Figure 2.3). About 40% of India's thermal units are reaching minimum generation levels in the range of 60-70% of installed capacity (Figure 2.4).

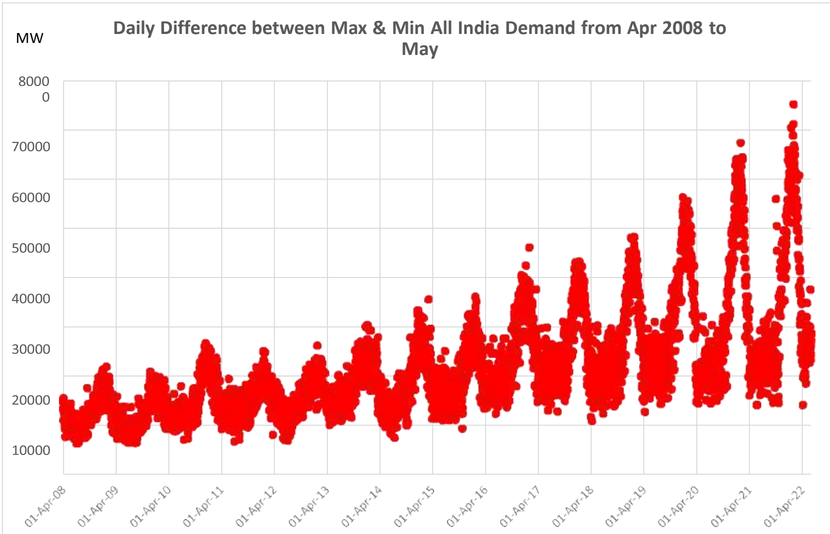


Figure 2.2 Difference between Max. and Min. All India Demand

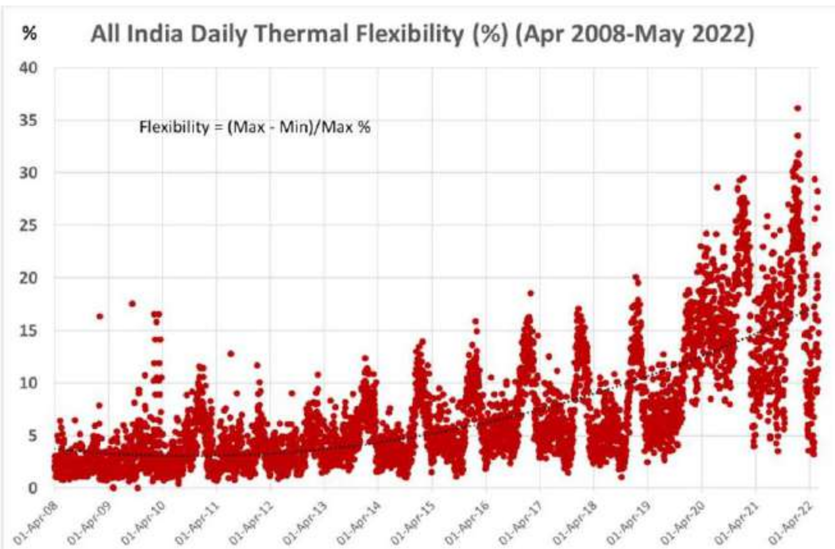
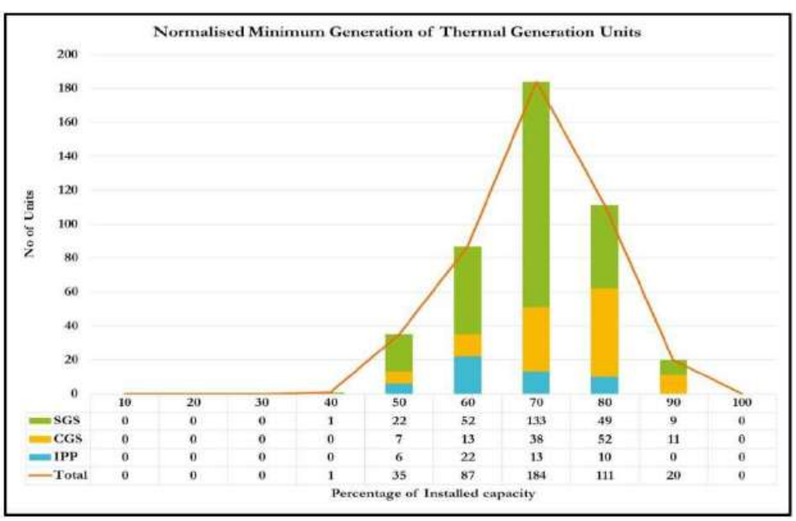


Figure 2.3 Trend of DailyThermal Flexibility



	10	20	30	40	50	60	70	80	90	100
SGS	0	0	0	1	22	52	133	49	9	0
CGS	0	0	0	0	7	13	38	52	11	0
IPP	0	0	0	0	6	22	13	10	0	0
Total	0	0	0	1	35	87	184	111	20	0

Figure 2.4: Distribution of average minimum generation of thermal units

A pilot study on *Security Constrained Economic Dispatch* (SCED) is operational in national grid since 1st April 2019. It aims at optimizing the production cost of generation at national level while satisfying all plant and system security constraints at all times. 52 thermal inter-state generating stations with 58GW capacity are part of the study. Technical minimum (55% at present) and ramp up/ramp down rates are part of the constraints honoured by SCED. The duals of the binding constraints in SCED have been extracted for the entire period and analyzed in the report on SCED pilot. As expected, the more expensive stations are constrained by technical minimum for most of the time (Figure 2.5).

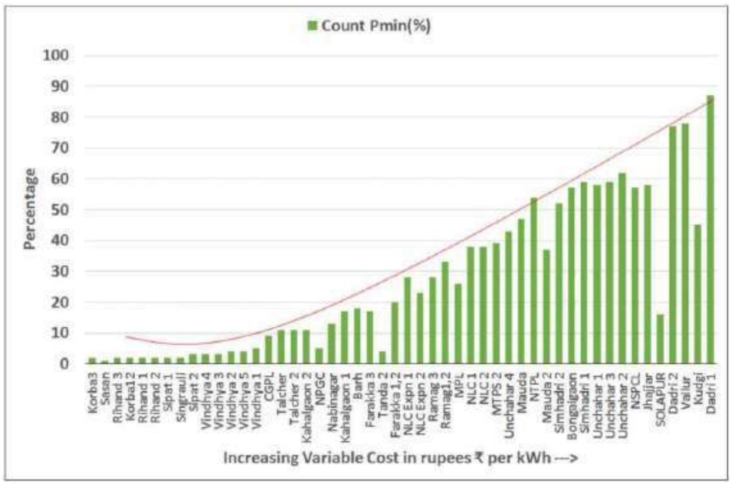


Figure 2.5 Percentage of time technical minimum constraints in SCED (Apr-Dec 2019)

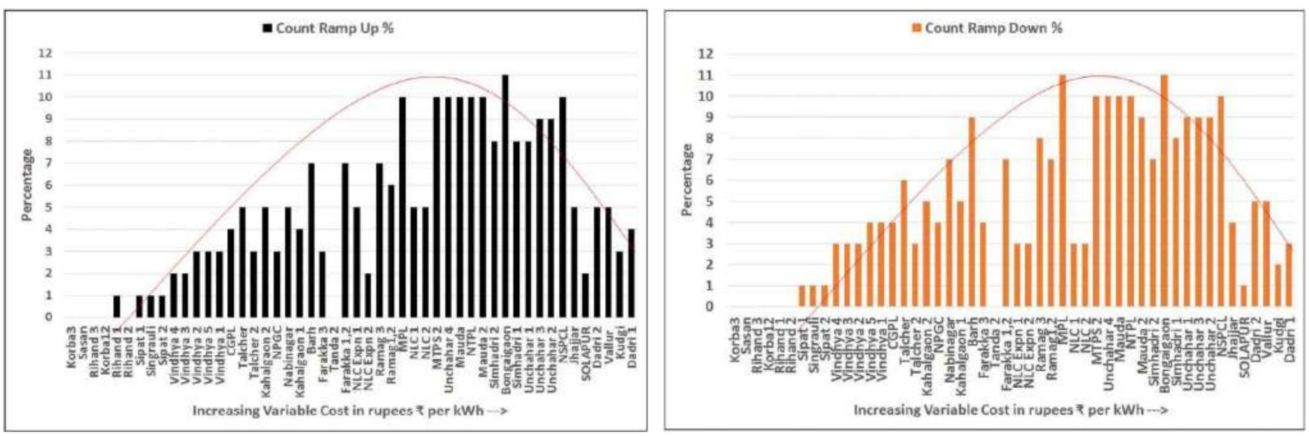


Figure 2.6 Percentage of time ramp up and ramp down constraints in SCED (Apr-Dec 2019)

In the present scenario, with maximum renewable penetration around 18-20% (in energy terms), there are some instances where thermal flexibility is exhausted. Figure 2.7 shows an example from 27th January 2019, showing the trend of total schedule for the thermal ISGS. It can be seen that the total ISGS generation moves from nearly technical minimum (during morning off-peak), to nearly DC (during morning peak), in a matter of a few hours due under drawl by states. Such need for flexibility would get exacerbated with increasing RE.

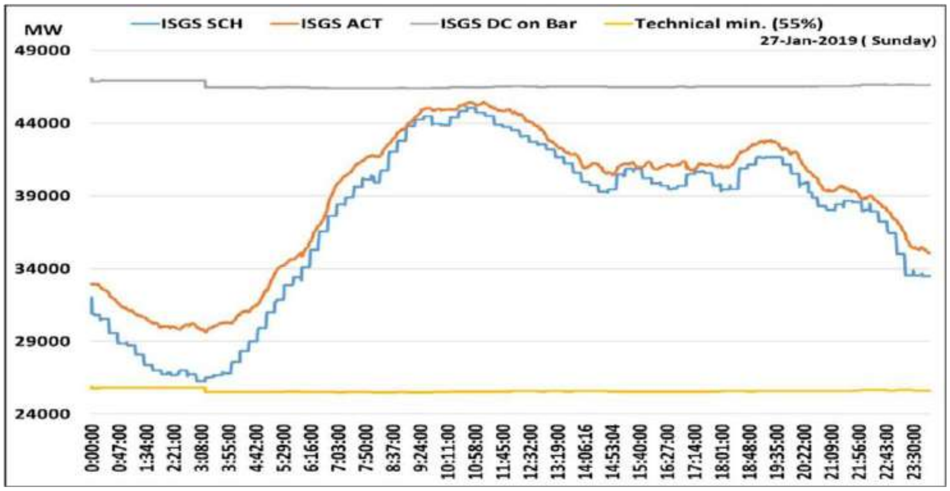


Figure 2.7 Trend of thermal ISGS schedule on 27th January 2019

There are major solar power parks in operation across several locations in the grid. A cloud cover over large solar parks has the potential to create large changes in solar output. These large changes in the generation may disrupt load-generation balance and pose as a potential threat to system operation. In order to manage these unexpected events, it is required that generation fleet has enough flexibility available with them.

2.2 Flexibility for Grid Support Services

The need for flexibility is also manifested in the primary and secondary frequency response provided by thermal units. Experiences from testing of primary frequency response and operation of Automatic Generation Control are summarized below:

2.2.1 Primary Response: Primary response is an important aspect for ensuring frequency control in the interconnected power system. IEGC 2010 mandates Free/RestrictedGovernor mode of operation in coal based units above 200MW. Onsite testing exercise is being carried out in compliance to IEGC, as per requirements it is desired that coal based unit displays sustained stable response corresponding to change in frequency. It is desired that primary response is sustained and stable at all load levels and there is minimum interaction with other control loops in the plants

Secondary Response: Continuous operation of Automatic Generation Control (AGC) has commenced from 20th July 2021. While doing so, all unit level constraints suchas P_{max}, P_{min} and ramp rates furnished by the stations are being honoured. Despite a significant capacity of 62GW included under AGC, the aggregate response obtained fromthe power plants for frequency control is often inadequate. A maximum of around +/- 1500 MW only is being obtained from all the power plants put together. A key reason forthis inadequate response from the power plants is attributed to a limit amounting to 5% of the unit capacity on the AGC, ΔP sent from NLDC imposed on the request of power plants. On account of the above, despite reserves being available in several plants, the same remains unutilized in secondary control.

2.3 Flexible Capacity Required/Available

As per CEA's report on optimal capacity mix for 2029-30 the likely total installed capacity by the end of 2029-30 projected is 8,38,783MW comprising of Hydro 61,657MW (including Hydro Imports 5,856MW), PSP 10,151MW, Small Hydro 5,000 MW, Coal 2,68,511MW, Gas 25,080MW, Nuclear 18,980MW, Solar 299,404MW, Wind 140,000MW and Biomass 10,000MW. With this installed capacity, the INDC target set for India i.e. the percentage of non- fossil fuel capacity in the total installed capacity is to be 40% by 2030 which is likely to be met. The likely renewable installed capacity shall be 450,000MW by March 2030. Recently, GOI has revised the commitment of renewables to 500GW. Hence with higher penetration of renewables (2030) and so as to avoid RE curtailment, the thermal units may have to operate below 40% minimum technical load.

As per the CEA report "*Flexible operation of thermal power plants for integration of renewable generation*" there will be maximum requirement of around 84GW flexible power (for integration of 175 GW RES capacity) from the grid connected thermal capacity of 140GW in year 2021-22. Study on maximum RES generation day in a month, 12 maximum RES generation days corresponding to 12 months of the year, 2021-22 have been calculated after prediction of hourly Generation for year, 2021-22 from Solar, Wind, Nuclear, Gas, small hydro, biomass and then coal. Actually coal generation is calculated figure and it is achieved by subtracting hourly generation of all sources except coal from hourly demand as predicted in EPS and the balanced generation to be met from thermal power plant.

The study highlighted that power generation BAU will lead to operation of the thermal plants at 26% capacity on the most critical day. However, considering flexing of the hydro power, gas based stations, pump storage station the minimum technical load could be improved to 46% from 26%. It is also found from the report that maximum RES generation of 107,798MW, 107,413MW will be available in the month of June, July respectively and ramp down & ramp up rate as calculated will be 380MW/min. & 375MW/min. respectively. As Indian high ash contained coal is not suitable for 26% minimum load operation, various steps have been proposed to improve the average minimum load operation of coal-fired power plant to 45%. However, this figure may be decreased further below 40% considering the 500 GW renewable integration by 2030. Detail study is proposed to ascertain the figure.

2.4 Ramp Rate Required/Available

The detailed analysis on average ramp rate required considering 175GW Renewable installed capacity has been done in CEA's report "Flexible Operation of Thermal Power Plant for integration of renewable Generation" which is reproduced below:

2.4.1 Maximum Ramp Up Rate

(379 MW/min when total demand is 200 GW)

Let us consider the day of highest ramp up rate, when maximum ex-bus generation from thermal plant is 154GW. After considering 10% reserve capacity and 7% APC, about 184GW thermal capacity would be synchronized on that day. Considering 1%/min ramping by the scheduled units, the system capability comes out to be 1840 MW/min. This is substantially higher than the ramp up rate required (379 MW/min.).

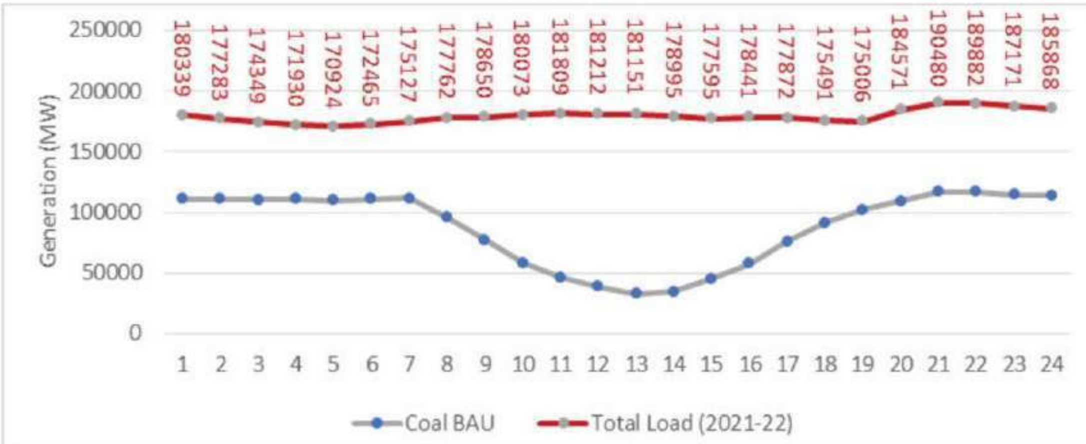


Figure 2.8

2.4.2 Maximun Ramp Down Rate

(422 MW/min when total demand = 185 GW)

Maximum ex bus generation required from thermal is 140GW. Considering 10% reserve and 7% APC, about 167 GW thermal capacity has to be synchronized. If we consider 1% ramp rate of each unit, then the system ramp capability comes out to be 1670 MW/min which is again substantially higher than the requirement on that day of 422MW/min. Hence, Indian grid is comfortably placed in case individual units maintain a basic ramping capability of 1%/min. Therefore, it may be concluded that ramp rates are not a challenge for integration of renewable generation from 175 GW RES into Indian grid.

However, the future ramp requirement may be increased to 1.5%- 2% considering 500GW renewable integration by 2030. The detail study is required to ascertain the figure in the light of 15-minute renewable generation time block.

3. STUDIES CONDUCTED

A number of flexibility studies in association with national/international partners (IGEF/VGB/GE/USAID/JCOAL/TEPCO/BHEL/Siemens) has been carried out at Central/State/Private plants. The flexible operational tests have been conducted at 40% load and higher ramps at number of stations in collaboration with OEM and others. These tests would add to the knowledge base and shall strengthen the understanding of the challenges involved in flexible operation of thermal units.

3.1 Pilot Tests/Studies

The pilot tests/studies conducted already under international cooperation and with the help of OEM are as follows:

1. Dadri TPS of NTPC in collaboration of IGEF, Germany
2. Mauda TPS of NTPC in collaboration of BHEL
3. Sagardighi TPS of WBPDCL in collaboration of BHEL
4. Ukai TPS of GSECL in collaboration of USAID, BHEL
5. RBTPS, JV of Tata Power, DVC in collaboration of IGEF/VGB, Germany
6. DSTPS of DVC in collaboration of IGEF/VGB, Germany

The results of concluded pilot tests at various power stations are as described below:

3.1.1 Dadri TPS, (NTPC), Dist. Gautambudh Nagar, UP

Test Date: 21 & 22/06/2018
Unit No.: 6
Unit Capacity: 500MW
Following tests were conducted:

	Test	Target	Achieved
a.	Minimum Load Test at 40%	200MW	200MW
b.	Ramp Up Test	3%/min	~ 1.5%/min
c.	Ramp Down Test	3%/min	~ 1.5%/min
d.	Ramp Up Test	1%/min	~ 0.86%/min
e.	Ramp Down Test	1%/min	~ 0.5%/min

The results are based on IGEF report dated 28/09/2018.

3.1.2 Mouda TPS, (NTPC), Dist. Nagpur, Maharashtra

Test Date: 16/02/2019
Unit No.: 1
Unit Capacity: 500MW
Following tests were conducted:

Test	Target	Achieved
a. Ramp up Test (3%)	3%/min	~ 2.04%/min
b. Ramp down Test (3%)	3%/min	~ 2.01%/min
c. Ramp up Test (1%)	1%/min	~ 1.04%/min
d. Ramp down Test (1%)	1%/min	~ 0.92%/min

Test Date: 29/05/2019
Unit No.: 2
Unit Capacity: 500MW
Following tests were conducted:

Test	Target	Achieved
a. Minimum Load Test at 40%	200MW	200MW
b. Ramp up Test (3%)	3%/min	~ 1.14%/min
c. Ramp down Test (3%)	3%/min	~ 1.68%/min
d. Ramp up Test (1%)	1%/min	~ 0.85%/min
e. Ramp down Test (1%)	1%/min	~ 0.9%/min

3.1.3 Sagardighi TPS, (WBPDCL), Dist. Musheerabad, West Bengal

Test Date: 27/06/2019
Unit No.: 3
Unit Capacity: 500MW
Following tests were conducted:

Test	Target	Achieved
a. Minimum Load Test at 40%	200MW	200MW
b. Ramp Up Test	3%/min	~ 1.6%/min
c. Ramp Down Test	3%/min	~ 2.6%/min
d. Ramp Up Test	1%/min	~ 1.1%/min
e. Ramp Down Test	1%/min	~ 0.67%/min

The flexibilisation test was conducted by BHEL team and was also witnessed by representative from TPRM Division, CEA.

3.1.4 Ukai TPS, GSECL, Gujarat

Test Date: 3rd to 7th March, 2020
Unit No.: 6
Unit Capacity: 500 MW
Following tests were conducted:

Test	Target	Achieved
Minimum Load Test at 40%	200 MW	200 MW
Ramp Test (3%)	3%/min	1.6%-2%/min
Ramp Test (1%)	1%/min	~1.0%/min

3.1.5 RBTPS, (Tata Power, DVC JV), DIST. Dhanbad, Jharkhand

Test Date: 22/07/2021 to 27/07/2021
Unit No: 2
Unit Capacity: 525MW
Following tests were conducted:

Test	Target	Achieved
Minimum Load Test (40%)	210MW	210MW 190MW (36%)* *achieved for short duration of 10min.
Ramp Up/Down Test	1%/min	

The ramp rates achieved were as follows:

	Upward direction	Downward direction
290 MW – 525 MW	0.95%/min	1.52%/min
MW – 290 MW	do	0.95%/min
210 MW – 225 MW	do	0.38%/min

3.1.6 DSTPS, (DVC), Andal, West Bengal

Test Date: 28/03/2022 to 31/03/2022
Unit No: 2
Unit Capacity: 500MW
Following tests were conducted:

Test	Target	Achieved
Minimum Load Test (40%)	200MW	201MW 173MW (34.6%)* *achieved for duration of over 2hrs.
Ramp Up/Down Test	1%/min	

The ramp rates achieved were as follows:

	Upward direction	Downward direction
From 55% – 72% Load	2.26%/min	
From 82% – 62% Load		1.54%/min

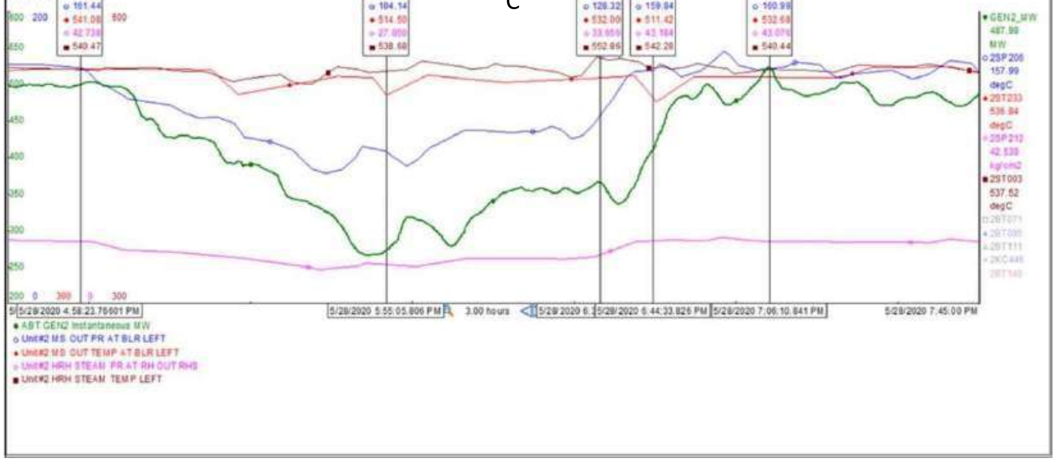
3.2 Observations from the Pilot Studies

Following were the observations for pilot project at

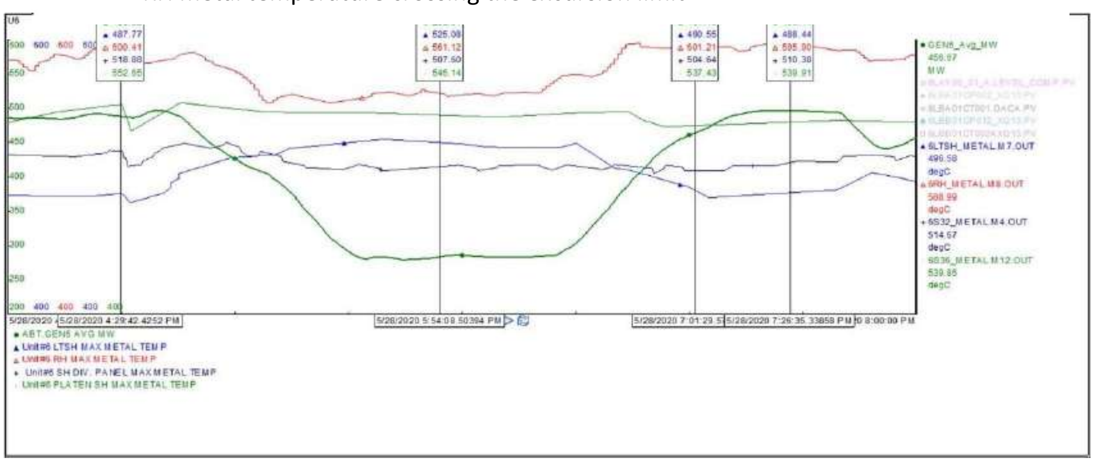
3.2.1 Excessive fluctuations in Steam temperatures- MS and HRH.

