

FLEXIBLE OPERATION OF COAL BASED GENERATING UNITS

- A Strategy for low cost integration of renewable energy into grid