Steam temperature control becomes difficult as fuel flow rate and feed water flow rate decrease.

Typical MS and HRH steam temp fluctuation ~ 20-30 Deg C

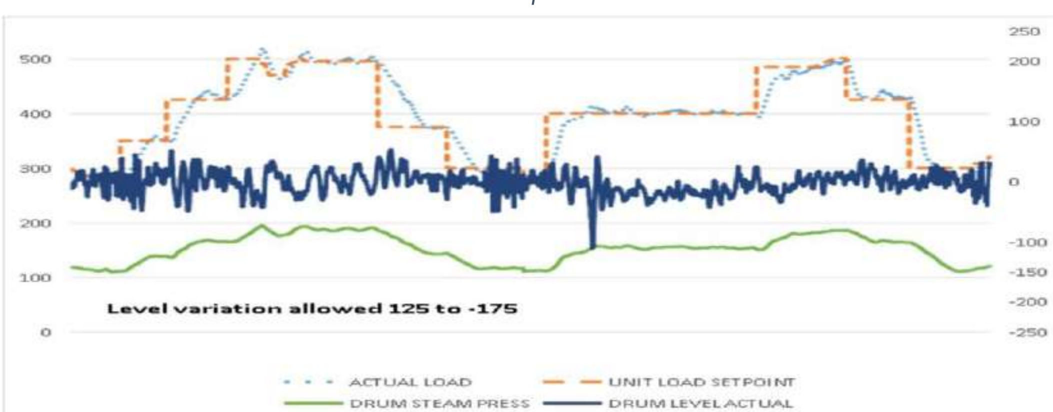


RH metal temperature crossing the excursion limit



3.2.1 High Drum level swings during ramping.

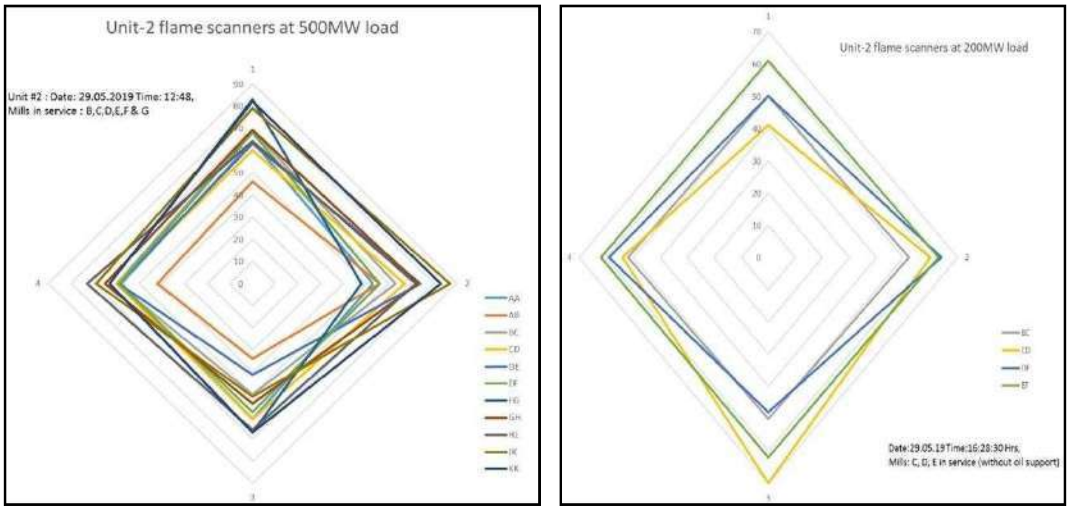
Drum level fluctuation



3.2.2 Flame disturbance during ramping and at MTL.

Fuel flow and air flow decrease, and balance of fuel and air sometimes collapses at some space in furnace of boiler, and combustion becomes unstable.

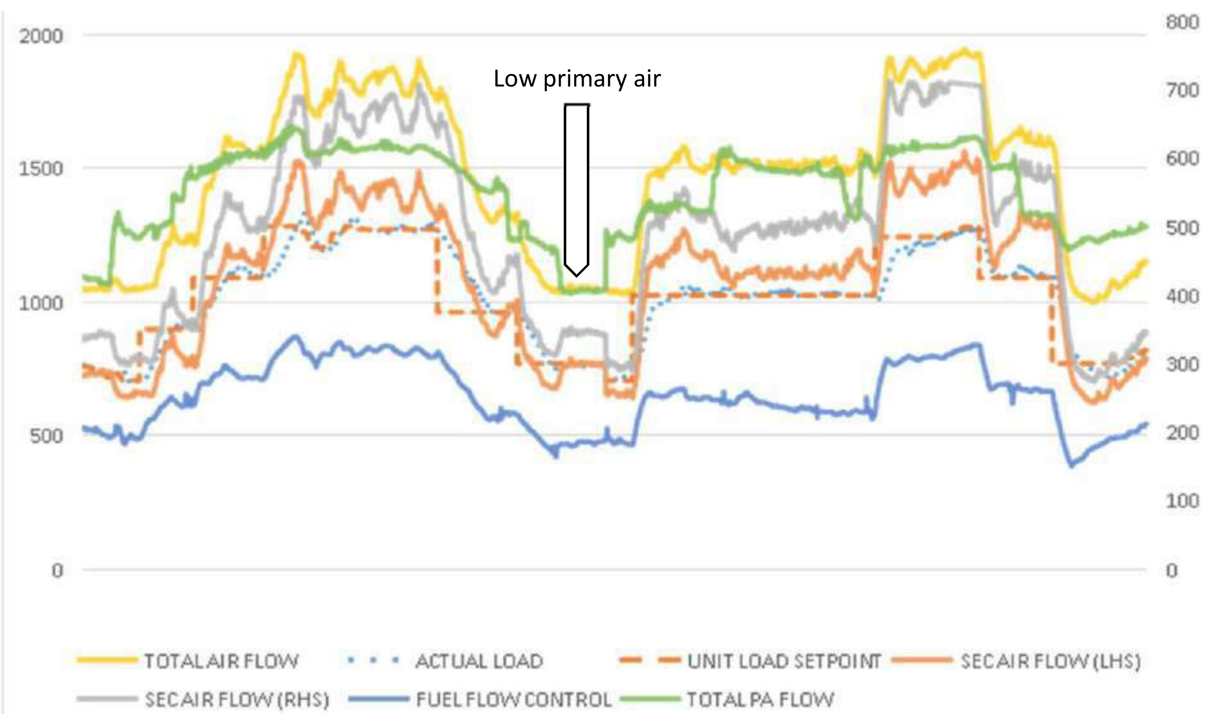
Flame scanners at 100% vs 40% load- Mouda U#2



3.2.3 Occasional furnace pressurization.

3.2.4 Chances of Stalling of Primary Air fans at low loads

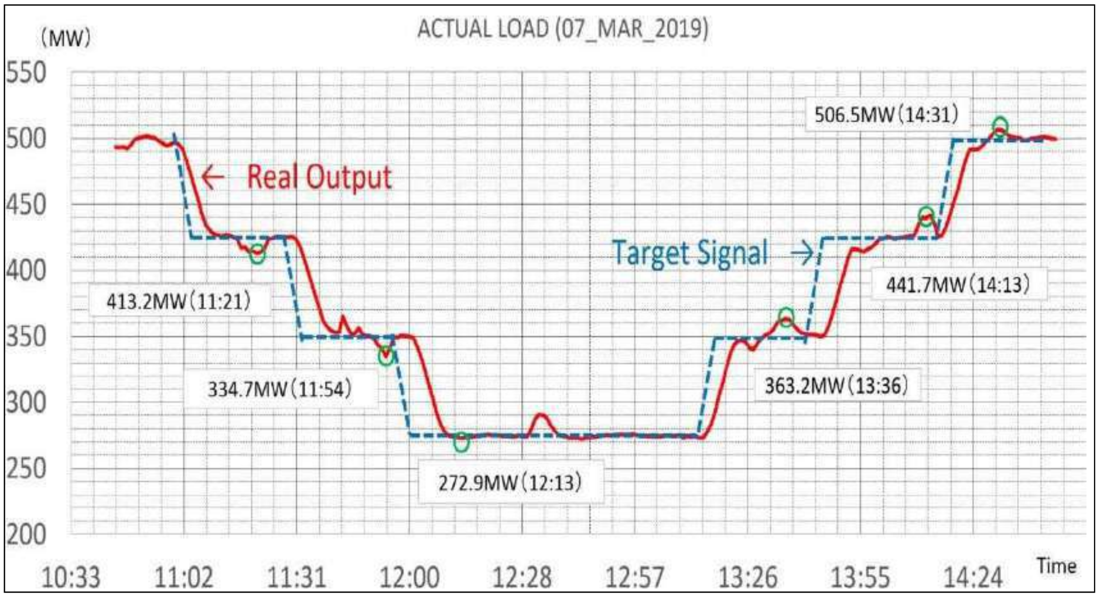
Low primary air flow can lead to stalling- Mouda U#2



3.2.6 Low boiler flue gas exit temperature, leading to acid corrosion?

3.2.7 With 3% ramp commands, actual ramp rate achieved in full load range from technical min. loading to full load was only 1.3% due to manual milling system operation.

Typical Ramp rate – Target vs Actual achieved



4. CHALLENGES OF FLEXIBILISATION

The challenges being faced for flexibilisation of the coal fired power plants are mainly due to the operation of thermal power plants as base load stations in the past so as to cater to unceasing power shortages in the country. It has resulted in low automation levels, low optimization of plant operation beyond the rated load and low ramping capability. The studies have generally found that on design basis, the units have enough flexibility of operation, but as a matter of fact, lack of some control logics and lack of enough tuning at test operation, actual flexibility of operation is limited. Further, the inferior quality of coal has added to the challenges of flexibilisation which impacts the stabilization of flame at low loads. After the introduction of new emission norms for thermal power plants in Dec, 2015, the compliance of $SO2$ and NOx limits are mandatory. Meeting NOx limits at low operating loads shall be a matter of concern needs to be tackled. The various roadblocks faced in flexibilisation of coal fired power plants and the possible mitigation strategies are discussed in details below:

4.1 Plant Capabilities

The flexing capability of a unit depends on the following factors

- Design- Thin-walled components/special turbine design will be better at flexing, shorter start-up time, higher ramp rate.
  - Boiler drum in Sub-critical units can pose challenges during flexible operation.
  - Super-critical units are better for load ramping operations but flexible operation at lower minimum load is challenging below benson point. However, operating the super-critical units on sub-critical mode has a very high impact on efficiency.
- Vintage- In older units the damage will be faster
- Coal- Poor coal quality will restrict flexible operation. (Discussed in the next section)
- Milling System- The start-up time and load ramp-up depend on the time to start the mills. It can vary from 10 minutes to 15 minutes.
- Control system- A good control system offers a huge advantage for maintaining proper parameters during flexible operation and to reduce the operational delays.

4.2 Impact on fuel quality

There is a large variation of quality amongst the different regions. Boilers are designed to burn coal of specified quality and any changes to the specified quality will significantly impact the performance and controllability of boilers. Change in coal from the design coal to a lower quality coal affects boiler operation and performance and particularly during low load operation with poor coal quality, the combustion stability of the boiler is severely affected and require additional support of secondary fuel (fuel oil). Challenges with poor coal quality include:

- Boiler slagging and fouling
- Increased corrosion and erosion
- Boiler tube metal temperatures excursion

- Lower boiler efficiency
- Overloading ash handling system
- Overloading of dust removal system and increased emissions

It is important to understand, how the different constituents in coal influence the performance during flexible operation and what improvements can be made. There is a wide variation in Indian coal fed to power stations from different sources. GCV varies from 2500 to 6000 Kcal/kg, Moisture - 8% to 15%, Volatiles- 18 to 30%, Ash- 25 to >50%.

4.2.1 Moisture – Part load efficiency is an important consideration of flexible operation and moisture affects unit efficiency by impacting thermal performance. Moisture has a flame quenching tendency and absorbs latent heat. High coal moisture content will lower the coal's gross calorific value (GCV), which means that that more fuel quantity will be required to be fired for the same heat input to the unit. The increased moisture in the fuel reduces boiler efficiency. Moisture also affects the pulveriser capacity and along with increased fineness in a coal adversely affects the coal handling capability. Coal moisture affects the following:

- Boiler efficiency
- Mill drying/ Tempering air requirements
- Gas velocities through the unit
- Choking in coal pipes
- Flame stability
- Precipitator efficiency

4.2.2 Ash -The challenges include, loss of reliability and availability, boiler slagging, fouling, high-temperature metal wastage, cold-end corrosion, stack emissions, increased deterioration in APH performance, duct leakages, increased water consumption, increased maintenance costs and lower unit efficiency. The quantity, chemical composition, and size of the ash are the variable that affect unit performance as well asthe marketability of ash & disposal. Ash quality affects the following:

- Mill wear
- Erosion
- Slagging and fouling
- Ash handling equipment performance
- APH performance
- SH/RH steam temperatures
- ESP Performance & Particulate emissions
- Capacity of CHP, bunkers, mills, boiler hoppers, ESP etc.

4.2.3 Volatile Matter - The volatile matter is an index of the gaseous fuels produced upon heating of the coal as it enters the furnace, mainly hydrogen and hydrocarbons that sustain ignition. Typical range of VM is 18% to 30%. Higher VM coals generally produce less NOx and are also easier to control in the combustion system, especially in low load operation.

Some of the Indian coals have VM of around 15% and stable combustion becomes extremely difficult, even at higher loads. There have been increased occasions of unit trips on flame failure (even during base load operation) at stations burning low VM coal. The problem gets aggravated further when coal fineness, A/F ratio and/or distribution of A/F is non-optimal, low volatile fuel results in furnace imbalances and increased amounts of de-volatilized carbon char seeking oxygen in the upper furnace and resulting in secondary combustion.

4.2.4 Sulphur Content - Sulphur in coal determines the degree of expected corrosion in the high/low temperature regions of the boiler. The amount of SO_2 that will be produced depends on the Sulphur content of the coal. A small part (2-3%) of the Sulphur in coal converts to SO_3, and the amount of SO_3 produced and retained in the flue gas determines the dew point of the flue gas and the collection efficiency of the precipitator. Sulphurcontent affects APH corrosion, duct & ESP corrosion. The problem is further aggravated during flexible operation when maintaining the flue gas temperature above the dew point becomes challenging.

4.2.5 Nitrogen Content- Nitrogen content (in volatile and fixed carbon) causes NOx formation. Fuel NOx ranges from 60–80% of the total NOx in pulverized coal units. The NOx formation can be reduced with staged combustion. During flexible operation, without sufficient automation for air flow control and combustion optimization NOx control becomes challenging.

4.2.6 Gross calorific Value (GCV) - The heat produced by combustion of unit quantity of a solid or liquid fuel when burned at constant volume in an oxygen bomb calorimeter under specified conditions, with the resulting water condensed to a liquid. There is alarge variation of GCV in Indian Coal, typically varying from 2500-6000Kcal/kg. The GCV of the fired coal is one of the key determinants of the technical minimum level.

4.2.7 Ash fusion temperatures

Ash fusion temperatures can be exacerbated by reducing atmospheres that are related with penthouse or convection pass air in-leakage that is upstream of the boiler O_2 probes. This can be a serious problem in Indian power stations with increased flexing and combined with high ash Indian coals.

4.3 Impact on Plant life

Flexible operation increases the creep-fatigue damage caused by thermal stresses, especially in units originally designed for base load operation. The creep-fatigue is a dominant failure mode for damage and failures of many fossil plant components. Creep-fatigue damage mostly occurs at stress concentration points like header bore holes, ligaments, rotor grooves, etc. due to large plastic strain. Accelerated Corrosion fatigue damage during flexible operation is another common factor. Maintaining optimum water and steam chemical parameters is challenging during frequent cycling. Almost all components of the Boiler, turbine and generator are affected ranging from severe to moderate. Following are some of the severely affected components:

Thick wall components	▪ Casting such as turbine valves and casings ▪ Turbine Rotor ▪ Thick-walled vessels ▪ MS, CRH, HRH headers (especially Y-piece section)
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 tube ▪ Welded joints
Degeneration of insulation due to thermal transients	▪ Generator insulation ▪ Transformer insulation ▪ Insulation of HV drives (FD, ID, PA fans, mills motor)

The pilot studies carried out in the Indian power stations revealed the following deviations/damage mechanisms during flexible operation.

1) High exhaust hood temperatures
2) High steam seal temperatures
3) High rate of change of metal temperatures
4) Last stage blade vibration
5) Solid particle erosion
6) Main steam and reheat steam temperature differential
7) Internal corrosion and oxygen pitting of waterwall tubes
8) Higher rates of internal corrosion of steam tubing due to increased exfoliation
9) Accelerated creep damage to steam (superheater and reheater) tubing
10) Chemistry upsets/excursions resulting in hydrogen damage
11) Fatigue corrosion due to cycling stresses on waterwall tubes
12) Furnace subcooling resulting in external tube failures
13) Overheating during low load operation by improper burner configuration
14) Steam line quenching
15) Higher risk of furnace explosion due to low turn down of fuel capabilities
16) Economizer inlet header thermal fatigue cracking

These damages impact the thermal units by:

1) Increased life consumption leading to increased maintenance, operation (excluding fixed costs), and overhaul capital expenditures.
2) Increased time-averaged replacement energy and capacity cost due to increased Equivalent Forced Outage Rate (EFOR).
3) Efficiency loss- Increased cost of heat rate changes due to low load and variable load operation.
4) Increased cost of start-up fuel, auxiliary power, chemicals, water, and extra manpower for start-ups.
5) Environmental Impacts

4.4 Impact on Environment

4.4.1 ESP

At low loads, there can be instances when the temperature in the ESP falls below the dew point and there is a built up of ash due the moisture, which becomes difficult to remove. Moreover, with high Sulphur coal there can be severe acid corrosion due to maintaining lower flue gas outlet temperature. During frequent start-ups, the ESPs ate kept out ofservice during oil firing. During this period, maintaining the particulate emissions becomes challenging. Due to lower efficiency of the thermal units during minimum loads, the specific CO_2 emissions increase.

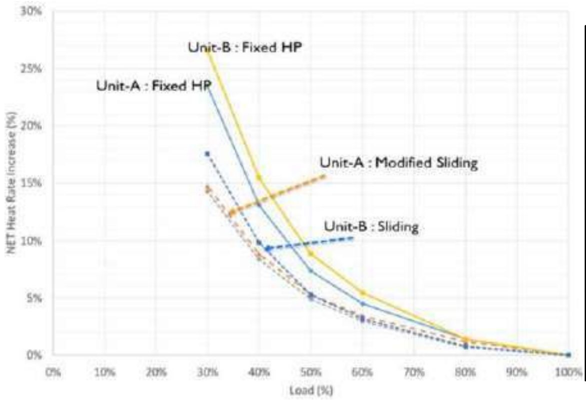
4.4.2 FGD operation during flexibilization

During flexible operation, there can be many issues with the FGD operation, which would need precise controls and modified operation procedures. Frequent start-up can have issues of solidification of slurry and accumulation of start-up oil on the linings. Long period of shutdown will require proper lay-up and flushing of slurry in order to ensure that lime slurry does not solidify. During load variations and frequent low loads, the operation of different streams and circulating pumps need to be optimized through automated controls.

A common problem observed during low load operation is reduction of inlet flue gas temperature, which is likely to impact the reaction rates. In some of the designs regenerative heat exchangers are used but in effect there may be a substantial decrease in exit temperature which in turn will reduce the gas buoyancy and induce dew point corrosion in the duct and chimney. Some FGD units bypass FGD plants (those with fluegas by-pass system), during start-up and low loads and charge the FGD after the temperatures stabilizes.

4.5 Impact on Efficiency

The loss on account of deterioration in efficiency of the unit at part loads is another major category of flexing costs. A typical deterioration of efficiency (net heat rate) for different categories (based on GE inputs is shown in figure-4(a). It may be noted that as per another study by NTPC this will vary from machine to machine and these losses will be significantly lower if the unit is run on sliding pressure (Figure-4(b)).



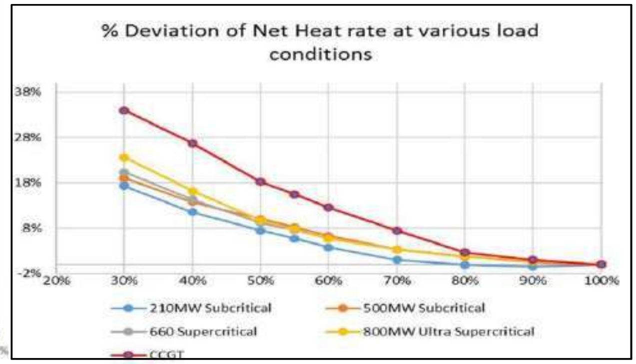


Figure-4(a): Net Heat rate Increase VS Loading Factor 4(b) NHR increase on fixed/slidingpressure

There is a good reason to put in extra efforts in modifying the operational practices for improvement in part load efficiency. Any plant modification/retrofits for improving the efficiency at part load will have a very short payback as degradation in efficiency is the biggest cost for low operation.

In a pulverized coal unit, there would be a less significant loss in efficiency if the unit operates on variable pressure mode. It is therefore worthwhile to make provision for sliding pressure operation for improved part load efficiency.

Combustion optimisation and reduced excess air, further improve the heat rate. Similarly, during test runs conducted at different units (500 MW coal fired of State Utilities, India), the heat rates were measured at different loads (90%, 55% and 40 %) under various conditions. One of the areas, where optimisation became difficult wasthe air flow requirements at 40% load which contributed to the increased stack losses. Otherwise at upper load conditions, significant improvement in heat rates were observed after optimization of air flow and operating the unit on sliding pressure. However, during varying load conditions, optimization is difficult and can interfere with the unit's ramping capability. Upgrading the C&I systems would be necessary for achieving the desired benefits.

Various auxiliaries in water and steam cycle of the unit have been designed with 2x50% configuration required at 100% TMCR for ensuring reliability. For low load operations at 40% TMCR, running both set of auxiliaries may not be required and thus single stream operation may be adopted which will allow for reduction in auxiliary power consumption. VFD installation may also be explored in units which operate on low loads for long duration.

A cautions decision would be required based on cost benefit analysis between APC reduction and controls and hardware modification cost for unit reliability.

4.6 Impact on Maintenance and unit Operators

As flexible operation leads to increased life consumption of plant components, increased outages and failures, it calls for revisiting the maintenance practices, increased inspection schedules and ensuring sufficient spares. Some of the components will have accelerated wear and failures during flexing operation (like mills, boiler pressure parts, valves) and would require increased maintenance. The maintenance strategy has to be devised, based on the extent of flexibilization. The frequency of significant load following, number of start-ups, coal quality, vintage of the machine.

Installing digital tools for online condition monitoring and damage assessment (like EOH/ EHS calculator) can be of great help in getting inputs of focused maintenance and on deciding the frequency of maintenance and component replacement.

Personnel safety is of first and foremost priority in operation and maintenance of coal based generating unit whether it is on flexible operation or on base load. Flexibilization of units adds to the safety risks and calls for added precautions. Sometimes serious and fatal injuries are caused by catastrophic equipment failure due to negligence and poor operation and maintenance practices.

In most of the cases, the boiler is often the most dangerous equipment, if not operated and maintained properly and in that case, it can act like a potential explosive.

Maintaining optimum chemical parameters is another challenge during flexible operation and the operating procedure must be modified to take care of the same. Moreover, flexible operation may require short of long shutdowns and adequate preservation needs to be ensured.

Some of the key takeaways from the field Tests for developing techniques for Low Load Operations:

4.6.1 For minimum load operation the mantra is sustaining stable combustion by manipulating the firing rates, maintaining even temperature distribution within the different zones of the boiler, managing the coordination between the boiler and turbine. Reducing the number of mills in service. At 40% load 3 mills were kept in service

4.6.2 **Optimisation of primary air flow**. The primary air flow in mills were reduced. A review of primary air flow curve should be considered for low load.

4.6.3 **Optimisation of secondary air flow**. Tertiary vanes of elevations that were not in service were reduced, ensuring just adequate flow for burners cooling. It was ensured that the wind box pressure did not collapse to zero. Measurement of secondary air flow was not available. This could have helped in further optimization of the process. It is therefore recommended to make provisions for SA measurements at individual burners.

4.6.4 **Measurement of excess air** for combustion /Flue gas O_2 measurement may be validated with CO measurement as CO is unaffected by air in-leakages. It is advisable to use both the measurements.

4.6.5 **Sliding pressure** induces a sluggish load response for drum boilers. But the advantages are far more. Modification of sliding pressure curve (increased slightly) in small steps is to be done to ensure that there is no steaming in economizer and no DNB.

4.6.6 **BFP recirculation valves** must be able to operate at intermediate positions (inching type). At 40 % load, one TDBFP can meet the feed water demands. The changeover of driving steam source must be ensured. Ensure readiness of MDBFP on hot standby.

4.6.7 During the test runs, a number of manual interventions were made in the presence and advice of the OEM. In particular, there were issues during fast load changes and manual intervention on the firing system raising the risk of combustion instability and boiler puffs. During such operation, the safe functioning of the burner management systems must be ensured. For severe demands during regular low load and ramping operation, enhancement of controls, monitoring and diagnostic systems is worthwhile and has been recommended in all the studied carried out, including the OEM's. As per the limitations encountered during the field tests, upgrades for automatic loading control and combustion management will be required.

4.6.8 The unit control system consists a number of loops and sub loops, with master controllers and coordinated by CMC. In older base load units, the C&I systems were designed to provide responsive control in the higher load range and oftenthe C&I specs aimed at automatic operation in the range of 60% to 100% MCR. The automatic control at lower loads becomes poor and sluggish mainly due to changing unit response characteristics.

4.6.9 Another limitation with low load operation is the improper sizing of many control valves for low load or low flows operation, causing poor control response and sometimes hunting of valves. All these control valves must be checked for correct operation at low load and necessary modifications be done. Replacement or placing additional valves may be necessary.

4.6.10 Additionally, for cyclic operation, review and modifications will be required for the alarms and protection logic. A review and evaluation of the alarms and protections setting is required as the unit would operate at different levels from those for which these were designed to operate. Before finalizing any changes, the opinion of the OEM must be taken. Examples include-minimum air flow, minimum mills loading, temperature setting, modification of sliding pressure curve, primary air flow curve, temperature settings etc.

4.6.11 When a base load unit is converted to operate on flexible mode, the operator's view of the process (displayed on LVS or other screen) needs to be modified to include the actions that may be needed during the particular operating regime. These screens can include the important or problematic processes along with trends to facilitate the operator to react fast in case of any process deviation during the cycling operations, for example, a screen for low load operation and for start-up (cold, warm & hot) and for shutdown.

4.6.12 The life of a steam turbine is directly related to thermal transients experienced over time. The typical steam turbine start-up ramp rate is well-defined by the OEM, as there are limits to the heating rates of the turbine parts.

4.7 Roadblocks & Mitigation strategies:

The pilot studies and subsequent operations presented some challenges which were taken up with international partners for suggestive mitigation plans. A brief of the roadblocks, mitigation plans and the retrofit requirements is given below:

S.no.	Roadblocks	Mitigation plan	Remedial measures
A	**Equipment Operating Mode:-**		
1	Achieving >1% Ramp rate (up and/or down); Increasing number of ramps up/down during the day.	Address excursions w/metal and steam temperatures, pressure swings, poor grid frequency response; condenser vacuum; limits on load range.	Advance process control loop tuning, Mill automation, providing additional tube metal sensors, heat flux sensors etc.
2	Minimum load program is not in place; Difficult to reduce load below 55% of MCR without oil support	Establish program; Implement a Systematic Approach to Minimum Load Reduction	Control loop tuning upto 40% MTL, mill automation, single fan/pump operation, implementation of hardwares like Variable Orifice in coal flow pipes-, coal pipe flow measurement, low load scanners.
3	Heat Rate at low operating loads w/ varying fuels; Net heat rate >2% deviation from design due to running at reduced loads; Influence on the Energy Charge Rate and overall production costs. Increase in Auxiliary Power	Benchmark performance; Evaluate controllable losses vs. fuel quality, Modified Sliding pressure operation during ramp up/down. Installation of VFDs for high energy drives.	Top heater installation, single drive operation pumps and fan, installation of VFDs for high energy drives.

S.no.	Roadblocks	Mitigation plan	Remedial measures
	Consumption at Part Load.		
B	**Pressure Parts and Life Availability**		
1	Flow Accelerated Corrosion (FAC) inEconomiser tube	FAC programintegration	Top heater installation, Automation in maintaining Boiler water pH
2	No thermal gradient measurement on economizers	Pegging/heating in deaerator and fillingof hot water in boiler filling during light up.	Installation of additional thermocouple in economiser tube
3	Thermal Fatigue	Possibility of inter connection of drains to hot fill the boiler tobe explored;	Interconnection of Deaerators among theunits. Thermal Fatigue can be minimized through maintaining the Startup/Shutdown curve provided by OEM. This can be done through plotting design Vs Actual curve during startup/ shutdown in the dashboard so that immediate correction canbe made in case of anomalies.
4	Steam Temperature control needs improvement following synchronization to mitigate reported excursions in major SH/RH/LTSH components; Mismatch in heat pick up in MS left & right.	Close monitoring of deviation of MS/HRH and metaltemp during ramping.	Advance process controlof steam/ water cycle and load control. Installation of additional metal temperature sensors.
			SH/RH spray controlvalves upgrade.

S.no.	Roadblocks	Mitigation plan	Remedial measures
C	**Operations**		
1	Operations team need overheat mitigation guidance	Better guidance to evaluate stress on boiler and turbine components	Control loop tuning and Boiler fatigue monitoring system
2	High Energy Drain / Boiler stop valve passing problem	Monitoring of high energy valves with temp gun in running condition	Replacement plan forthese valves during annual outages
3	Boiler insulation degradation impactsoperations	Insulation mapping in boiler in running condition	Phase wise replacementplan
4	No temperature sensorsin the furnace walls to assess overheating, heat flux, impacts of reduced load operation		Additional temperature sensors installation in S bend
5	APH gas temperature control; SCAPH not effective.	SCAPH to be made through for air heating.	Automation in SCAPH control to maintain APH gas temp. Increasing capacity of Steam Coil Air Preheater and APRDS System.
6	Drum level control challenges lead to load swings in drum level even with mild disturbance.	Auto loop tuning offeed water cycle	Single pump operation and installing regulating type recirculation Advance process controlof drum level
7	No simulators are available to carry out testof flexible operation to evaluate behaviour at varying load conditions.		Simulator to be upgraded with the measures of advance process control and withmore automation.
D	**Maintenance**		
1	High pressure control valves are passing e.g. sprays ,BFP recirculationvalves , high energy drains etc.	Integrate high pressure control valves modernisationplan.	Phased replacement. Changing on-off BFP re-circulation valve with modulating control valves.

S.no.	Roadblocks	Mitigation plan	Remedial measures
2	Frequent problem in PA fans as they run close to stalling zone.	Continuous tracking of PA fan characteristics curve and provisioning of alarm much before fan operating near the stalling zone.	Single PA fan operation, automated single drive control package to avoid stalling.
3	Thermal Fatigue and Creep Damage	Integrate thermal mitigation strategy.	Boiler fatigue monitoring system and Turbine stress monitoring system.
E	**Combustion and Boiler Performance**		
1	Furnace exit O2, Furnace Exit Temp measurement are not taken.	Furnace Exit O2 measurement and Furnace Exit Temp measurement to be done. Furnace Exit O2 measurement and Furnace Exit Temp measurement to be done.	Furnace exit O2% probe installation and Furnaceexit temperature measurement.
2	Mill Performance; No provision to measure fuel flow imbalance in mills; Frequent burner choking; Coal rejects from mill hoppers.	Mill performance mapping at various load & coal quality tobe done to identify best & worst mill; Need to establish mechanical blue-printideal for flexible operations. Mill performance evaluation, finesses measurement and coal flow balancing.	Milling system coal pipe measurement system installation. Installation of coal flow sensors and variable orifices* in coal pipes. (* may be only useful below 30% operation)
3	Implement program and strategy for low load and reduced mill operations	Optimize mill operations and/or identify roadblocks and/or issues during planned shut-downs (record observations)	Optimising no of milling operation with milling automation

S.no.	Roadblocks	Mitigation plan	Remedial measures
4	Poor flame stability and load response with 30% -50% high ash domestic Indian coal and/or low quality imported coals	Flame Quality Scanner Performance improvement- Explore application method to display both intensity and frequency; Identify opportunities to improve mill configurations for optimal A/F ratios	Flame scanner upgrade in control, repositioningof scanners and replacement of coal pipenozzles with low turn down of flame length, coal blending. Coal mill classifier upgrade for improving mill fineness, digital solutions for flame stability at low load operation and for achieving required ramp rates.
F	**Instrumentation and Controls**		
1	Control loops are not tuned at part loads.	Controls tuning.	Control tuning up to minimum load operation.
2	Water wall temp are not available.	Water wall metal temp. Monitoring.	Additional thermocouple installation.
3	No FEGT measurement.	Furnace Exit Gas Temp. Monitoring.	FEGT measurement installation.
G	**Environmental Controls**		
1	Dry ash evacuation Capacity is inadequate due to reliability issues.	ESP augmentation for dry ash evacuation.	Augmentation in Ash Handling System.
2	NOx control to achieve regulatory requirements	NOx controls	Implementation of NOx abatement system
3	Impact on NOx/SO2	NOx / SO2 controls	Implementation ofControl System
H	**Cycle Chemistry**		
1	Chemical dosing is mostly completed manually	Automation is needed.	LP Dosing automation with VFD drive.
2	Condenser tube leakage identification need modification.	Continuous monitoring of condensate cation conductivity.	Attending condenser tube leakages.
3	Deposits in HP turbine	Maintain Steam Purity	CPU installation

S.no.	Roadblocks	Mitigation plan	Remedial measures
4	Chemical parameters control at start-up (e.g. controlling DO)	Improve strategy for start-up and part load operations	Nitrogen purging in condensate storage system.
5	Maintaining Water Chemistry parameters at load less than 55% say at 40% will be challenging due to Absence of CPU in several stations.	Improving Water Chemistry for load load operation.	CPU installation
6	Some stations do not havea practice for Turbine/ Hot well/feed water/ Generator layup, recently Preparation of instrumentair connection is in progress for RH coil lay up; Common reserve shut-downs increased insome station from 1-2 weeks to 2 months.	Implement Layup program with required system equipment to managecorrosion when vacuum cannot be held.	Design Wet/Dry layup program & implement the same.
I	**Steam Turbine Generator**		
1	HPT heating takes 3-4 hrs time during cold start up;	Startup procedure need to be revisitedfor aligning with flexible operation.	Electric heater blanketingon HPT can reduce the time
2	Shaft Vibration / pedestal vibrations are important parameters which needs to be monitored in all operative conditions including low load operation.	TG vibration problemto be addressed for better load following and low load operation.	To be studied with OEMand solution to be implemented.
3	TDBFP recirculation - ”open/close” type and often leads to drum level disturbance	Replacement of TDBFP recirculationvalve with control valve type.	Replacement of On-off re-circulation valve with control valve.
4	Main Steam Temperature variation during Ramping (10-20^{0}C).	Improve control	Advance process control

S.no.	Roadblocks	Mitigation plan	Remedial measures
5	Creep/Fatigue damage mitigation on high-temperature components needs to understood	Installation of Turbine and BoilerStress Monitoring System	Equivalent Operating Hours (EOH) installation
6	At low load, both TDBFP operation is not possible as CRH source of motive steam for drive turbine is not lined-up.	Motive steam source from CRH shall be made operational.	Control Valve operationto be tuned higher parameter
7	Increase in cation conductivity at CEP discharge during minimum technical load operation.	Possibility of installing condensatepolishing unit shall be studied if not installed for improving condensate and feed water chemistry.	CPU Installation.
8	Drop in Main / ReheatSteam Temperature.	Load ramping to be limited	MS/RH Spray isolation valve internal checkingto be scheduled during shutdown/AOH. • Calibration of instrument for Spray Flow, Temperature Tx etc shall be planned on a scheduled timeline.

5. PROCEDURE FOR LOW LOAD TESTS

5.1 General

With increase in Renewable Energy Integration to grid, conventional thermal power plants would be required to cycle. The plant would then be required to operate below current technical minimum load and require faster ramp up and ramp down rates. In such a scenario the life of critical components such as Boiler, Steam Turbine & Pumps gets affected. The increased fuel cost also presents the challenge to utility to achieve optimum efficiency. In order to generate electricity economically utilities need to revisit the conventional operation and maintenance practices and, optimize their operation with advanced digital solutions. The typical operating modes of thermal power plants are undergoing changes especially as a result of the increasing percentage of renewable in electric power generation. The future trend comes along with expanding the grid, increasing power storage capacity, participation of renewable power generation in grid control and residual load generation by thermal power plants. Main challenges are the fast start-ups, fast load change rates as well as efficient low load operation and high demand of primary frequency response.

This chapter discusses procedures to be adopted for pilot testing of coal-fired power plants that serve the aforementioned circumstances without any additional measures.

The pilot test runs should be conducted after careful study of the unit beforehand and accordingly the test targets should be decided in consultation with OEM. Study should involve the evaluation of process limitations and an assessment of the impact of low load operation (temperature/pressure gradients) on the components. Any stretching of the targets during the test run should be avoided for the safety and security of the plant.

5.2 Good O&M Practices/Prerequisites for flexibilisation

It is essential that some basic practices are followed before preparing a unit for flexing. The below indicative list contains the broad preparation items and is not exhaustive.

a) All auto loops should be available and fine tuning of CMC must be carried out to minimize the deviation of parameters like MS/HRH steam temperature, throttle pressure, drum level, excess O_2% at economiser outlet and flue gas temperature at boiler outlet.
b) Attemperator system (isolating valves and control valves) and control valves are to be set tight and must give fast response to the changing system demand.
c) Optimise minimum coal loading in a mill by fine tuning primary air flow vs coal flow curve to avoid lean air mixture and possible flame failure tripping.
d) Dirty air flow test at regular interval to evaluate partially plugged coal pipes and burners
e) Burner tilts should be operational in full range in auto mode.

f) SADC damper operation should be checked any leakage from damper should be minimized and correct feedback must be made available. (Feedback is not available in DCS for BHEL units)
g) WWSB and LRSB operation scheduling should be done at higher load during such opportunity.
h) Air heater soot blowing must be carried out at least once in a shift
i) Air heater air leakages and other tramp air should be minimised.
j) Replacement or repairing of expansion joints if required and major duct revamping if any.
k) Water chemistry instrumentation (SWAS System) should be set right and linked with DCS.
l) SCAPH auto operation to be made through to contain flue gas temperature less than acid dew points
m) Check leakages in system under vacuum. Helium leak detection test may be conducted to identify leakages. Air Leakages above 20 kg/hr (observed in Rotameter installed in Vacuum Pump / Main Ejector exhaust) needs to be attended.
n) Boiler side high energy piping hanger indicator are to be marked and monitored.
o) Low load FRS (30% FRS) to be used to reduce deviation in or maintain flow rate in economiser during cold or warm start up.
p) Turbine stop and control valves to be inspected w.r.t valve position in control room.
q) Boroscopic inspection provisions shall be made available for LP turbine.
r) Ensuring availability of deaerator pegging / heating with auxiliary steam sources and from turbine extraction.
s) Feed water treatment with AVT(O) or AVT(R) is to be suitably deployed.

5.3 Procedure for low load tests

For a 500 MW unit, the test procedure for ramp down from full load **(500 MW)** to 40% load **(200 MW)** and vice versa is tabulated below: -

5.3.1 Test procedure for load ramp down tests from full load (500 MW) to 60% load (300 MW) at 1% (5 MW) per minute (Target Time: 70 minutes) and 3% (15 MW) per minute (Target Time: 13 minutes):

a) Stabilize the unit load at full load with 6 mills with CMC in service & APC ON.
b) Give the load set point of 450 MW.
c) Start reducing the mill loading of bottom most Mill gradually after putting in manual mode to meet firing demand.
d) Stabilize the unit around 450 MW for 10 mins.
e) Give the load set point of 400 MW.
f) Start reducing the mill loading of bottom most mill gradually till the mill is completely unloaded. Trip the bottom most mill.
g) Stabilize the unit around 400 MW for 10 mins.
h) Give the load set point of 350 MW.

i) Start reducing the mill loading of bottom most mill gradually to meet firing demand.
j) Stabilize the unit around 350 MW for 10 mins.
k) Give the load set point of 300 MW.
l) Start reducing the mill loading of bottom most mill gradually till the mill is completely unloaded. Trip the bottom most mill.
m) Stabilize the unit around 300 MW.

5.3.2 Test procedure for load ramp down tests from 60% load (300 MW) to 40% load (200 MW) at 1 % (5 MW) per minute (Target Time: 30 minute) and 15 MW per minute (Target Time: 37 minutes):

a) Stabilize the unit load at 60% load with 4 mills and CMC in service (APC On)
b) Give the load set point of 250 MW.
c) Start reducing the mill loading of all mills gradually with higher unloading of bottom most mill to meet firing demand.
d) Maintain both PA Fans in service if 3 or more mills are in service, if further load ramp down is taken up and fans are operating near to their stall zone then manually switchover to single PA Fan operation. Switchover to Single FD and ID fans can be done to optimize Aux power consumption.
e) Stabilize the unit around 250 MW. (for 10 mins)
f) Give the load set point of 200 MW.
g) Start reducing the mill loading of all mills gradually with higher unloading of bottom most mill to meet firing demand.
h) Stabilize the unit around 200 MW. 60%-40% load ramp rate of 3% will cause wide temperature fluctuations. It requires multiple iterations with different combination of mills.

5.3.3 Test procedure for load ramp up tests from 40% load (200 MW) to 60% load (300 MW) at 1% (5 MW) per minute (Target Time: 10 minutes) and 3% (15 MW) per minute (Target Time: 7 minutes):

a) Stabilize the unit load at 40% load with 3 mills and lesser loading in bottom most mill.
b) Give the load set point of 250 MW.
c) Start increasing the mill loading of all mills gradually with higher loading of bottom most mill to meet firing demand.
d) Stabilize the unit around 250 MW for 10 mins.
e) Give the load set point of 300 MW.
f) Start increasing the mill loading of all mills gradually with higher loading of bottom most mill to meet firing demand.
g) Manually take second BFP also in service, if not taken earlier, and balance both BFP.
h) Manually take second PA Fan in service, if not taken earlier, and balance both fans.
i) Equalize loading of all mills. FD & ID Fans as well
j) Stabilize the unit around 300 MW for 10 mins.

5.3.4 Test procedure for load ramp up tests from 60% load (300 MW) to full load (500 MW) at 1% (5 MW) per minute (Target Time: 40 minutes) and 3% (15 MW) per minute (Target Time: 13 minutes):

a) Stabilize the unit load at 60% load with 4 mills with CMC in service.
b) Take the fifth mill in service (preferably adjacent to mills already in service and topmost amongst the standby mills) with minimum loading and allow the mill to stabilize.
c) Give the load set point of 350 MW.
d) Increase the mill loading of fifth mill gradually to meet firing demand. Simultaneously adjust the mill loading of other four mills to meet firing demand and till the time fifth mill is sufficiently loaded and stabilized.
e) Stabilize the unit around 350 MW for 10 mins
f) Give the load set point of 400 MW.
g) Increase the mill loading of fifth mill gradually to meet firing demand. Simultaneously adjust the mill loading of other four mills to meet firing demand and till the time fifth mill is sufficiently loaded and stabilized.
h) Stabilize the unit around 400 MW and equalize the mill loading.
i) Take the sixth mill in service (preferably adjacent to mills already in service and topmost amongst the standby mills) with minimum loading and allow the mill to stabilize.
j) Give the load set point of 450 MW.
k) Increase the mill loading of sixth mill gradually to meet firing demand. Simultaneously adjust the mill loading of other five mills to meet firing demand and till the time sixth mill is sufficiently loaded and stabilized.
l) Stabilize the unit around 450 MW for 10 mins.
m) Give the load set point of 500 MW.
n) Increase the mill load of sixth mill gradually to meet firing demand. Simultaneously adjust the mill loading of other five mills to meet firing demand and till the time sixth mill is sufficiently loaded and stabilized
o) Stabilize the unit at full load and equalize the mill loading.

5.4 Critical Operating Parameters

- Generator Load
- Main Steam Pressure, Temperature, Flow
- Reheat Steam Pressure, Temperature
- Drum Level, Deaerator Level and Hotwell Level
- Oxygen % in FG at Economiser outlet
- Windbox pressure, SA flow, PA Flow, PA Header pressure, Furnace pressure
- SADC & Burner tilt positionFlame intensity
- Air Heater outlet temp – Flue gas
- Metal temperatures – SH, RH, Drum / Separator
- Condensate flow / FW Flow
- Condenser Vacuum

- Extraction Steam Pressure, Temperature
- Casing Metal temperatures of HP /IP Turbines
- Vibrations of HPT, IPT, LPT, Generator bearings and shafts.
- Chemical Parameters for Main Steam, Feed water, Condensate system, etc.

5.5 Data Logging

Following time stamp data from DCS should be recorded for further analysis and study.

a. Boiler load vs

- Feed water Temp at Economiser Inlet/Outlet
- Platen SH I/L Header Temp
- Final SH O/L Header Temp
- Separator Level
- Excess Oxygen
- Separator Metal Temperature

b. Turbine

- Turbine First Stage Pressure
- First Stage Temperature
- HP Control Valve Body Temperature
- IP Control Valve Body Temperature
- Turbine Inner Casing Temperature
- Turbine Outer Casing Temperature

The template for observing some of the important parameters are as indicated in the Table 5.1 on the following page.

Table 5.1 Template for Study of Minimum Load Operation

Load (MW) :
Coal Flow (TPH) :
Air flow (TPH) : **Date :**
O2 (%) : **Time :**

S.No.	System	Parameter Description	Unit	Value	Observation
1	Boiler	Main Steam Pressure Left	Kg/cm2		
		Main Steam Pressure Right	Kg/cm2		
		Main Steam Temp Left	°C		
		Main Steam Temp Right	°C		
		HRH Pressure Left	Kg/cm2		
		HRH Pressure Right	Kg/cm2		
		HRH Temp Left	°C		
		HRH Temp Right	°C		
		SH DSH SPRY WTR FLOW	TPH		
		RH DSH SPRY WTR FLOW	TPH		
		Seperator Level	M		
		BRP Status			
		Burner Tilt Position	%		
		Steam Flow	TPH		
		Secondary AiR Flow	TPH		
		DP across Windbox to Furnace	MMWC		
		RAPH outlet FG Temp	°C		
		RAPH Flue Gas Inlet Temp	°C		
		PRS Pressure & PRDS Pressure	Kg/cm2		
2	Flame Intensity	Eleveation wise Intensity	%		
		Furnace Draft	MMWC		
		Flue Gas Furnace Exit Temp	°C		
		Flame Position			
3	Boiler Tube Metal Temp	HRH Max Temp	°C		
		SH PLATEN Max Temp	°C		
		Right Spiral Temp	°C		
		Front Spiral Temp	°C		
		Left Spiral Max Temp	°C		
		Rear Spiral Max Temp	°C		
		Final SH Max Temp	°C		
4	Boiler Header Temp	SH Left OL Hdr Temp	°C		
		SH Right OL Hdr Temp	°C		
		RH Left OL Hdr Temp	°C		
		RH Right OL Hdr Temp	°C		
		RH Left IL Hdr Temp	°C		
		RH Right IL Hdr Temp	°C		
		Sep OL Metal Temp Left	°C		
		Sep OL Metal Temp Right	°C		
		Eco Link Header Temp 1	°C		
		Eco Link Header Temp 2	°C		

5	**Fans (PA/ID/FD)**	Pitch (Fan-A/ Fan-B)	%		
		Head (PA Fan)	**MMWC**		
		Current	**AMP**		
		Flow (Primary)	**TPH**		
6	**Milling System**	No of mills in Service	**NOS**		
		Mill loading (TPH)	**TPH**		
		Mill current	**AMP**		
		Mill vib	**MM/SEC**		
		Mill Inlet temp	**°C**		
		Mill Outlet Temp.	**°C**		
		Mill Bowl DP	**MMWC**		
		Air Fuel Ratio	**TPH**		
		PA Flow through Standby Mill			
7	**TDBFP parameters**	Recirculation valve position			
		Speed (A/B)	**RPM**		
		Flow (A/B)	**TPH**		
		Live Steam pressure (A/B)	**Kg/cm2**		
		No of BFP in service	**NOS**		
		Aux. Control Valve Position	**%**		
		Scoop position	**RPM**		
		TPBFP Exhaust Hood Temp (A/B)	**°C**		
8	**Turbine Parameter**	4th Stage Pressure	**Kg/cm2**		
		HP Exhaust Temp L-1	**°C**		
		Turbine HP Exh Ur/Lr casing inner meta	**°C**		
		Turbine HP Lower Casing Inner metal tem	**°C**		
		Turbine HP Upper casing Inner metal tem	**°C**		
		Turbine IP Exhaust Pressure	**°C**		
		Turbine IP Exhaust Temp	**°C**		
		Turbine LP Exhaust temp	**°C**		
		Turbine Gland Steam Seal Header Temp	**°C**		
		Gland steam temp	**°C**		
		Gland steam supply CV position	**%**		
		Gland steam leak off CV position	**%**		
		Turbine IP Exh Ur/Lr casing inner metal	**°C**		
		Turbine IP Lower Casing Inner metal tem	**°C**		
		Turbine LP Upper casing Inner metal tem	**°C**		
		Condenser Vaccum	**°C**		
		Heater Drain Pump Status	**bar(abs)**		
		Heater Drain Pump Status	**°C**		
		CEP Pump & Motor Vibration			
9	**Turbovisory System**	TG Shaft & Pedestal Readings			
10	**Turbine Bearing Metal Temp**	TG Bearing Temp Readings			
Note	**Based on initial discussion with Technical Teams,indicative problem areas are provided in Observation Cum Remarks cell. However actual issues/deviations faced during the trial shall be**				

Source: PPGCL

6. MODIFICATIONS REQUIRED

The previous chapters have analyzed and emphasized the need for thermal power plants to be flexible, to explore the capability to flex and limitations thereof. This chapter focuses on modifications needed and retrofit options for increasing operational flexibilityof coal fired units. For getting more flexibility, it does not require to retrofit the entire plant but retrofit only certain subsystem of power plant that are most effective in tackling plant flexibility. The technical measures shall depend on the levels of minimum load operation to be adopted (50%, 40% or below). The operation at 55-50% load may onlyneed reassessment of O&M practices, maintenance of critical components, automation/optimization of controls. However, lower load operation shall require additional measures like proper flame detection systems, efficient measures to optimize combustion process (A/F ratio), stable minimum mill operation, use of steam coil air preheater. Temperature measurements are crucial to optimize the startup and shutdown procedure. The technical solutions are primarily aimed at

- Ensuring safety & reducing the detrimental impact of the flexible operation on the life of the unit.
- Achieving flexibility with lowest cost.

Once there is a certainty that the unit can support flexible operation, then options of optimizing the costs and reducing lifetime impacts/improving reliable operation need to be exercised. Decreasing the technical minimum load (w/o oil support) is beneficial, because it provides a larger range of generation capacity. This helps plant operators maintain operation when power demand is low and avoid expensive start-up and shutdown procedures. Reducing the minimum load in hard coal-fired power plants is subject to certain technical limitations. These limitations are fire stability, flame control, ignition, unburned coal and CO emissions. In low load operations, the fire can become unstable when the hot flue gases do not completely ignite the inflowing pulverized coal and hence additional support from oil firing is needed to maintain flame stability and achieve complete combustion of the coal. There are several retrofit options that can be deployed for achieving stable technical minimum load operation of 40% and below (w/o oil support) and increasing ramps to 3%, while using Indian coal.

6.1 Measures for Minimum Load Operation

The operating data recorded during the minimum load test conducted at various plants indicated that several process limits were reached. The APH flue gas outlet temperature dropped below the dew point and the flame stability could not be assured. As these limits cannot be pushed further by means of controls, several technological changes would be required to achieve a stable minimum load operation. Using the test data, a thermal study of the boiler can be carried out in order to find and avoid damages to the boiler systems. Evaluation of the process limitations also need to be carried out. The most commonly used coal, as well as the potential range of coal, including coal with maximum problematic contents (ash, moisture, etc.) should be analyzed. Based on the thermal study findings, relevant remedial measures can be identified.

6.1.1 Control Optimization

Controls play a pivotal role in the operation of coal-fired power plants. It allows smooth transition between different operating loads and ensures stable operation by adjusting all relevant process variables. The control system monitors and controls the critical parameters viz. - temperature, pressure inside the boiler, the feed-water mass flow in the water-steam circuit, the loading of the coal mills and the turbine valve positions. Basedon the plant specific needs control modifications can be adopted for improving the flexibility. Based on assessment of individual units following improvements may be explored, some of which may require improvement by implementing modified controlsolutions and hardware (valves, etc.) as follows:

6.1.1.1 Drum Level Control

The pilot tests conducted showed that drum level controls were not tuned for the wide operating ranges (100%-40%). In this context the replacement of the feed water recirculation valves with modulating type valves will improve the drum level control. Currently, the opening of the valves causes large disturbances. Furthermore, an upgrade or implementation of new controls is necessary for the turbine-driven boiler feed water pumps when fed by auxiliary steam from another unit's. These controls are not generally working satisfactorily, thereby increasing the risk of a trip and demanding maximum operator attention– The BFPs would be run through a sequence control in auto mode.

6.1.1.2 Flue Gas Temperature Control

At 30% load APH outlet temperature is expected to be around 90 deg C, which is below the acid dew point temperature. On account of low APH cold end temperatures, corrosion on the APHs may occur. SCAPH should be deployed, which would enable the flue gas temperature to be controlled through the use of the steam APH. The SCAPH should be taken into operation automatically, whenever needed. This control combined with the upgraded temperature control would prevent corrosion in the APH. Economizer bypass system will also maintain the flue gas temperature above acid dew point to avoid corrosion. At low load, to meet required mill inlet temperature, economizer bypass system can improve flue gas temperature entering RAPH.

6.1.1.3 Automated Start/Stop of Mills

Automated start-up and shut-down sequences for the mills are necessary to enhance the flexible operation.

6.1.1.4 RH Steam Temperature Control

The RH steam temperature should be sufficiently high for the turbine for improving heat rate at part load operation. The RH steam temperature should be controlled using burner tilts as part of the automated control. Currently, burner tilts are operated manually and consequently RH steam temperatures are dropping during low load operation. This causes an avoidable loss of efficiency. The influence of the burner tilts needs to be further tested as well as the design and integration of the logics for the automated RH steam temperature control.

6.1.1.5 Measures for Ramp Rate Improvement

The thermal feasibility study of the boiler will also be useful for enhancing the ramp rates of the plant. With the help of the model study, it will be possible to explore measures to decrease SH and RH MTMs in cycling operation regimes, e.g. by effectively applying the burner tilts. The findings of the thermal study will also provide the basis for the optimization of various controls. The ramp rate improvements, as well as stable minimum load operation, strongly depend on a stable and optimized combustion. In addition to the control modification mentioned in 6.1.1 following may be required:

6.2.1 Control Optimization

6.2.1.1 Burner Tilt Controls

Burner tilts should be used to control RH MTMs in addition to RH steam temperatures. A feed forward from the load to burner tilts should be added, which needs to be validated through physical tests. Furthermore, an observer to both RH steam and RH MTM should be added, to predict where the temperature will be in few minutes based on actual temperature developments. This would make it easier to anticipate changes and enhance the control.

6.2.1.2 Furnace/Differential Pressure (Δp) Control

The set point should be given automatically depending on load. SADC passing should be minimized to make this control effective.

6.2.1.3 Furnace Pressure Control Upgrade

The secondary air is controlled is based on FD fan operation (blade pitch /VFD). Usually at part load since the air requirement reduces and because of passing of SADC windbox Δp is difficult to maintain, therefore SADC passing should be reduced by proper maintenance.

6.2.1.4 Unit CMC

These changes should enable the load to change sooner in the upward direction, and the pressure later. This would have two effects:

› Better cooling of RH tubes when steam flow increases, less MTM increase
› Better drum level stability

6.2.1.5 SADC Damper Control

Schedule check to be made for checking the DCS value and actual value at local for all the SADC dampers. Digitalization initiatives shall be taken for fine control of SADC dampers. Modifications in O_2 vs Load curve to be reviewed in consultation with OEM.

6.3 Measures for Startup Time Improvement

Decreasing start-up time enables a more rapid response to power demand. Start-up procedures are complex and expensive since they usually require auxiliary fuel, such asoil, during the ignition & stabilization period. There are various technical factors that limit the reduction of start-up time. Thick-walled components allow higher operating parameters (steam temperature and pressure, say) which increase efficiency. But quick temperature changes in thick-walled components induce thermal stress, which acts as a limiting factor for the start-up time. With "thinner" component designs, flexibility can be higher but efficiency is compromised. Since temperature changes induce thermal stress, each material is assigned a maximum allowable value. Exceeding this value reduces the materials lifespan. In general, reducing wall thickness increases the allowable temperature change rate. This translates into a faster start-up by boosting the ramp rate. Wall thickness can be reduced by using superior materials

6.3.1 Optimized Startup Control

An upgrade of control system with modified logics can improves precision, reliability and speed. For instance, it allows operation closer to the material limitations of important components, such as the boiler. This can mean operation at higher temperatures without significantly reducing the material lifespan, unlocking the available margins within the design limits of the system. Predictive digital solutions can be used to optimize several parameters to shorten boiler/turbine start-up time. Start up control system with modified logics can not only shorten the startup time but also improve repeatability & reliability of the startups.

6.3.2 Startup Curve

Design vs actual trending can be checked by using real time data source dashboard during start up for easy monitoring. With this immediate deviation of different start up parameter against corresponding design start up parameter can be corrected.

6.4 Other Measures

There are various other options available for increasing the flexibility aspects, some of the solutions are summarized below.

6.4.1 Boiler Combustion System

6.4.1.1 Minimum Mill Operation

In the direct firing configuration, reducing the net power of a power plant requires burners and coal mills to both run at part load. At a certain firing rate, the fire becomes unstable, requiring the power plant controller to limit the low load operation to avoid damaging pressure pulses that can occur inside the boiler. The fire stability typically represents the lowest threshold for the low load operation. At a certain lower net power output, it is feasible to shut down some of the mills and have the remaining mills operate closer to their design point. Since coal mills typically supply a single burner level, turning off a mill leads to a boiler operation with a reduced number of firing levels.

In the Indian context, with typical use of high ash content coal, one must take care of the minimum flue gas velocity in the system to avoid accumulation of ash within boiler/ducts and a 2-mill operation philosophy with related control system/logics modification is suggested. Further following are recommended for the mill operations

- Adjacent mill operation is recommended to achieve the stable flames and fire ball.

- With bottom mills steam temperatures cannot be achieved and hence bottom mill operation is not recommended.
- Mills shall not be operated below 60% of mill rated capacity or 50% of feeder speed to maintain uniform air & fuel mixture.
- Modification of the control philosophy to control primary & secondary air flow.
- Modification/ change in Mill outlet temperature control set point.

6.4.1.2 Firing System

The aspect of flame stability is particularly important at lower loads for safe operation of the boiler. It's important to have physically healthy flame. It is evident that burner redesign modification is an important for achieving lower technical minimum load without oil firing support. The re-design focuses on stabilizing the near field conditionsof the burner by manipulating the entry velocity, turbulence and therefore flame stability at low load, while minimizing changes to the balance of the burner system and maintaining the full load capability. The major issue with firing system is to stabilize coalflame and detection of low intensity flames inside furnace.

6.4.1.3 Combustion/Flame monitoring

In low load operation, complete combustion of fuel/fireball condition & stability is of utmost importance from safety point of view. Improved control over fireball stability is required. Due to lean air/fuel mixtures and less number of mills/firing levels in operation, flame stability may be an issue. At lower loads, the pressure drop in the coal piping can negatively affect fuel-air distribution between burners and thereby reduce flame stability. With only two to three mills in service it is more important that stable combustion be maintained locally as well as in the fireball and that the flame scanners detect properly when a stable flame is established. At full load operation, flame scanners see a bright flame; whereas at low load operation the devices see a dim flame. The combustion monitoring flame scanners sensors should have a wide dynamic range that can prove flame at full load as well as at the lowest loads without recalibration. These features help avoid "nuisance" trips where a scanner may not "see" a still stable flame.

6.4.2 Condensate Throttling

Condensate throttling is a proven measure for primary control to enable fast increase of turbine power in case of grid frequency deviations. In this case the main condensate control valve is throttled to a calculated position allowing a reduced condensate mass flow flowing through the LP feed water heaters. Considering a certain response time, the extraction steam mass flows of the LP feed water heaters and the deaerator/feed water tank are reduced. The surplus steam remains in the turbine and generates additional power. A sketch of the system is shown in Figure 6.1. This condensate throttling compensates the transient time behavior of the boiler. The accumulated condensate is stored in the condenser hotwell or a separate condensate collecting tank. Parallel to the above mentioned measures the firing rate of the boiler has to be increased to meet the load requirements.

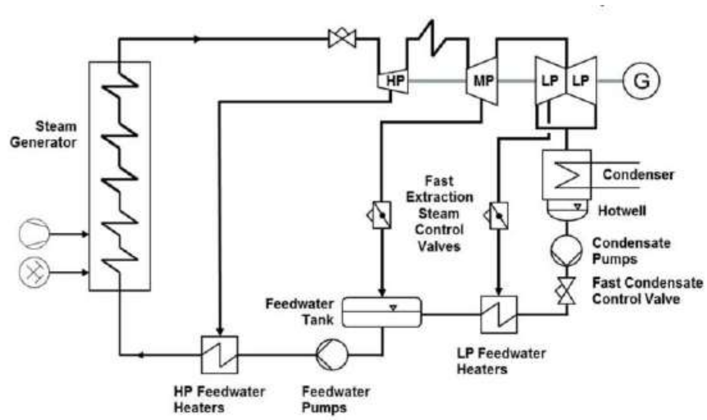


Figure 6.1 Condensate Throttling

6.4.2.1 Response time

The response time of condensate throttling depends on the time required for reduction of condensate mass flow. Therefore, normally a fast acting main condensate control valve is used. By means of additional fast acting valves in the extraction steam lines the response time behavior can be optimized. The response time of 20s for 7% power at 100% load has been achieved through condensate throttling and main steam valve throttling at NTPC Dadri. Standalone, condensate throttling is able to provide 3-4% power at 100% load. The results of tests conducted by BHEL at Unit-1 of 2x600 MW SCCL plant with valve wide open condition are 2.9% at 30secs to 4.0% of running load in 120 secs.

6.4.2.2. Capacity

The resulting turbine power increase depends on the amount of throttling of the main condensate control valve and the actual unit load. The higher the unit load, the higher is the amount of additional turbine power which can be generated by condensate throttling.

6.4.2.3 Duration

Duration of condensate throttling operation depends on the amount of buffer volumes provided for condensate and feed water. The slower the boiler, the larger the buffer volumes have to be.

6.4.3 Heat Conservation System

Steam turbine heat conservation systems can support in reducing the startup time by eliminating cold startups by keeping the unit in warm condition.

6.4.4 HP Turbine Deactivation

Few advanced supercritical turbines have feature of HP deactivation. At very low load there are chances of HP turbine exhaust temperature reaching material limits and causing windage. To prevent this usually turbine trip is initiated if the temperature reaches to 510^{0}C. With HP deactivation, instead of tripping the entire turbine, only HP turbine is tripped and protecting the unit to operate at lower load to bring back to grid again quickly. Advanced supercritical turbines are benefitting from this feature and the same could also be implemented in existing 210MW and 500MW units with suitable in measurement.

6.4.5 Co-Start

To enable faster hot startup time, turbines can be rolled via IP turbines. In the Co-Start sequence the steam turbine already starts to accelerate from turning gear speed when the reheat steam temperature exceeds the IP component temperature. In the standard start- up sequence the steam turbine starts to accelerate from turning gear speed when both,the main and reheat steam temperature exceed the HP and IP component temperature. With the Co-Start feature the steam turbine start-up under hot conditions is up to 90 minutes earlier compared to a standard hot start. The exact time saving depends on several boundary conditions e.g. boiler temperature gradients, initial component and steam temperatures.

6.5 Measures for Efficiency Improvement (Heat rate)

6.5.1 Sliding Pressure Control (Modified)

- Achieving lower minimum load with relatively higher efficiency levels.
- For a cycle operating with constant boiler pressure, the efficiency of the unit at part load will be better by adopting sliding pressure control than it is by throttling to control the power on machine.
- For a cycle operating with sliding boiler pressure, it may be very useful to have an overload arc available to respond to fast changes in power demand. This would support better frequency response and short peak needs.
- Turbines that feature partial arc can be readily adapted to the specific requirements of a utility by careful selection of appropriate admission arc areas.

6.5.2 Top Heater

Usual steam turbine power plants have regenerative feed water heating cycles to increase the feed water temperature and thereby improving the cycle efficiency. This optimization is carried out in consideration that units are running in base load operation. In part load scenario, the final feed water temperature starts dropping and leading to more thermal stress on boiler and many a times limiting the NOx devices to operate. Therefore, an innovative method of keeping the final feed water temperature constant irrespective of load can be achieved by having the additional feed water heater with controlled extraction. The top heater gets only activated in part load and could increase the heat rate upto 0.6% at corresponding 50% part load efficiency*. This additionally benefits the Boiler as then economizer temperature is not changing with load change thus saving the life consumption in Boiler components with less fatigue. A typical configuration of Top Heater arrangement is shown in Figure 6.2.

6.5.3 Optimization of Auxiliaries

The thermal power units are designed for high efficiency performance at rated load. Operating at lower loads deteriorates the efficiency of the unit. The efficiency of the unit can be improved by many means including reducing the auxiliary power consumption.

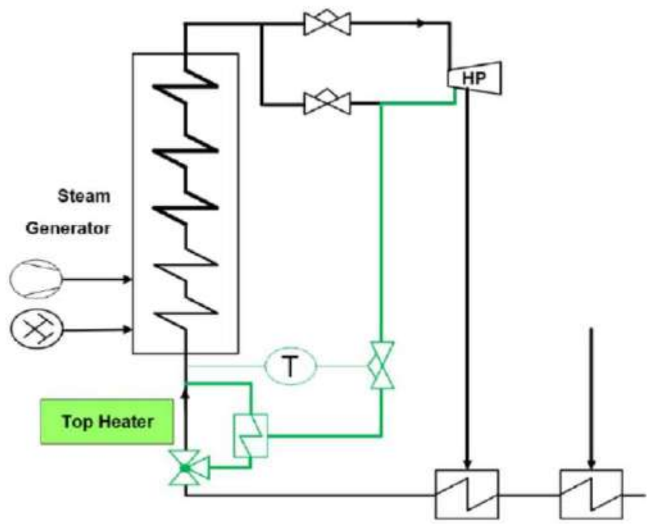


Figure 6.2: Typical arrangement of Top Heater

The plants have most of the auxiliaries rated for 2x50% which are both operated at any operating point. Hence to reduce the auxiliary power consumption at loads less than 50% the auxiliaries should be operated as 1x50% mode without affecting the safety and security of the plant. This will reduce the auxiliary power consumption at low loads.

Further, at variable load operation of the unit from 100% to 40% MCR, optimization of the auxiliary load for lower power consumption can be achieved by utilizing variable frequency drives.

6.6. Measures for Condition Monitoring

Part load operation leads to changes in main and reheat steam temperature. Usually conventional operating hours' calculations are based on normal operating hours and sometimes accounting for startup. With frequent load changes resulting in temperature changes which leads to changes in thermal stresses of high temperature rotors and casings, thick-walled components like Boiler drum & headers. Therefore, conventional maintenance intervals may not be sufficient. Now with possibility of real time monitoring, it is possible to account for both load changes and equivalent operating hours (EOH) based on actual thermal stresses. This helps utilities for better maintenance planning by clearly identifying the need of inspections based on the actual operation. Also this helps utilities identifying which operating modes are causing higher damages to component life therefore mitigating/avoiding such operations. The primary requirement for long term reliable operation is to adapt operation and maintenance for the new operation regime. Few of the solutions presented in this chapter are to enhance monitoring health of the plant.

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*The solution is implemented in Wai Gao Qiao, 1040 MW unit, China). (https://www.energyforum.in/fileadmin/user_upload/india/media_elements/misc/20200000_Misc/20200515_lr_Fast_Ramping_VGB_Webinar/3_Improved_Ramp_rates_Chittora_Rev1_komp.pdf).

Condition monitoring systems monitor components like boiler and piping for creep and fatigue. It monitors the temperature differences, pressure, and sends alarms when the allowable limits during load changes have been exceeded. It is integrated into the existing C&I system. Condition monitoring leads to effective life cycle asset management. Condition Monitoring for flexibilisation should include the following modules.

- Fatigue Monitoring System
- Vibration Monitoring System including Blade Vibration
- Generator Monitoring System

6.6.1 Fatigue Monitoring System

In today's environment only very few power plants can operate in the pure base load mode. Continual output/ load changes shall be common, this means stressing the boiler and turbine components far beyond the traditional operational levels. The boiler and turbine maintenance has to meet these new requirements. The fatigue monitoring provides the power plant maintenance and the operating personnel with a tool that contributes to better scheduling of maintenance. Further the operational conditions and procedures (e.g. start up, load changes) can be optimized based on the results of the monitoring system.

By computing the creep and low-cycle fatigue the residual life of the boiler and turbine, which is dependent on the operating mode of the power plant, can be recalculated time and again. For the power plant operator, the implementation of FMS provides a continuous overview of the service life utilization of the major equipment's, so that

- The time for a necessary inspection can be selected optimally and thus the operating time between two inspections maximized,
- Power plant safety can be increased,
- Operating modes causing heavy wear can be detected and if possible prevented,
- Components can be operated close to the material limits, so that the operating time of the plant can be maximized and operating costs minimized.

6.6.2 Vibration Monitoring System

Availability of steam turbine in a power plant depends on its performance in all operating conditions. In recent past, there has been couple of Low Pressure Turbine free standing stage blades failure experienced. LP turbine blades due to highest centrifugal forces and operation in wet region are susceptible for failures. Operational risks for blade failure could be monitored through non-contact type blade vibration monitoring system. While the system can provide the useful insight on vibration behavior, it is even more important to get it monitored by experts.

Apart from all the above solutions, some digital solutions can be leveraged to monitor health of key components of the turbine and help reduce the negative impact on flexible operation & avoid unforeseen forced outages. Simple solutions like the following can provide advance notice to take corrective actions. Valve monitoring can avoid unplanned outage due to valve failures. Torsional vibration monitoring system can avoid rotor cracking due to Grid excitations. Turbine monitoring can alert about the excessive lifetime consumption of the critical ST parts and helps avoid unplanned outage.

6.6.3 Generator Monitoring

Although from capability point of view, generator may not pose serious constraints for flexible operation, it is important to monitor its health and take utmost preparatory care of generator going to be subjected to cyclic operation. Real time monitoring of certain generator key parameters goes long way in identifying impending problems and helps users to prepare and take corrective actions much in advance. Moving to condition-based maintenance (instead of regular preventive maintenance) by monitoring key parameters like partial discharge (PD), rotor flux, rotor shaft voltage, end winding vibrations, stator temperature etc. are important.

Following impacts of flex operation need to be observed/anticipated for and suitable timely corrections need to be done to avoid unplanned generator failures.

i. Possible relative movements between bars and core.
ii. De-cohesion between bars and between bars and supporting rings.
iii. Deformation and crack of pole to pole connection.

6.7 Recommendation

The utilities shall conduct detailed study/tests and cost benefit analysis for finding the most optimal solutions to improve the flexibility of plants as the measures required are plant specific and shall depend on the level of flexibilisation. This may be done in consultation with OEM/main plant (BTG) manufacturer /BTG designer.

7. COST OF FLEXIBLE POWER

As discussed in earlier chapters, the flexible operations for coal power plants are technically feasible by upgradation of controls, etc. The pilot tests conducted at various plants is the proof that Indian plants are capable to flex. Converting the baseload coal fired power plants into flexible plants would most likely incur costs, which would require compensation. To improve the availability of flexible power in the grid by conversion of baseload coal fired power plant into flexible power plants, it should be economically feasible for the generating companies. In this chapter, we shall discuss some indicative costs involved for converting a baseload coal plant into a flexible plant. Since majority of the energy transacted is through the long-term power purchase agreements, the discussion shall be centered on the cost based approach.

7.1 Factors Influencing Cost

a) The cost of undertaking flexibilisation in the plant is dependent on the following factors:
b) Automation levels in the plant.
c) Coal quality.
d) Age & size of units.
e) Type of machine, component material composition and design philosophy.
f) Maintenance philosophy, lay-up practises and water chemistry controls.
g) Operational expertise and practises adopted.
h) Extent of cyclic operation - depth, breadth and frequency.

7.2 Cost Components

The impact of thermal power plant flexibility on the costs are mainly exhibited through *Capital Expenditure (CAPEX)* - one-time expenditure incurred in the installation /retrofitting of various equipment required to make the plant capable of low load operation, and *Operational Expenditure (OPEX)* - the recurring cost of flexible operation due to decreased efficiency, loss due to the reduced life of the plant, increased O&M cost, increased forced outages, increased oil consumption. Increased spends on water, chemicals, manpower and other miscellaneous activities. Increased chances of non-conformance to grid regulations leading to financial losses.

7.3 Studies with International Partners

Cost related studies have been conducted with international agencies having vast experience in the field of flexibilisation. The studies were conducted from year 2016 to 2018. The details of the scope are summarized in Table 7.1. The cost implication has been brought out by the various studies under the heading of capital and operational expenditure.

Table 7.1 Studies conducted by International partners

Associates	Owner/ Plant	Study	Scope
IGEF/VGB	NTPC: Dadri Unit 2 (200MW) Simhadri Unit 1 (500MW)	Dec 2016-June 2017	Special Task Force on Flexibilisation. Flexibility assessment
USAID/Intertek	NTPC: Ramagundam Unit 2 (200MW), Jhajjar Unit 1 (500MW)	Jan-July 2018	Cost of flexing due to start up and load following
USAID/Intertek	GSECL: Ukai Unit 4 (200MW), Ukai Unit 6 (500MW)	Aug- Nov 2018	Cost of flexing due to start up and load following
Engie Lab	Dadri Unit 4 (200MW) Farakka Unit 6 (500MW)	Nov 2018-Sept 2019	Capital Cost estimation to enable flexibility & increase in running cost due to load ramping and start up.
Siemens	NTPC Simhadri (500MW) Dadri (490MW)	Feb-Aug 2018	Technical and Commercial Proposal for interventions after study
GE	NTPC Talcher Kaniha (500MW)	Feb-Aug 2018	Technical and Commercial Proposal for interventions after study

7.3.1 Capital Expenditure (Capex)

Capital expenditure is required at plant level for the various interventions to meet the demands of flexible operation. The type of interventions required would vary from plant to plant depending on the unit age, etc. as detailed in item 7.1 and accordingly scope of work shall vary. The outcome of various studies conducted are detailed as below:

7.3.1.1 IGEF Study. The special Task Force on flexibilization with the support of IGEF provided an estimate of the Capex. The VGB studies at NTPC Dadri (210MW) and Simhadri (500MW) provided one-time cost required for preparing units for low minimum load operation and indicated the cost of interventions below 40% load will be significantly higher. The estimates are summarized in the following table:

Table 7.2 Capital Expenditure

S.no.	Intervention	Rs. Crore / Unit
1	For 40% Technical Minimum Load	3.9 to 7.8
2	Start-up Optimization	2.25 to 7.8
3	To manage the consequences of cycling	0.65 to 1.95

(Source: IGEF Task Force Sub-Group1 Committee Report on Flexibilisation of Thermal Plants Oct, 2017)
(S*ource: NTPC)*

It is important to understand the cost difference between the actual costs required to guarantee flexible operation (one-time Capex) and the provision of Capex to be able to repair the damages that occur due to flexible operation and reclaim back the machine to normal. The damages get accumulated till the breakdown of components, which may need replacement to be able to run again.

7.3.1.2 Siemens Study Based on Siemens proposal for the implementation of flexibilization measures at Dadri and Simhadri NTPC stations, approximately Rs.20 to Rs.50 crores is estimated considering the measures required in the units. The proposal consisted of implementations of the following:

- Temperature Optimizer
- Fatigue Monitoring System
- EOH Counter
- Optimization of Control Loops
- BFP Recirculation Valve
- Auto ON/OFF of Fans and Pumps
- Mill Scheduler

7.3.1.3 GE Study. Based on the proposal for the implementation of flexibilization measures at Talcher NTPC station, approximately Rs.20 to Rs.50 crores is estimated based on the measures required in the units.

7.3.1.4 Engie Study. As per the study done for Dadri and Farakka NTPC stations the cost of capital expenditure is estimated:

- Between Rs.3.2 crore and 5.6 crore for extended load following with P_{min} 40%.
- Between Rs.4.1 crore and 8.0 crore for frequent warm starts.

7.3.1.5 Capex at Dadri

The order for retrofit work for flexible measures at Dadri 500MW unit to reduce the minimum load operation to 40% was placed by NTPC in 2019. The retrofit work included the implementation of following measures-

a) Predictive MS Temperature Control
b) RH Temperature control
c) Installation of Modulating Recirculation Valves in BFPs
d) Automation in Milling System
e) Flue Gas Temperature Control
f) Single Drive Operation- Automated Start/Stop of ID/FD/PA Fans.
g) Condition Monitoring System- Boiler Fatigue Monitoring System and Equivalent Operating Hours.

Total capex implication of the above retrofits for Dadri unit is around rupees five and half crore. The results of the retrofit works undertaken are awaited.

7.3.2 Operational Expenditure (OPEX)

The increase in OPEX is clubbed in the following three broad categories:

a) Cost due to increase in Net Heat Rate.
b) Cost due to increase in O&M due to reduction in life of components.
c) Cost due to increase oil consumption for EFOR

Generally, units are designed to be operated on a base load condition and all the components are accordingly designed for operation for certain creep life hours and certain fatigue life in terms of no. of starts. As the operation regime changes and moves away from base load operation to cycling operation, the component life gets consumed at a faster rate. Life consumption, Increase in Equivalent Forced Outage (expressed in terms of increased O&M costs have been derived based on the costs on assessment studies at Ramagundam, Jhajjar and Ukai plants conducted by USAID GTG-RISE with technical support from Intertek AIM, US.

7.3.2.1 Cost due to increase in Net Heat Rate

It has been observed that the extent of deterioration in Net Heat Rate depends on the percentage unit loading. The estimates are based on combustion engineering boiler design and GE make turbines. For a typical 200/210/500/660 MW unit the increase in tariff due to increase in Net Heat Rate at different loading factors is as given in table below. The base Energy Charge Rate (ECR) has been assumed to be 200 paisa/kWh based on the average ECR of NTPC stations from April 2018 to October 2018.

Table 7.3 Increase in Variable Costs due to HR deviation

S.no.	Unit loading %	200/210 MW		500 MW		660 MW	
		Increase in NHR (%)	Addl. Paisa/ Kwh	Increase in NHR (%)	Addl. Paisa/ Kwh	Increase in NHR (%)	Addl. Paisa/ Kwh
1	90%	NIL	0	1.0%	1.1	1.0%	1.6
2	80%	0%	0	1.7%	3.4	1.7%	3.5
3	70%	1.1%	2.1	3.3%	6.7	3.3%	6.6
4	60%	3.8%	7.5	6.3%	12.6	5.7%	11.5
5	50%	7.5%	15.0	10.0%	20.0	9.2%	18.4
6	40%	11.6%	23.2	13.8%	27.6	14.4%	28.7
7	30%	17.3%	34.6	19.0%	38.0	20.4%	40.8

(**S***ource: NTPC)*

7.3.2.2 Cost due to Increased Life Consumption (Damage costs)

Flexible operation leads to a higher rate of deterioration of components. This is observed in increased failure rate and more frequent replacement of components. The impact on life of components increases with increase in no. of start stops the unit undergoes in a year. As a result, the operation and maintenance cost are significantly higher in units operated on a daily or weekly start-stop basis.

USAID-Intertek Study: An estimate of the increase in O&M Cost due to reduction in life of components is given below. It is based on study conducted under USAID GTG-RISE program with technical support from M/s Intertek AIM, USA at Ramagundam, Jhajjar TPS of NTPC and Ukai of GSECL. The study was based on the five to ten-year historical cost data of the units (all the costs are at 2017 levels for NTPC & 2018 for GSECL Units). The corresponding level costs 28.7 Lakhs/MW for 210 MW unit and 19.22 Lakhs/MW for 500 MW unit is based on the CERC normative O&M cost for year 2016-17.

As per estimates by USAID-Intertek study, the cost of flexibilization at two stations is summarised below. These costs are as per defined typical cycle. Most of the wear-and-tear cycling costs are owing to the O&M and capitalized maintenance costs and the increased Equivalent Forced Outage Rates (EFOR) costs. The table below provides the best estimates of the costs which includes forced outages. There is a variation in cost estimates of similar type of units at NTPC and GSECL. In fact, no two units will have the same costs due to variation in factors affecting the costs like coal, age of plant, operating practices, operator's skill and design. The incremental cost due to each event is expressed as percentage of the normative O&M costs.

Table 7.4 O&M Cost Impacts on 200 MW & 500 MW Units

MW	Event	NTPC- O&M Cost (INR-Lakh)				GSECL- O&M Cost (INR-Lakh)			
		Per Event	Per MW	Per MW (Current level) As allowed by CERC 2017	% Addl. / event	Per Event	Per MW	Per MW (Current level) As allowed by CERC 2017	% Addl. / event
200	Cold Start	91.3	0.46	28.7	1.59%	42	0.21	28.7	0.73%
	Warm Start	51.4	0.26		0.90%	28.9	0.14		0.49%
	Hot Start	38.0	0.19		0.66%	20.6	0.1		0.35%
	Significant load following	0.5	0.00		0.01%	0.2	0.001		0.003%
500	Cold Start	262.2	0.52	19.22	2.73%	174.9	0.35	19.7	1.78%
	Warm Start	151.6	0.30		1.58%	127.7	0.26		1.32%
	Hot Start	123.0	0.25		1.28%	78.4	0.16		0.81%
	Significant load following	2.7	0.01		0.03%	2	0.004		0.02%

(S*ource: USAID GTG-RISE Pilot on Coal Flexibility, data furnished by NTPC)*

As per the estimates of Intertek (table above), the per event impact ranges from 0.01% to 2.73%. Surely, the actual costs will depend on the number of such events.

Engie Lab estimates that on a yearly basis, the capital expenditures and additional maintenance result in a 0.3% to 4.3% cost impact versus the total costs of a unit, or expressed in rupees per kWh produced on such a unit: 0.01 to 0.15Rs/kWh. The absolute non-fuel costs over a 10-year period are approximately (not discounted over 10 years with a weighted average cost of capital). But this estimate is based on the current level of flexibilization, where units are operating on 55% and above without much load following. There can be a significant variation, based on the level of flexibilization (number of events in a year).

7.3.2.3 Cost due to additional oil consumption due to increased EFOR

As per studies carried out by EPRI based on global data, there is a significant increase in EFOR due to varying operational modes and on units ageing. The norms for specific oil consumption had been fixed at 0.5ml/kWh as per CERC norms for 2014-19. Based on the increased EFOR (as per EPRI) the norms for specific oil consumption may be allowed as per the Table 7.5. The loading factor calculation is done with on-bar availability i.e. Reserve Shut Down (RSD) is to be ignored.

Table 7.5 Oil Consumption due to increased EFOR

S. No.	Operation Mode	EFOR	Increase in EFOR	Sp. Oil Consumption
1	Base Load	5	-	0.5
2	Load Following (Loading Factor <60%)	7.06	2.06	0.70
3	Minimum Load (Loading Factor 40 % to 50%)	7.19	2.19	0.72
4	Minimum Load (Loading Factor 30-40%)	>7.19	>2.19	0.8
5	Minimum Load (Loading Factor 30-40%) with provisions for varying coal			1.0

(**S***ource: NTPC)*

In the Indian context, with varying coal quality, providing for additional secondary oil for low load operation will positively impact the safety and reliability of the units.
Assuming the cost of oil at Rs. 45,000/kL, the impact on ECR due to oil is shown in Table 7.6 below:

Table 7.6 ECR Impact due to increased Oil Consumption

S. No.	Specific Oil Consumption	Increased ECR (p/kWh)
1	CERC Norms (Present): 0.5 ml/kWh	2.5
2	At 0.7 ml/kWh	3.5
3	At 0.8 ml/kWh	4.0
4	At 1.0 ml/kWh	5.0

In addition to the above costs, the increase in fixed costs/unit due to lower PLFs of units providing flexibility needs to be recovered. Due to flexible operation there would be loss of availability due to increased maintenance requirements and increased EFOR which will make it difficult for the generator to recover full capacity charges.

7.4 Efficiency Studies/ Tests

To arrive at the plant efficiency, the efficiency of turbine is multiplied by the boiler efficiency. Turbine generator cycle heat rate (TGCHR) is defined as the heat supplied to the steam divided by the electric power generation. It does not include losses in the combustion or heat losses in flue gases and therefore represents the efficiency of a part of the process. The heat supplied to the cycle is calculated as

$$Q = Q_{MS} + Q_{RH} + Q_{SHspray}$$

Where, Q heat supplied to the cycle Q_{MS} heat supplied to main steam Q_{RH} heat supplied to RH steam $Q_{SHspray}$ heat supplied to SH spray. The heat is calculated as mass flow multiplied by difference of specific enthalpy. The mass flows of main steam and SH spray are measured, the RH steam mass flow is calculated as main steam flow minus extraction flow. The extraction flows are calculated from heat and energy balances of preheaters.

For determining the heat rate degradation at low operating load of 40%, it was decided by CEA to conduct the efficiency performance tests in thermal units at various thermal plants in collaboration with international partners, IGEF, Germany and TEPCO, Japan. Further, CEA entrusted the OEMs (BHEL/GE/Siemens) to conduct heat rate degradation computational studies based on heat balance.

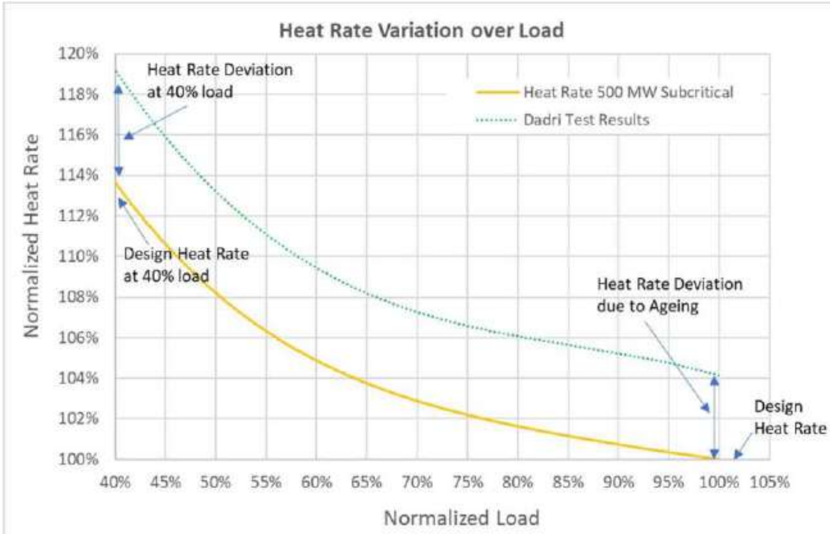
7.4.1 Efficiency Tests at Low Load

The efficiency tests were conducted at Dadri TPS, Maithon RBTPS, DSTPS, Andal and Mouda TPS in collaboration with IGEF, Germany and TEPCO, Japan, respectively. The data collected from these tests has been analysed to understand the performance deterioration at part loads. To analyse the data, NTPC Dadri 490MW (subcritical), NTPC Mouda 660 MW (supercritical), DSTPS, DVC and Tata power Maithon 525MW (subcritical) have been considered.

In order to study the effect, the load and heat rate are normalized i.e. load has been normalized to rated capacity of unit and heat rate has been normalized to rated heat rate at 100% TMCR conditions. The results of the heat rate and load are as represented in following figure.

7.4.1.1 Dadri Efficiency Test

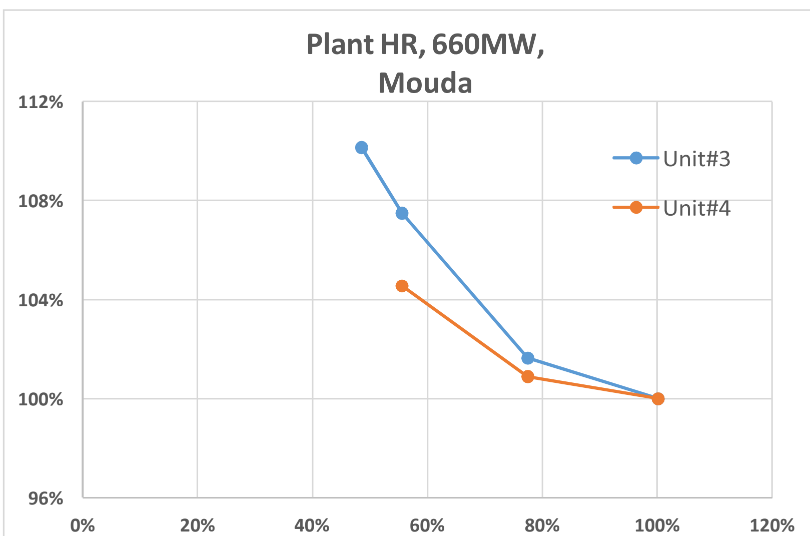
For part load efficiency assessment of 490MW Dadri Unit 5 of NTPC, data was analysed by Siemens. The TGCHR was done during the minimum load test on while the average load was 195MW.



(**S***ource: Siemens)*

7.4.1.1 Mauda Efficiency Test

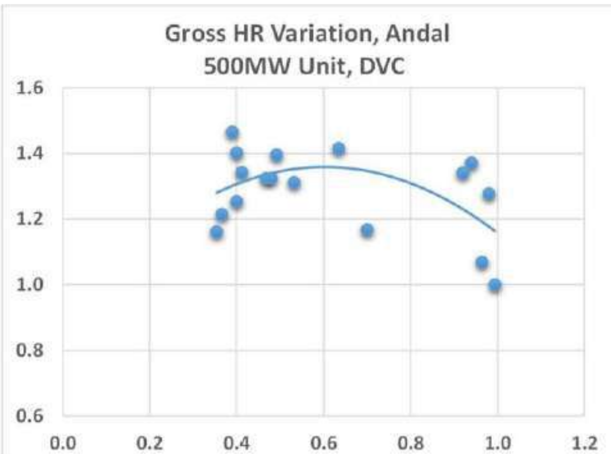
The tests were conducted from Jan 6 to 9, 2020 at Mouda STPS, NTPC on unit 3 and 4 of rated capacity 660MW.The tests were conducted in collaboration with TEPCO/JERA, Japan. The test results of the heat rate degradation with respect to loading is given in the chart below. The tests could not be conducted at low load of 40% due to theapprehensions of the owner, however, on unit 3 test could be completed at 49% load condition.



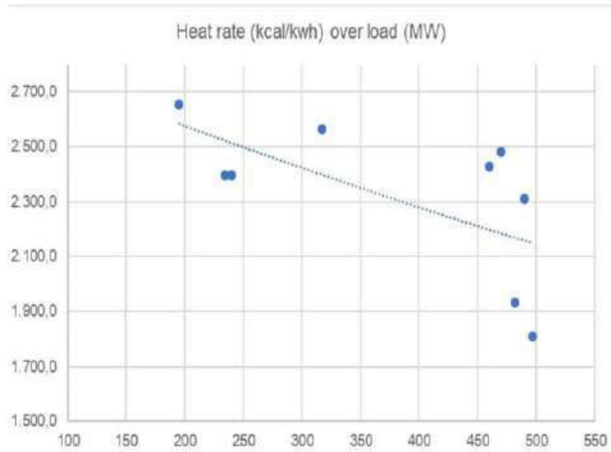
(**S***ource: JCOAL Report)*

7.4.1.3 Andal Efficiency Test

The efficiency test was conducted on unit 2 of rated capacity 500MW in collaboration with IGEF/VGBE, Germany. The heat rate has been calculated at around fifteen load points, however, the results are not showing normal trend of deterioration, refer plot above (left side). These results as such cannot be effectively used for assessing the impact at low loads. However, it needs to be considered that the coal quality variation was very high, GCV was in a range between 3,545 kcal/kg to 5,640 kcal/kg. Excluding the datawhich have the highest coal variations, the graph changes accordingly (right side). It reflects the deterioration in heat rate with respect to the loads. From the revised plot (rightside) the heat rate deterioration can be estimated as 20% at a low load of 40% when compared at rated load (100%).



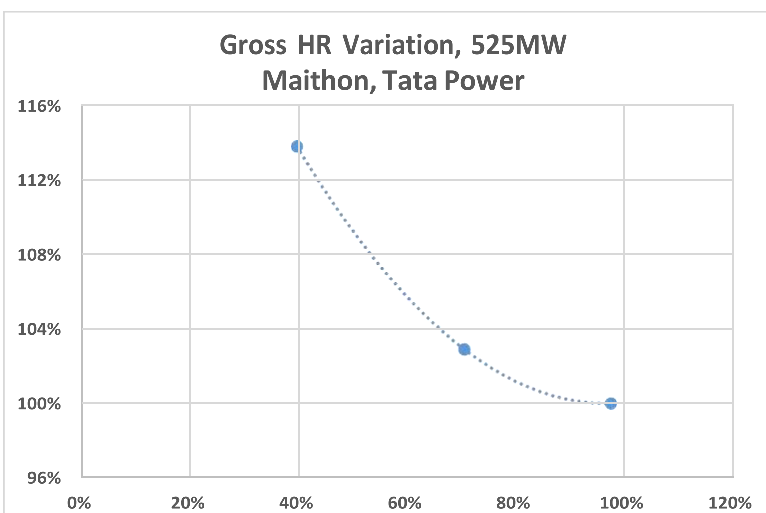
(Source: IGEF Report)



(Source: VGBE/IGEF)

7.4.1.2 Maithon Efficiency Test

The Maithon efficiency test was conducted on unit 2 of rated capacity 525MW in collaboration of IGEF Germany. The TGCHR was done during the minimum load test on 22 July, 2021 between 14:30 and 15:30 while the average load was 211 MW. Boiler efficiency was assumed as 88%, the overall plant HR was calculated from the TGCHR.



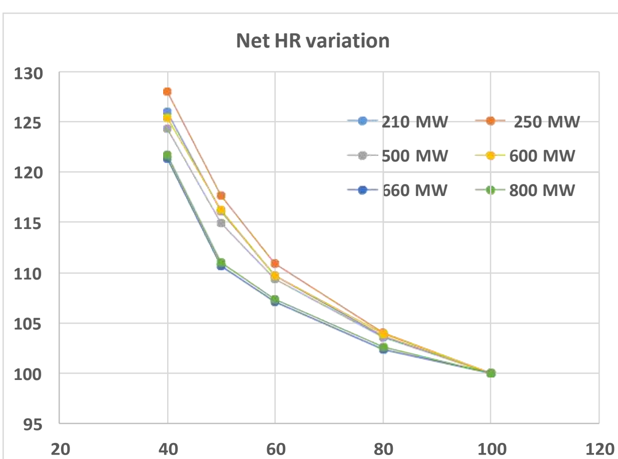
(Source: IGEF Report)

7.4.1.4 Summary- Efficiency Tests

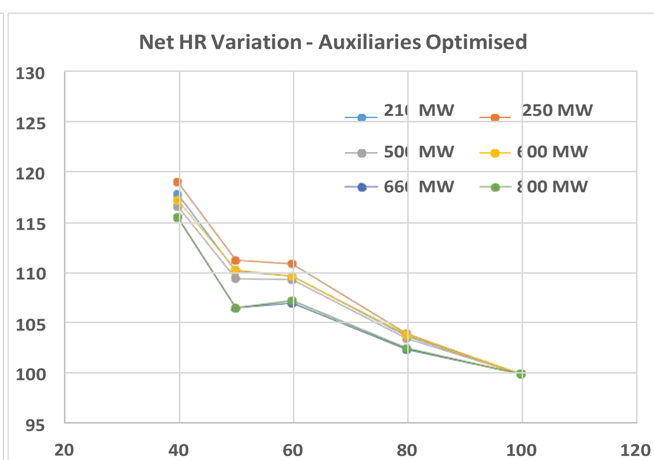
In Maithon, DVC TATA JV the efficiency tests were carried at three load points (515MW, 373MW and 211MW) and it is seen from the test report that the gross HR degradation is 14% at 40% load from 98% load. Similarly, in the case of Mauda, NTPC the efficiency test was carried on supercritical unit at four loading points (660.8 MW/511.3 MW/366.8 MW/320.4MW) and it is seen from the test report that the gross HR degradation is about 10% at 49% load from the full load. In the case of Andal, DVC, as discussed above the gross heat rate deterioration is predicted as 20% at a load of 40%. It is seen in the case of Dadri, the overall plant HR behavior was found to follow the same pattern as of original HBD calculations. The deviation from design heat rate at 100% and at 40% is found to be same and this deviation can be attributed to ageing of the plant as per standard ASME degradation curves. Therefore, HBD calculations with applied ageing can predict the performance at part load with reasonable accuracy. However, to confirm the HR degradation, efficiency tests needs to be conducted as per the prescribed standard procedures on sufficient number of units of different unit sizes to arrive at HR deterioration figures.

7.4.2 Heat Balance Studies

The heat rate degradation studies were performed by OEMs (*BHEL/GE/Siemens*) for various unit sizes at different loading conditions based on heat balance. The heat balance calculations done by *BHEL* indicates the heat rate (gross) degradation from full load to 40% load is in the range of 13.5% to 16.5% and heat rate (net) degradation in the range of 21.3% to 27.9%. However, when considering *modified* auxiliary power scheme at 50% to 40% load, the heat rate (net) degradation is drastically reduced (about 30%). Hence, it is obvious that the scheme of auxiliary control needs to be modified for low load operationat 50% and below to get the significant performance benefits.



(*Source: BHEL HB Study)*



(*Source: BHEL HB Study)*

GE, India has also conducted study for the heat rate deterioration at different loads levels for different unit sizes of thermal units. The heat rate (net) degradation is found to be in the order of 12% to 14% for different unit sizes at a load of 40%. The degradation of HR is found to be very low when compared to BHEL study (estimated) which is in the range of 21.3% to 27.9%. Similarly, *Siemens, India* conducted the heat balance study details of which are tabulated in Table 7.9.

Table 7.8 Heat Balance Study (GE)

% Load	% Deviation NHR			
	210MW	500MW	660MW	800MW
100%	0%	0%	0%	0%
90%	0%	1%	1%	1%
80%	0%	2%	2%	2%
70%	1%	3%	3%	3%
60%	4%	6%	6%	6%
55%	6%	8%	8%	8%
50%	7%	10%	9%	10%
40%	12%	14%	14%	16%
30%	17%	19%	20%	24%

Table 7.9 Heat Balance Study (Siemens)

% Load	% Deviation NHR			
	210MW	500MW	6600MW	800MW
100%	0%	0%	0%	0%
90%	1.1%	0.8%	1.0%	0.8%
80%	2.3%	1.4%	2.0%	1.3%
60%	6.1%	4.5%	4.2%	3.0%
50%	7.3%	7.7%	6.2%	4.8%
40%	9.5%	10.0%	8.9%	7.0%
35%	13.0%	15.0%	14.0%	13.8%

7.4.3 Impact of low load on Tariff

The impact of low load operation on HR was studied by major OEMs (BHEL/GE/ Siemens) while conducting heat balance for various unit sizes. As there was sizable variation in the HR deterioration among the studies, the deterioration in HR was considered by the committee based on the heat balance study report of BHEL, SIEMENS, GE and actual efficiency tests to study its impact on tariff. Further, the impact of capital cost for upgradation of controls has been considered as six to ten crores and the amount may increase upto 30 crores for older units commissioned before 2010. The increase in O&M cost has beenconsidered based on the loading levels of the units and at 40% loading it has been assumed as 20%.

The study conducted by CEA indicates the impact of low load operation at 40% on variable part of tariff is around 15% whereas the impact on fixed part of tariff is around 2.77%-7.63% depending on the unit size. The summary of the study conducted is given inTable 7.10 below and the assumptions considered are given in Annexure-I.

Table 7.10 Possible Impact of Low load Operation on Tariff

(a) Impact in Paisa/kWh

Capacity (MW)	Loading	NHR (% Increase)	Variable Tariff (Increase in Paisa/kWh)	Fixed Tariff (Increase in Paisa/kwh)						
				Due to O&M	Capex (Rs 6 cr./ Unit)	Total	Capex (Rs 10 cr./ Unit)	Total	Capex (Rs 30 cr./ Unit)	Total
200	50%	10.0	13.74	5.14	1.71	6.85	2.85	7.99	8.56	13.70
	45%	13.0	17.86	7.99	1.71	9.70	2.85	10.84	8.56	16.55
	40%	16.0	21.97	11.42	1.71	13.13	2.85	14.27	8.56	19.98
500	50%	10.9	14.60	3.42	0.68	4.11	1.14	4.57	3.42	6.85
	45%	13.6	18.30	5.33	0.68	6.01	1.14	6.47	3.42	8.75
	40%	16.0	21.50	7.61	0.68	8.29	1.14	8.75	3.42	11.03
660	50%	8.7	11.10	3.08	0.52	3.60	0.86	3.95	2.59	5.67
	45%	11.9	15.30	4.79	0.52	5.31	0.86	5.66	2.59	7.39
	40%	14.6	18.70	6.85	0.52	7.37	0.86	7.71	2.59	9.44
800	50%	8.6	10.66	2.74	0.43	3.17	0.71	3.45	2.14	4.88
	45%	12.0	14.86	4.26	0.43	4.69	0.71	4.97	2.14	6.40
	40%	15.0	18.58	6.09	0.43	6.52	0.71	6.8	2.14	8.23

(b) Impact in Percentage terms per kwh

Capacity (MW)	Loading	NHR (% Increase)	Variable Tariff (% Increase)	Fixed Tariff (% Increase)						
				Due to O&M	Capex (Rs 6 cr./ Unit)	Total	Capex (Rs 10 cr./ Unit)	Total	Capex (Rs 30 cr./ Unit)	Total
200	50%	10.0	9.82	1.96	0.65	2.62	1.09	3.05	3.27	5.23
	45%	13.0	12.76	3.05	0.65	3.71	1.09	4.14	3.27	6.32
	40%	16.0	15.70	4.36	0.65	5.02	1.09	5.45	3.27	7.63
500	50%	10.9	10.60	1.41	0.28	1.69	0.47	1.88	1.41	2.82
	45%	13.6	13.29	2.19	0.28	2.48	0.47	2.66	1.41	3.61
	40%	16.0	15.61	3.14	0.28	3.42	0.47	3.61	1.41	4.55
660	50%	8.7	8.44	1.29	0.22	1.51	0.36	1.65	1.09	2.38
	45%	11.9	11.63	2.01	0.22	2.22	0.36	2.37	1.09	3.09
	40%	14.6	14.22	2.87	0.22	3.08	0.36	3.23	1.09	3.95
800	50%	8.6	8.39	1.17	0.18	1.35	0.30	1.47	0.91	2.08
	45%	12.0	11.70	1.81	0.18	1.99	0.30	2.12	0.91	2.72
	40%	15.0	14.63	2.59	0.18	2.77	0.30	2.89	0.91	3.50

Note:

1. Increased tariff = increased fixed tariff + increased variable tariff
2. Increased fixed tariff = due to increase capex + increase O&M expenses

7.4.4 Recommendations

7.4.4.1 Modifications (Retrofit)

For achieving minimum technical load (40%) and higher ramp rate, the primary focus of the utility shall have to be on optimizing the existing control system. Improvements in some of the areas shall be essential, like achieving automated control operation whichshall include proper tuning of operation so as to avoid temperature and pressure excursions. Control optimization shall include main/reheat steam temperature control,boiler feed water recirculation control, flue gas temperature control. Better combustion control shall include, optimum fuel to air ratio, fuel to load coordination, furnace pressure control, burner tilt control and proper flame monitoring at low loads. Condition monitoring of boiler and turbine, flame monitoring is essential from the safety point of view. To reduce the running cost of the unit at low loads, the optimization of auxiliariesis essential for improving heat rate. The above measures are essential for a unit and may require a capital investment of around six to ten crores. In case of very old units which have not upgraded their plant control and instrumentation system previously, the capital investment will be about 30 crores depending on the retrofit.

7.4.4.2 Compensation Mechanism

i) Cost of modification/retrofit shall form part of the capital investment, and wherever applicable, this shall be recoverable through fixed part of tariff separately in 5 to 7 years' time periods as done in case of R&M.

ii) Costs due to increase in O&M expenses, shall have to be compensated as part of the fixed tariff. The increase in O&M costs shall depend on level of flexibilisation and in the study conducted by CEA (refer Table 7.10) the increase in annual O&M cost has been considered as 9%, 14% and 20% at 50%, 45%, 40% loading, respectively.

iii) Below 55% technical minimum load, the heat rate deterioration becomes even steeper and thermal power plants are not compensated for this deterioration. Units running technical minimum load below 55% can be additionally compensated in ECR to the extent of heat rate deterioration. As per the study conducted by TPRM Div., CEA, unit operating at loads lower than 55% technical minimum load can be suitably compensated in their variable tariff as summarized in Table 7.10, initially, which can be modified suitably after receiving sufficient data.

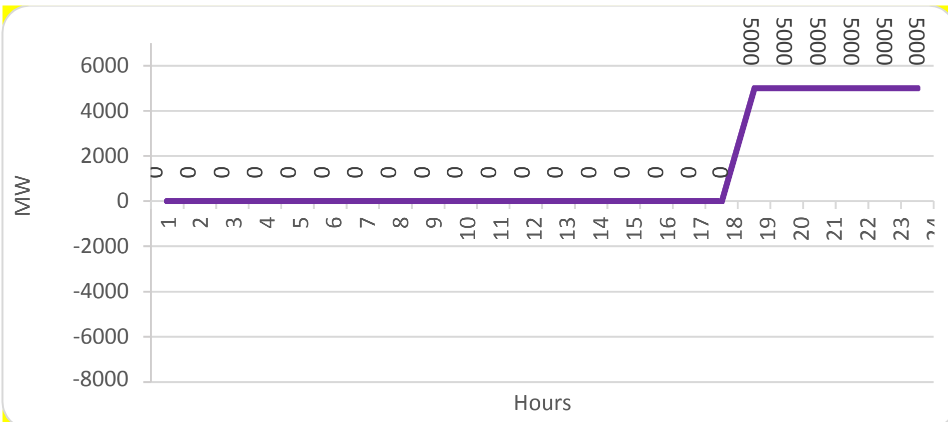
iv) Further, the compensation on account of forced outage due to operation at lower loads may have to be compensated as per the details indicated in Table 7.5.

v) There may be scenarios, wherein the flexible capabilities may have been created, however, the opportunity or the schedule to flexibilise may not become available to the particular unit. Hence, increased O&M cost may not be considered as part of fixed cost whereas the increased capital cost on account of retrofit shall continue to be recovered. The variable costs related to flexibilisation should be reimbursed for the cycling period by way of increase in the tariff.

vi) The Compensation on account of EFOR may be allowed 1.0 paisa/kWh initially as specific oil consumption may increase from 0.5 to 0.7 ml/KWh. It is also suggested to review after one year considering actual start/stop due to low load operation.

8. TWO-SHIFT OPERATION

CEA's 2019 report, "Flexible operation of thermal power plants for integration of renewable generation" suggested to run 5000 MW out of 10000 MW old small size (151 MW or less) units for six hours in the evening peak hours for integration of generation from 175 GW RES. Most of these units are more than 25 years old and have high Energy Charge Rating (ECR).



CEA reports, 2019 - Two shift Operation of thermal units

8.1 Classification of Two-Shift Operation

Category 1 - Operate during Peak Demand period: these plants will have to deliver the peak loads with full available capacity during the peak hours (about 6 to 7 hrs.), with increased demand and reduced or no solar, After the peak hours are over, these plants will not be required to deliver any power and therefore would be put on hot standby. Plants in this category are likely to have an annual PLF of 30% or lower.

Category 2 - Shutting down during Peak Solar Generation Period**:** In this category plants will be under shut down during of solar peak generation period (10 am to 4 pm or 10 am to 5 pm) and units will generate in the evening peak with hot startup. The PLF of plants will be better than plants under category-1.

Two-shift operation is a costly mode of operation because of lower PLF and accelerated equipment life consumption due to daily start stop and increased forced outages. In the Indian market context, it will make economic sense for the older plants (with near-zero fixed costs/fully depreciated capital costs) to be retrofitted for a two-shifting mode of operation. As these plants would be on bar for a limited duration, the overall emissions will be much lower, compared to the plants operating on lower loads for a longer duration.

The start-ups in daily two-shifting operations will mostly be hot start-ups, which are less damaging (equipment life consumption) than warm or cold start-ups. These plants are best placed, economically to deliver the peaking power (which can be opted as an Ancillary service product or suitable compensation mechanism to be installed). More study regarding startup optimization, minimization of equipment damage is required for two shift operation of thermal power plants.

8.2 Two-Shift Operating Experience

8.2.1 CESC Limited is operating the 2x67.5MW, BHEL make units of Southern Replacement TPS, commissioned in 1990 and 1991 respectively, in single/two shift mode for last 5 to 6 years, depending on merit order and system/network requirement. Running hours varies from 6 to 18 hours per day and type of start is hot or warm or cold depending on the number of hours of shutdown. No retrofitting (hardware/software) was done for single/two shift operation.

8.2.2 Another example of two-shift operation is of TANGEDCO, Tamil Nadu which is classified under category 2. The two shift mode operation was started in April 2022 and is being continued to accommodate the renewable generation as and when required. The units are at full load during evening peak hours and mostly units are operating for 16 hrs. in a day from 5pm to 11am, daily in hot startup mode. About all 210 MW units of the TANGEDCO are being operated in two shift mode which are more than 30 years old and 3 of which are more than 40 years old. The unit operated in two shift mode are given in table 8.1.

The following have been experienced during two shift operation of the units by M/s.TANGEDCO.

1. Oil consumption is more and the generation cost & Auxiliary power consumption percentage have increased.
2. Heat rate, Specific Coal Consumption, Specific Oil consumption have increased. Overall efficiency is under study. The operational issues, equipment condition and other safety related issues are being monitored meticulously during the two shift operation periods. The details of outcome of the study by TANGEDCO shall be available after monitoring the two shift operation for a longer period.

Table 8.1 TANGEDCO Units Operated in TwoShift Mode

S.no	Station	Unit	Commissioning Date
1	TTPS, 5x210 MW	I	07.09.1979
		II	17.12.1980
		III	16.04.1982
		IV	11.02.1992
		V	31.03.1991
2	MTPS, 4X 210 MW	I	07.01.1987
		II	01.12.0987
		III	22.03.1989
		IV	27.03.1990

Source : TANGEDCO Ltd.

8.3 Recommendation

It is proposed to initiate study by an expert committee for two shift operation of thermal power plants considering integration of 500 GW non fossil fuel capacity by 2030. The technical feasibility and recovery of cost system of two shift operation need to be elaborated by the committee. Further, the committee may also explore the possibility of exemption of FGD installation in these power plants considering the limited hours of operation and daily/ monthly average SO2 emission will be within prescribed limits.

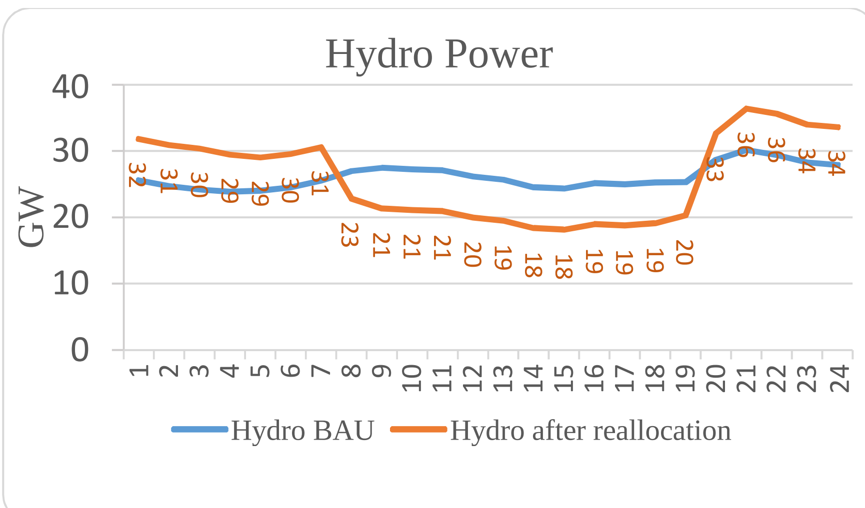
9. FLEXIBLE POWER FROM DIFFERENT SOURCES

Flexible power required for the balancing of grid may be available from following sources:

- Reallocation of hydro generation
- Gas flexing
- Pump Storage
- Low load operation of thermal power plants
- 2-shift operation thermal power plants
- Demand Side Management
- Battery Storage

9.1 Reallocation of Hydro Generation

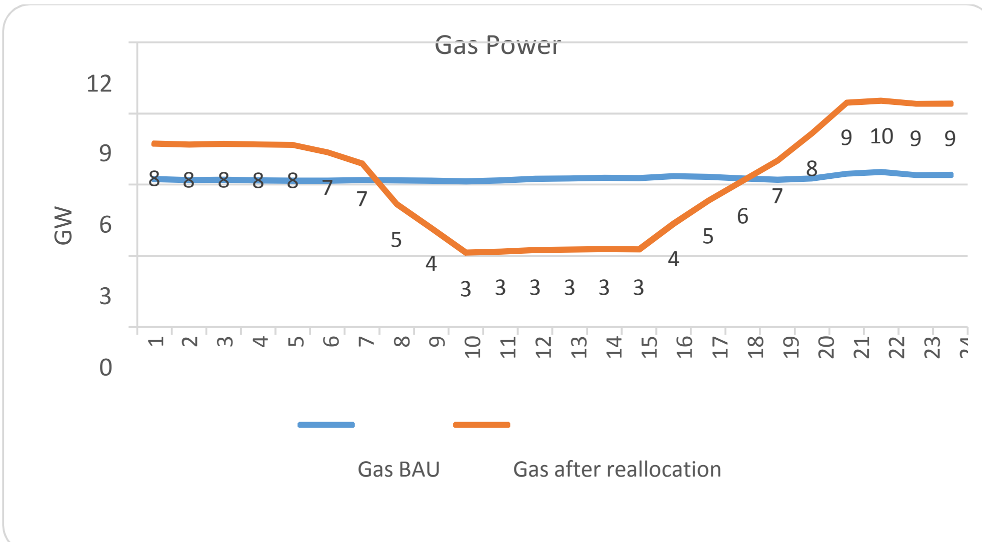
Present hydro generation is shown in blue colour in fig. below. Proposed reschedule is shown as in brown colour where reduced generation during day time and higher generation during peak demand hours is proposed. To achieve the target, the coordination with central and state hydro generator is essential. It has been observed that states hydro plants are operating continuously to meet the demand of states and states do not draw power from grid during day time because of their very cheap hydro power compared to grid power.



It is suggested to implement separate tariff for flexible hydro power which will be higher than cost of peak grid power and cost of solar power may be reduced specially from 11 am to 4 pm. If the tariff is revised as above, many hydro rich states will draw power from grid during day time and operate hydro plants during peaking hours for financial benefit of the organization. The minimum tariff of flexible hydro power should be greater than the off-peak grid power.

9.2 Gas Flexing

Presently installed Gas Power Plant capacity is about 25GW but about 9 GW is operating due to low availability of gas. Out of 9 GW, a few cannot operate intermittently as they are directly connected to oil fields. There is possibility of flexible operation of gas power plant which are connected with the gas grid. Present generation and proposed generation of the gas power plants are shown in blue and brown colour in the fig below.



9.3 Pump Storage

We have enormous potential for small pump storage with a cost of 3-4 cr/MW,it is possible to develop PSS by identifying the location in consultation with Hydro wing, CEA, NHPC or state hydro sector. In fact, development of pumped hydro storage schemes is a precursor to integrate renewable power generation.Central/State/Private Pump Storage plants should operate in pumping mode during the solar generation period and generating mode during peak demand period. They can be utilized for meeting the peak demand of the grid or balancing the grid only.

9.4 Flexibilisation of Thermal Power Plants

9.4.1 Low Load Operation of Thermal Power Plants

About 70 percent of the country's energy demand is being met from thermal generation thus it is essential that maximum flexible power will be available from thermal power plants. The maximum and minimum gross thermal capacity of 232GW and 148GW are required in 2029-30 as specified in CEA's report on "Optimal Generation Capacity Mix for 2029-30". If required measures shall be implemented for operation of TPPs at 40% load instead of present 55 percent minimum load, then it shall be possible to achieve about 21GW additional flexible power from the thermal fleet. The details are as under:

Max. Gross Coal Capacity Required (as per Optimal gen. report)	= 232 GW,
Max. gen. (75% units)	= 174 GW
Spinning reserves (7%)	= 12.18 GW
Auxiliary consumption (7%)	= 11.32 GW
Ex-bus gen.	= 150.49 GW
55% min. load (aux. 7.5%)	= 76.56 GW
40% min. Load (aux. 8%)	= 55.38 GW

21.18 GW (76.56-55.38) more Renewable integration is possible by lowering the min load from 55% to 40%.

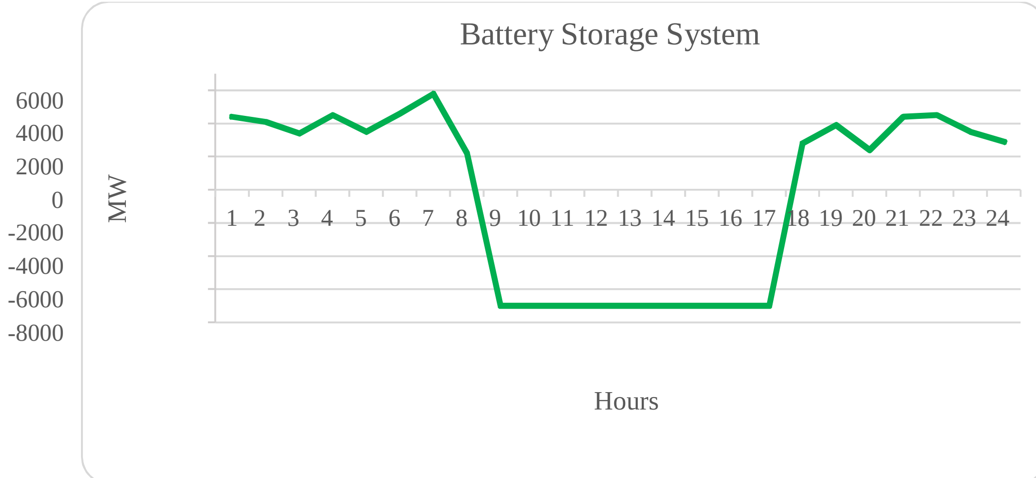
Capex = 10 Crore per unit (average)
Total no. of Units = 600
Total investment = 600X10 = 6000 Crore

9.4.2 Two-Shift Operation of Thermal Power Plants

After implementing low load operation up to 40% at thermal generating units, iffurther flexible power is required it can be available from 2-shift operation of old& small size thermal generating units. These units may run 6 to 7 hrs only duringpeak grid demand period or 6 to 7 hrs. shutting down during peak solar generation period.

9.5 Battery Storage System

The cost of battery energy storage system is assumed to be reducing uniformly from 7 Crore in 2021-22 to 4.3 Crore in 2029-30 for a 4-hour battery system which also includes an additional cost of 25% due to depth of discharge. If we consider 27GW BSS with an average cost of 5.65 Crore/MW, total cost shall be more than one lakh fifty thousand crore. Thus BSS shall be costly, which shall have to be imported, having less life about 9-10 years and disposal issues. Considering the above it is suggested to reduce BSS capacity accordingly.



9.6 Demand Side Management

Demand side management (implementing TOD metering) including measuretargeted at domestic, agricultural, industrial and e-mobility sector and hydrogengeneration would enable more rational consumption pattern of electricity. The cost of grid power will be of least during high solar period and highest in evening/morning peak. It shall encourages consumption of energy during day time than in the peak hours.

Supply of electricity to agriculture sector by dedicated feeders

Agricultural consumption = 211,295 MU
Agricultural consumption = 16.94 %

Shifting of 1000MW load from night hours to peak solar hour will improve about 1% technical minimum load of thermal generating units.

9.7 Recommendation

It is suggested that existing capacity of hydro, pumped storage, gas and thermal available for flexibilisation in the system should be utilized first in a safe and secure manner before adopting newer options such as Battery storage system, etc. on a large scale.

10. ROADMAP

The conduction of low load study/test run is essential for each unit to find the measures required to be implemented for flexible operation, as has been discussed in earlier chapters of the report. To implement measures in a unit as identified in low load test/study, it shall require a minimum six months' time. Hence, it is necessary to formulate a time frame for achieving flexibilisation of a very large fleet of 600 thermal units. It is expected that non-pithead thermal power plant shall be given minimum technical generation schedule in first stance and thereafter pithead based plants if required. This section deals with devising a phasing schedule based on the age of units andinputs received from the major OEMs.

10.1 Phasing Plan

On accomplishing 175GW RES capacity in the December, 2022 (may be in 2023), there shall be grid requirement of the operation of thermal units at 40% minimum load on an average as per the findings of CEA 2019 report. So far to the knowledge of committee, work has been awarded for the upgradation/flexibilisation of one unit in central sector in 2019. The final outcome of the flexibilisation work carried out has to be established. CEA consulted three major OEMs (BHEL, Siemens and GE) and also tried to consult others for their capabilities to carry out the flexibilisation work. The data provided by one of the vendors already conducting the flexibilisation work on one of the units seemed tobe more realistic than the other two vendors. There has been no response from the othersub vendors. Based on the present vendor capabilities, the following preliminary phasing plan has been drawn up by TPRM Div. CEA.

More than 24.64% thermal capacity is newly commissioned, January 2016 onwards (refer Table 9.1). These new units should necessarily be having advanced digital controls and features which shall help in faster adoption of the 40% load following operational regime. It shall be obligatory that such units numbering 101 units are brought under the purview of flexibilisation operating regime first.

Table 10.1

Commissioning Period	Units	Capacity(MW)
Since 2016 to till date	101	52,152
Between 2012 & 2015	160	80,384
Between 2001 & 2011	143	34,840
Upto 2000	196	44,143.5
Total	**600**	**211,519.5**

In the pilot phase, it is proposed that 11 units of central/state/pvt sector which were commissioned from Jan 2016 to December 2022 shall be taken for refurbishment (refer

Table 9.2). It is estimated that the refurbishment shall be completed in a period of one year, which shall be followed by performance evaluation and rectification period of six months. The experience gained in pilot phase shall be useful for future planning. The complete phasing plan as proposed is given in the Table 10.2. A minimum estimated time period of 8 years' may be required to make these units compliant of flexibility upto 40% load following and having higher ramp rates. The complete refurbishment work is estimated to end by December 2030, considering the work starts in January 2023. This phasing will help in proper identification and planning.

Table 10.2 Phasing Plan

Phasing	Sector	No. of Units	Time Period (Year)	Unit commissioned
Pilot Phase Jan,2023-Dec,2023	Central	4	1	Jan,2016 to Dec,2022
	State	3	1	
	Private	4	1	
Jan,2024-Jun,2024	Performance analysis and modification, if required.			
1st Phase July,2024-Jun,2026	Central	32	2	Jan,2016 to Dec,2022
	State	26	2	
	Private	32	2	
2nd Phase July,2026-Jun,2028	Central	24	2	Jan,2012 to Dec,2015
	State	30	2	
	Private	106	2	
3rd Phase July,2028-Dec,2029	Central	41	1.5	Jan,2001 to Dec,2011
	State	52	1.5	
	Private	50	1.5	
4th Phase Jan,2030-Dec,2030	Central	67	1	up to December,2000
	State	111	1	
	Private	18	1	
	Total	**600**	**8**	

In the 1st phase, the plants commissioned between January 2016 and December 2022, about 22.64% capacity (~15% Units) shall be considered and two years' time shall be required to complete the refurbishment.

Units commissioned between January 2012 and December 2015 shall be taken in 2ndphase (~27% Units) and unit commissioned January 2001 to December 2011 (~24% Units)shall be considered in 3rd phase and a shorter period one and half years' time is considered to be required due to the experience gained in earlier phase.

In the last 4th phase, remaining units (33%Units) commissioned up to December 2000 shall be considered requiring one year's time period for refurbishment. The details of all the phases including timeline is summarized in Table 10.2. The phasing may have to be reviewed considering the actual progress achieved on site.

10.2 Study/ Test Run of Each Unit

The conduction of low load study/test run is essential for each unit to find the measures required to be implemented for 40% low load operation without oil support. The measure shall also be identified for achieving minimum 1% ramp rate particularly in the lower load range 40% to 55%, 2% ramp rate in the load range of 56 to 70% and 3% in higher load range of 71 to 100%.

10.3 Measures Implementation

To implement measures in a unit as identified in low load test/study, it shall require a six months' time (approximately). (Refer Chapter-6 and Section 7.4.3.2.1 of Chapter 7)

10.4 Operator Training

Flexibilization of units adds to the safety risks and calls for added precautions. Equipment failure can take place due to negligence, poor operation and maintenance practices and low operator confidence due to the operation of plants for base load. For safe and efficient plant operation at very low load and frequent load cycling, there is an essential need for trained personnel. Training curriculum for trainer and power plant operators shall have to be prepared in association with major power plant operator and NPTI.

The training simulators provide a strong base for ensuring the right operational procedures and practices which need to be followed by operators. The existing training simulators may need to be upgraded for low load/high ramp rate operation at 40% load, which shall need to be ascertained. The training of personnel needs to be scheduled in advance before the units are put in high flexible mode of operation.

11. CONCLUSION AND WAY FORWARD

11.1 Conclusion

11.1.1 Low load operation (40%) of coal fired power plants is primarily required to fulfil theneeds of integration of renewables in the grid. Flexible power plants in the system enable the integration of more renewables, avoid wasteful curtailment, leading to a more efficient power system. Although, there maybe many options of flexible power for integrating renewables, coal fired plants is thebest option considering its availability, proportion and low cost.

11.1.2 The existing capacity of hydropower, pumped storage and gas-fired generation having good peaking performance is too small to meet the balancing requirements. It is of importance that the existing thermal resources available for flexibilisation in the system should be utilized first in a safe and secure manner before adopting newer options such as Battery storage system, etc. on a large scale.

11.1.3 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. Converting the base load coal fired power plants into flexible plants would most likely incur expenditure.

11.1.4 To assess the flexible capability, the thermal units need to be tested from safety, security & stability point of view and quantification of available flexible power, ramp rate, etc. These tests are also essential for accessing the need for retrofits which are plant specific. The low load test runs should be conducted after careful study of the unit beforehand and accordingly the test targets should be decided in consultation with OEM. Any stretching of the targets during the test run should be avoided for the safety and security of the plant.

11.1.5 The technical measures shall depend on the levelsof minimum load operation to be adopted. 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.

11.1.6 Indian power sector has got large fleet of subcritical coal fired units of capacity 500 MW and less, which are considered suitable for flexibilisation. Super-critical units are better for load ramping /flexible operation and more care is required around benson (dry/wet) point.

11.1.7 To ensure the security of the grid and safety of plants, presently the low load operation of coal-fired power plants should not be less than 35–40% of ratedpower due to Low VM and high ash content of Indian coal.

11.1.8 The coal-fired power units shall remain the main source of flexible power. However, there are many commercial issues like cost of retrofit, increased O&M cost, heat rate degradation cost, increased EFOR which would need to be compensated by the central and state regulators.

11.1.9 There is low operator confidence for flexibilisation due to operation of thermal plants as base load plants. Low load operation of units at forty percent calls for added precautions. Catastrophic equipment failure can take place due to negligence and poor operation and maintenance practices. Hence, operator training is essential for the implementation of flexibilisation.

11.1.10 Two shift operation of old thermal generating units is being carried out in some parts of the country in a piecemeal manner to meet the load generation balance. The need arises for carefully planning of two-shift operation countrywide.

11.2 Way Forward

11.2.1 Immediate action needs to be taken for preparing thermal generating units flexible as per the road map discussed in the report. Initially, the pilot phase of flexibilisation/refurbishment of 11 units of Central/State/Private sector may be carried out for performance evaluation (refer para 7.4.4.1). For funding some of the units under pilot phase, INDC *Technology Development & Transfer/ Fund Mobilization* or Govt. funding like PSDF may be utilized.

11.2.2 Availability of training simulators need to be ensured for the trainingof operators at 40% low load operation.

11.2.3 Regulation should be introduced for 40% minimum technical load operation of thermal generating units.

11.2.4 Suitable regulatory mechanism, should be introduced in central and state level, wherever applicable, for the compensation as discussed in the report (refer para 7.4.4.2).

11.2.5 Keeping in mind the requirement of flexible power in future, design of new thermal units should be such that it can be possible to operate these with optimized auxiliaries, at loads lower than 40% (say 30%) without oil support and, at higher ramp rates of 2-3% in lower load range.

11.2.6 Study should be initiated for finding the possibility of two shift operation of existing thermal generating units as per the grid requirement (refer para 8.4). Design of new thermal units should be such that it can be possible to operate in 2 shift mode on a regular basis.

ANNEXURE - I

Assumptions:

1. **Unit size 200 MW**
   BAU Mode:
   Capital Cost 6Cr/MW, O&M Cost 30lakh/MW, Coal Cost Rs 2000/ton, Heat rate 2430 Kcal/Kwh.
   Flexible Mode:
   Capital Expenditure w.r.t Flex. of 6/10/30 Cr./Unit, Increase in O&M Cost- 9% for 50%loading, 14% for 45% loading, 20% for 40% loading.

2. **Unit size 500 MW**
   BAU Mode:
   Capital Cost 6Cr/MW, O&M Cost 20lakh/MW, Coal Cost 2000Rs/ton., Heat rate 2390 Kcal/Kwh
   Flexible Mode:
   Capital Expenditure w.r.t Flex. of 6 /10/30 Cr./Unit, Increase in O&M Cost- 9% for 50%loading, 14% for 45% loading, 20% for 40% loading.

3. **Unit size 660 MW**
   BAU Mode:
   Capital Cost 6Cr/MW, O&M Cost 18lakh/MW, Coal Cost 2000Rs/ton., Heat rate 2280 Kcal/Kwh.
   Flexible Mode:
   Capital Expenditure w.r.t Flex. of 6/10/30 Cr./Unit, Increase in O&M Cost- 9% for 50%loading, 14% for 45% loading, 20% for 40% loading.

4. **Unit size 800 MW**
   BAU Mode:
   Capital Cost 6Cr/MW, O&M Cost 16lakh/MW, Coal Cost 2000Rs/ton., Heat rate 2200 Kcal/Kwh.
   Flexible Mode:
   Capital Expenditure w.r.t Flex. of 6/10/30 Cr./Unit, Increase in O&M Cost- 9% for 50%loading, 14% for 45% loading, 20% for 40% loading.

Annexure- B.2.1.4

ANNEXURE-I

Progress Report regarding achievement of 55% MTL

S. No	Details	Unit 1	Unit2	Unit3	-------
1	Name of Utility				
2	Plant Name and Address				
3	Capacity, MW				
4	Date of Commissioning				
5	Type of Unit: Supercritical/Subcritical/....				
6	Net Heat rate: Design/Actual				
7	Coal Quality (i) GCV (ii) Volatile matter (iii) Ash Content				
8	Maximum Generation (last 2 years) MW				
9	Minimum Generation (last 2 years) MW				
10	Maximum Ramp Rate Up (last 2 years)				
11	Maximum Ramp Rate Down (last 2 years)				
12	Whether 55% Minimum load Achieved (YES/NO) (i) If YES, specify the duration and time (ii) If NO, specify the reason for the same				
14	Any other details				

Annexure- B.2.1.5

ANNEXURE-II

Progress Report regarding achievement of 40% MTL

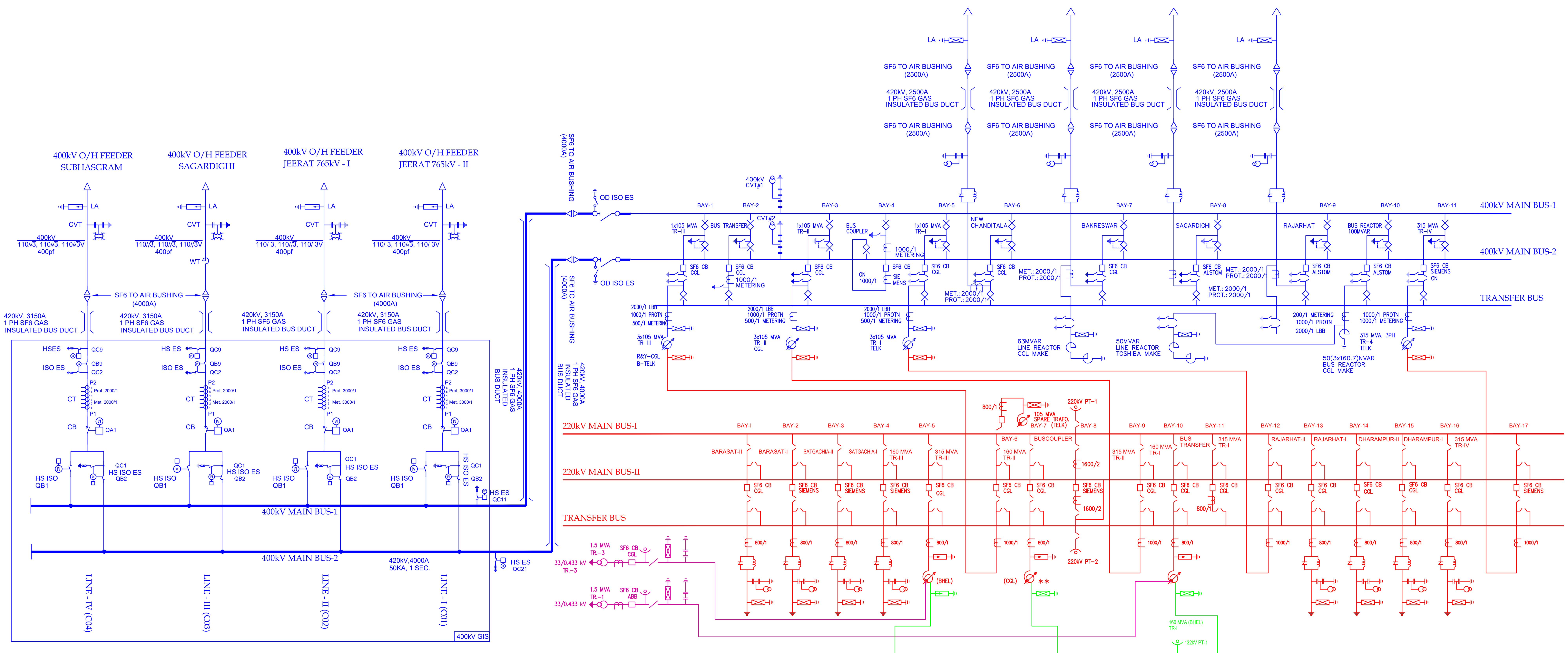
S. No	Details	Unit 1	Unit2	Unit3	-------
1	Name of Utility				
2	Plant Name and Address				
3	Capacity, MW				
4	Date of Commissioning				
5	Type of Unit: Supercritical/Subcritical/....				
6	Net Heat rate: Design/Actual				
7	Coal Quality (i) GCV (ii) Volatile matter (iii) Ash Content				
8	Maximum Generation (last 2 years) MW				
9	Minimum Generation (last 2 years) MW				
10	Maximum Ramp Rate Up (last 2 years)				
11	Maximum Ramp Rate Down (last 2 years)				
12	Whether 40% Minimum load Achieved (YES/NO) (i) If YES, specify the duration and time (ii) If NO, specify the reason for the same (iii) Whether low load test conducted at 40% (YES/NO) (a) If YES, measures identified/implemented for achieving the same. (b) If No, any action taken in this regard				
14	Any other details				

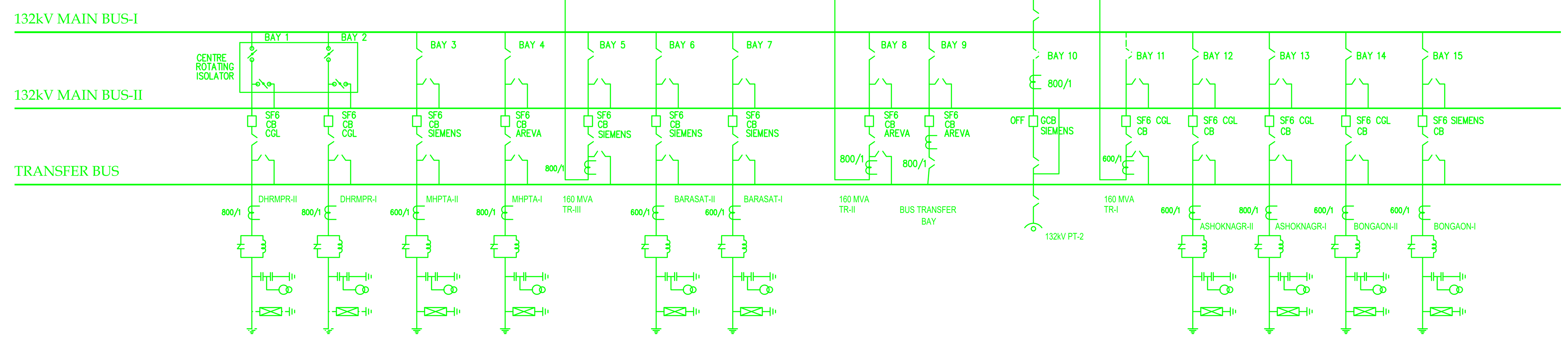
2000

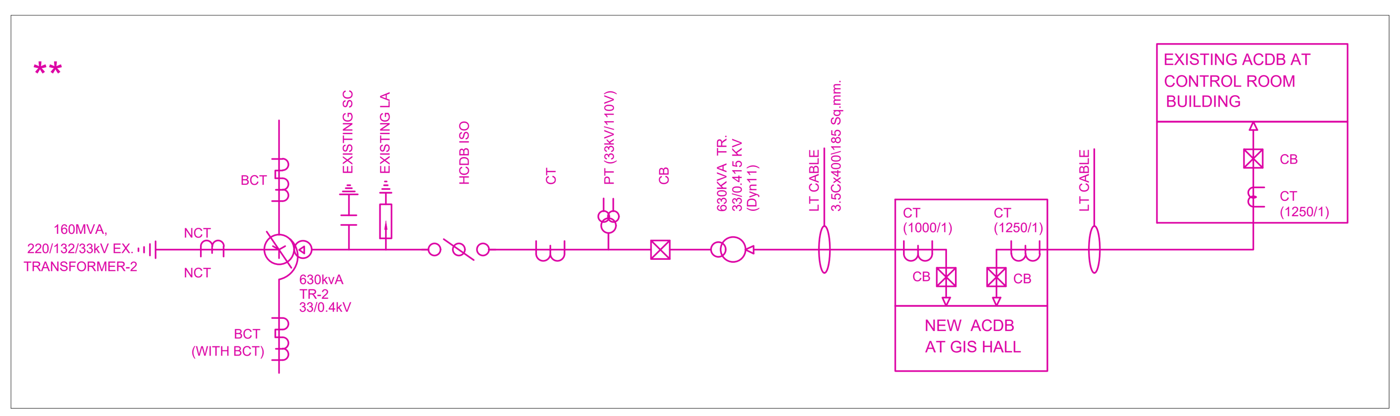
1250

Annexure B.2.2

SINGLE LINE DIAGRAM OF JEERAT 400/220/132kV SUB-STATION
WBSETCL







SLD FOR AUXILIARY SUPPLY

LEGENDS:

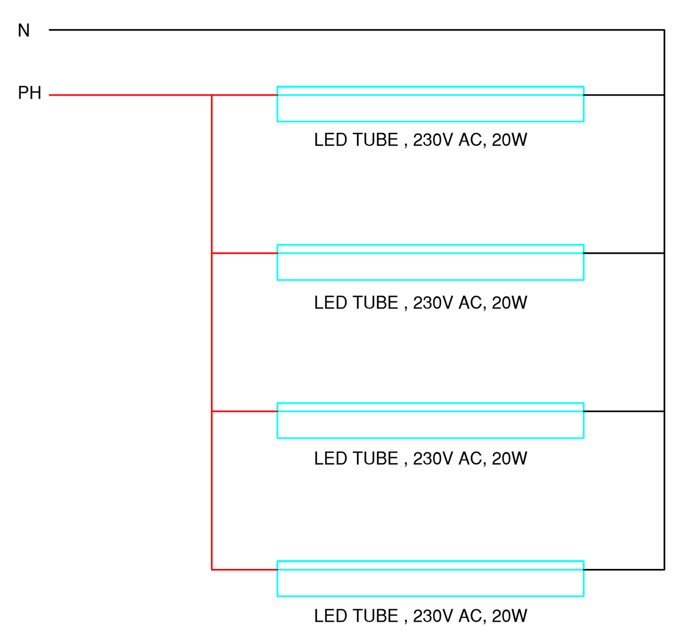
SYMBOL	DESCRIPTION
	AUTO TRANSFORMER
	2 WDG TRANSFORMER
	REACTOR
	CIRCUIT BREAKER
	PANTO ISOLATOR
	HCB ISOLATOR
	CENTRE ROTATING ISOLATOR
	CT
	PT
	CVT
	LA
	WAVE TRAP
	400 kV VOLTAGE LEVEL
	220 kV VOLTAGE LEVEL
	132 kV VOLTAGE LEVEL
	33 kV VOLTAGE LEVEL

400KV INDOOR EQUIPMENT LEGENDS :

SYMBOL	DESCRIPTION
	CIRCUIT BREAKER
	CURRENT TRANSFORMER
	ISOLATOR WITH ONE E/S
	HIGH SPEED EARTH SWITCH
	HIGH SPEED ISOLATOR WITH ONE EARTH SWITCH
	HIGH SPEED ISOLATOR WITHOUT EARTH SWITCH

400KV OUTDOOR EQUIPMENT LEGENDS :

SYMBOL	DESCRIPTION
	420 KV , 4000A , 50KA for 1 Sec. HCB, MOTOR OPERATED 3PH ISOLATOR WITH E/S
	420 KV, 4400pf Line CVT
	420KV, 3150A, 1.0 mH LINE TRAP
	336KV LIGHTNING ARRESTER
	SF6 AIR BUSHING (4000A)
	SF6 AIR BUSHING (2500A)



TYPICAL CONNECTION DIAGRAM OF LED TUBE

NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETER, UNLESS OTHERWISE SPECIFIED.
2. DIMENSION OF GLOW SIGN BOARD:- 2000X1250 MM.
3. MATERIALS USED:-
   a. FRONT MATERIAL- WHITE ACRYLIC SHEET (3MM THICK).
   b. ENCLOSURE MADE UP OF 0.8MM THICK GI SHEET.
4. PRINT TYPE:- UV PRINTING DIRECTLY ON ACRYLIC SHEET.
5. NUMBER OF LIGHTS:- 4 NOS LED TUBE OF 230V AC, 20W

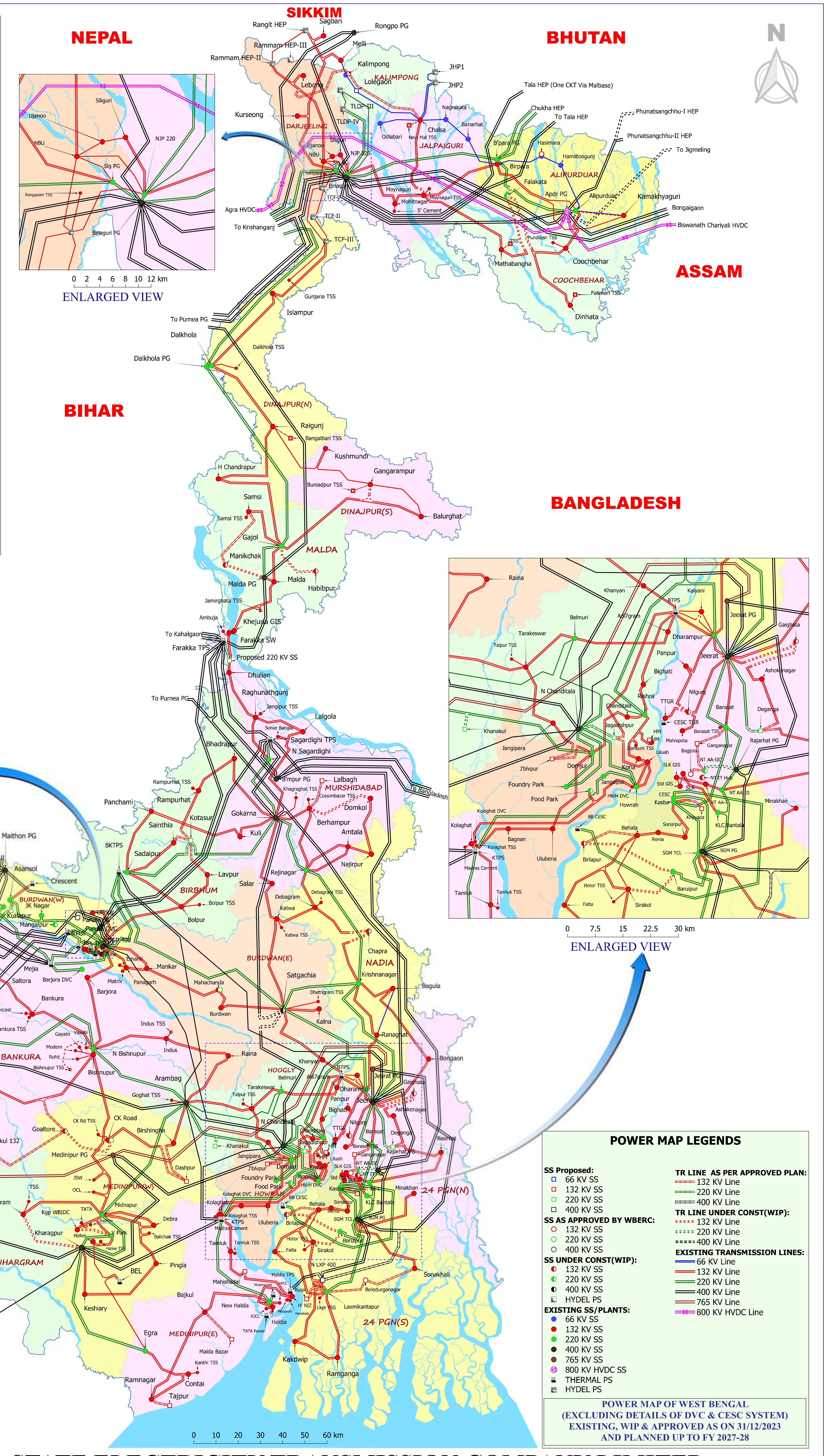
0	FIRST SUBMISSION	SN	SB	NK	11.03.21
REV	DESCRIPTION	PREP.	CHKD.	APPD. SIGN.	DATE

CUSTOMER	WEST BENGAL STATE ELECTRICITY TRANSMISSION COMPANY LIMITED.
THIS DRAWING IS THE PROPERTY OF M/S TECHNO ELECTRIC & ENGG. CO. LTD. AND NOT TO BE COPIED OR USED WITHOUT THEIR PRIOR PERMISSION	TECHNO ELECTRIC & ENGG. CO. LTD.
NOA NO.	SUPPLY: CEP/WBSETCL/Sub-Stn/Package-59 / Supply /2018-19/44 Dated:05.11.2018 ERECTION: CEP/WBSETCL/Sub-Stn/Package-59 / Erection /2018-19/45 Dated:05.11.2018
PROJECT	CONSTRUCTION OF 2 NOS. 400 KV GIS LINE BAYS FOR TERMINATION OF JEERAT(NEW)– JEERAT (WBSETCL) 400 KV D/C LINE (ERSS XVIII) , CONSTRUCTION OF 2NOS. OF 400 KV GIS LINE BAYS FOR TERMINATION OF SAGARDIGHI TPS – SUBHASHGRAM PGCIL 400 KV S/C LINE (ERSS XV A) AND MODIFICATION OF TERMINATION ARRANGEMENT OF 4 NOS. 400 KV EXISTING FEEDERS AT JEERAT 400 KV SUBSTATION (ERSS XV B), DISTRICT – 24 PARGANAS (NORTH) [Package-59]
SUBSTATION	400kV JEERAT SUBSTATION (EXTN.)
DRG. TITLE	GLOW SIGN BOARD
DRG. NO. :	0737WB/JERT/SUB/E/DRG/GSB/001
SCALE :	NTS — JOB NO: 0737WB — SHEET: 1 OF 1

POWER MAP OF WEST BENGAL AS ON 31/12/2023

INSTALLED CAPACITY

GENERATING STATION	EXISTING	WIP
WBPDCL:		
Kolaghat TPS (4 X 210)MW)	840 MW	
Bakreswar TPS (5 X 210) MW	1050 MW	
Sagardighi TPS (2 X 500 + 2 X 300 + 1 X 660) MW	1600 MW	660 MW
Santaldihi TPS (2 X 250) MW	500 MW	
Bandel TPS (1 X60 + 1 X 215) MW	275 MW	
Total=	**4265 MW**	**660 MW**
WBSEDCL :		
Purulia PSP (4 X 225) MW	900 MW	
Rammam-II HPS (4 X 12.75) MW	51 MW	
TCF HPS (3 X 3 X 7.5) MW	67.5 MW	
Jaldhaka HPS(4 X9 + 2 X 4) MW	44 MW	
Mini-Micro HPS	8.8 MW	
Total =	**1071.3 MW**	
DPL :		
Unit #7	300 MW	
Unit#8	250 MW	
Total =	**550 MW**	
NTPC :		
Farakka Unit # 1-3 (3 X 200) MW	600 MW	
Farakka Unit # 4-6 (3 X 500) MW	1500 MW	
Total =	**2100 MW**	
NHPC :		
TLDP-III (4 X 33) MW	132 MW	
TLDP-IV (4 X 40) MW	160 MW	
Total =	**292 MW**	
DVC(WB) :		
Mejia TPS (4 X 210 + 2 X 250 + 2 X 500)MW	2340 MW	
Durgapur TPS (1 X 210) MW	210 MW	
Durgapur Steel TPS (2 X 500) MW	1000 MW	
Raghunathpur TPS (2 X 600) MW	1200 MW	
Maithon HPS (2 X 20 + 1 X 23.2) MW	63.2 MW	
Total =	**4813.2 MW**	
CESC Ltd., HEL, Others :		
Budge Budge TPS (3 X 250) MW	750 MW	
Southern TPS (2 X 67.5) MW	135 MW	
Titagarh TPS (4 X 60) MW	240 MW	Not In Service
Haldia Energy Ltd. (2 X 300) MW	600 MW	
Cresent Power Ltd. (1 X 40) MW	40 MW	
Philips Carbon Black Ltd. (1 X 30) Mw	30 MW	
Total =	**1795 MW**	
Others :		
Bengal Energy Ltd. (1 X 40) MW	40 MW	
Hiranmoyee Energy Ltd. (3 X 150) mW	300 MW	150 MW
Tata Power, Haldia (2 X 45 + 1 X 30) MW	120 MW	
Total =	**460 MW**	**150 MW**
Grand Total =	**15346.5 MW**	**810 MW**



WEST BENGAL STATE ELECTRICITY TRANSMISSION COMPANY LIMITED

Annexure B.2.5

GENCO	Mode of Transport	Name of Thermal Power Station/ Performance of Utility#	Capacity (MW)	Actual Stock as % of Normative Stock	Normative Stock Reqd. (Days)	Daily Requirement @85% PLF (TT)	Normative Stock Required (TT)	Actual Stock			Receipt of the day (TT)	Consumption of the day (TT)
								Indigenous	Import	Total		
TVNL	RAIL	TENUGHAT TPS	420	46%	26	6.2	161.6	74.5	0.0	74.5	4	3
		TVNL - Total	420	46%	26	6.2	161.6	74.5	0.0	74.5	4	3
OPGC	PITHEAD	IB VALLEY TPS	1740	85%	17	26.2	445.2	379.7	0.0	379.7	30	24
		OPGCL- Total	1740	85%	17	26.2	445.2	379.7	0.0	379.7	30	24
WBPDCL	RAIL	BAKRESWAR TPS	1050	58%	26	13.6	353.4	205.0	0.0	205.0	14	15
	RAIL	BANDEL TPS	270	44%	26	4.0	103.8	46.1	0.0	46.1	8	4
	RAIL	KOLAGHAT TPS	840	19%	26	13.8	357.7	66.6	0.0	66.6	15	11
	RAIL	SAGARDIGHI TPS	1600	51%	26	21.9	568.5	290.5	0.0	290.5	14	26
	RAIL	SANTALDIH TPS	500	59%	26	6.9	179.8	106.4	0.0	106.4	7	8
		WBPDCL- Total	4810	50%	26	67.6	1758.7	877.4	0.0	877.4	58.0	71.5
NTPC	RAIL	BARAUNI TPS	710	61%	26	10.4	271.3	165.0	0.0	165.0	4	7
	RAIL	BARH STPS	2640	84%	26	37.2	968.0	782.8	26.8	809.5	22	40
	PITHEAD	KAHALGAON TPS	2340	101%	17	36.8	625.2	578.9	51.9	630.8	56	43
	PITHEAD	NORTH KARANPURA TPP	1320	69%	17	18.9	321.2	222.0	0.0	222.0	13	10
	PITHEAD	DARLIPALI STPS	1600	53%	17	24.7	419.3	221.3	0.0	221.3	28	28
	PITHEAD	TALCHER STPS	3000	77%	17	44.8	760.8	585.0	0.0	585.0	45	46
	PITHEAD	FARAKKA STPS	2100	168%	17	26.9	457.8	743.6	27.3	770.8	30	26
		Total-NTPC	51690	90%	21	713.5	14848.8	12712.8	717.2	13429.9	659.0	664.2
	RAIL	MUZAFFARPUR TPS	390	72%	26	5.5	142.8	103.0	0.0	103.0	7	6
	RAIL	NABINAGAR STPP	1980	120%	26	24.8	643.8	747.0	25.0	772.0	33	25
	RAIL	NABINAGAR TPP	1000	43%	26	14.9	387.8	166.4	0.0	166.4	11	15
		Total-NTPC JV	8790	102%	26	121.8	3167.9	3175.4	55.8	3231.2	90.1	114.5
CESC	RAIL	BUDGE BUDGE	750	88%	26	9.4	245.4	292.5	0.0	292.5	119%	
	RAIL	SOUTHERN REPL. TPS	135	71%	26	1.9	50.7	62.0	0.0	62.0	122%	
	RAIL	HALDIA TPP	600	88%	26	8.4	217.1	178.4	0.0	178.4	82%	
IPP	RAIL	JOJOBERA TPS	240	79%	26	3.3	87.1	50.6	0.0	50.6	58%	
	RAIL	MAITHON RB TPP(MPL)	1050	94%	26	12.6	327.6	348.7	0.0	348.7	106%	
	ROAD	DERANG TPP-	1200	48%	26	17.6	457.0	1269.4	0.0	1269.4	278%	
	RAIL	KAMALANGA TPS-GMR	1050	98%	26	15.6	406.3	167.9	0.0	167.9	41%	
	RAIL	VEDANTA TPP	600	85%	26	9.5	247.6	53.0	0.0	53.0	21%	*
DPL	RAIL	D.P.L. TPS	550	83%	26	7.5	195.4	162.8	0.0	162.8	0	7

Annexure B.2.6.1.1

ADMS instances :

Jharkhand

Date	Frequency	Deviation	Load Shed as per State
00:07:00	49.87	225	21
17:15:00	49.86	252	19.29
22:09:00	49.88	160	39
22:17:00	49.89	145	12.65

Odisha:

Date	FREQUENCY	Deviation	Load Shed as per State
12:17:00	49.81	198.9082	Yet to be received
22:09:00	49.88	241.826	
22:17:00	49.89	375.5272	
23:11:00	49.82	274.9155	

DVC:

Date	Frequency	Deviation	Load Shed as per State
12:44:00	49.86	480	Yet to be received

Annexure 2.6.1.2

UFR EASTERN REGION

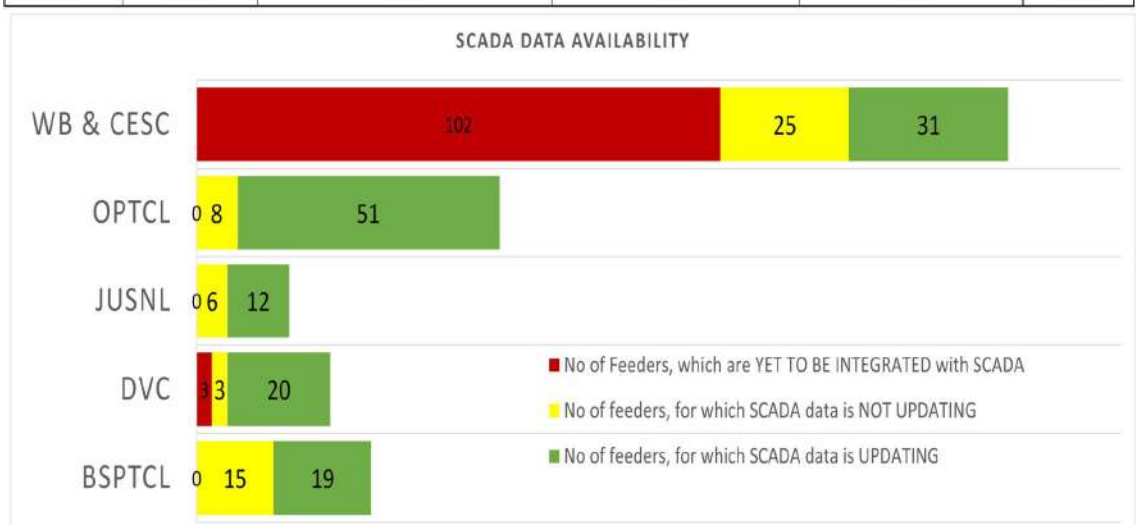
UFR_JH | UFR_DVC | FREQ 50.02 | UFR_OPTCL | UFR_BH | UFR_WB

	STAGE I		STAGE II		STAGE III		STAGE IV		Overall Reporting Percentage (Constituent wise)
DVC	46 / 134	100%	33 / 135.5	100%	23 / 136	50%	12 / 137	100%	88%
OPTCL	116 / 181.5	100%	73 / 183.5	94%	110 / 184	93%	29 / 186	92%	95%
BIHAR	23 / 126	60%	50 / 117.92	56%	47 / 153	0 %	27 / 84.47	33%	38%
JHARKHAND	17 / 61	60%	15 / 62	40%	15 / 61	67%	45 / 62	80%	61%
WEST BENGAL (incl CESC)	97 / 381	15%	125 / 374	47%	55 / 390	16%	54 / 386	38%	28%
TOTAL	299 / 883.5	49%	296 / 872.92	63%	250 / 924	36%	167 / 855.47	58%	
TOTAL FOR ALL STAGES AND ALL CONSTITUENTS							1013 / 3536	51%	

Figure to the right shows the percentage of feeders that are reporting to ERLDC.

SCADA data availability (Constituent wise) for UFR dated 18/04/2024

	Total No of Feeders	No of Feeders, which are YET TO BE INTEGRATED with SCADA	No of feeders, for which SCADA data is NOT UPDATING	No of feeders, for which SCADA data is UPDATING	Percentage Availability
BSPTCL	34	0	15	19	56%
DVC	26	3	3	20	77%
JUSNL	18	0	6	12	67%
OPTCL	59	0	8	51	86%
WB & CESC	158	102	25	31	20%
Total ER	295	105	57	133	45%



Annexure D.1

Anticipated Peak Demand (in MW) of ER & its constituents for May 2024

1	**BIHAR**	**Demand (MW)**	**Energy Requirement (MU)**
	NET MAX DEMAND	6929	4046
	NET POWER AVAILABILITY- Own Sources	429	320
	Central Sector+Bi-Lateral	6828	4376
	SURPLUS(+)/DEFICIT(-)	328	650
2	**JHARKHAND**		
	NET MAXIMUM DEMAND	2263	1247
	NET POWER AVAILABILITY- Own Source	355	201
	Central Sector+Bi-Lateral+IPP	1281	749
	SURPLUS(+)/DEFICIT(-)	-627	-297
3	**DVC**		
	NET MAXIMUM DEMAND	3548	2408
	NET POWER AVAILABILITY- Own Source	6161	3782
	Central Sector+MPL	308	175
	Bi- lateral export by DVC	2272	1691
	SURPLUS(+)/DEFICIT(-) AFTER EXPORT	649	-142
4	**ODISHA**		
	NET MAXIMUM DEMAND (OWN)	5500	3905
	NET MAXIMUM DEMAND (In Case of CPP Drawal of 800 MW(peak) and average drawl of 700 MW)	6300	4392
	NET POWER AVAILABILITY- Own Source	3270	3327
	Central Sector	1930	1346
	SURPLUS(+)/DEFICIT(-) (OWN)	-300	768
	SURPLUS(+)/DEFICIT(-) (I(In Case of CPP Drawal of 800 MW(peak) and average drawlm of 700 MW)	-1100	281
5	**WEST BENGAL**		
	WBSEDCL		
5.1	NET MAXIMUM DEMAND	9325	5678
	NET MAXIMUM DEMAND (Incl. Sikkim)	9330	5682
	NET POWER AVAILABILITY- Own Source (Incl. DPL)	5339	3178
	Central Sector+Bi-lateral+IPP&CPP+TLDP	2511	1335
	EXPORT (To SIKKIM)	5	4
	SURPLUS(+)/DEFICIT(-) AFTER EXPORT	-1479	-1169
5.2	**CESC**		
	NET MAXIMUM DEMAND	2465	1226
	NET POWER AVAILABILITY- Own Source	830	568
	IMPORT FROM HEL	541	393
	TOTAL AVAILABILITY OF CESC	1371	961
	DEFICIT(-) for Import	-1094	-265
	WEST BENGAL (WBSEDCL+CESC+IPCL)		
	(excluding DVC's supply to WBSEDCL's command area)		
	NET MAXIMUM DEMAND	11790	6904
	NET POWER AVAILABILITY- Own Source	6169	3746
	CS SHARE+BILATERAL+IPP/CPP+TLDP+HEL	3052	1728
	SURPLUS(+)/DEFICIT(-) BEFORE WBSEDCL'S EXPORT	-2568	-1430
	SURPLUS(+)/DEFICIT(-) AFTER WBSEDCL'S EXPORT	-2573	-1434
6	**SIKKIM**		
	NET MAXIMUM DEMAND	118	50
	NET POWER AVAILABILITY- Own Source	50	115
	Central Sector	128	82
	SURPLUS(+)/DEFICIT(-)	60	147
	EASTERN REGION		
	NET MAXIMUM DEMAND	30148	18560
	NET MAXIMUM DEMAND ((In Case of CPP Drawal of 800 MW(peak) and average drawl of 700 MW)	30948	19047
	BILATERAL EXPORT BY DVC (Incl. Bangladesh)	2272	1680
	EXPORT BY WBSEDCL TO SIKKIM	5	4
	EXPORT TO B'DESH & NEPAL OTHER THAN DVC	642	462
	NET TOTAL POWER AVAILABILITY OF ER	28204	17005
	(INCLUDING CS ALLOCATION +BILATERAL+IPP/CPP+HEL)		
	SURPLUS(+)/DEFICIT(-)	-4863	-3702
	SURPLUS(+)/DEFICIT(-) (In Case of CPP Drawal for Odisha)	-5663	-4189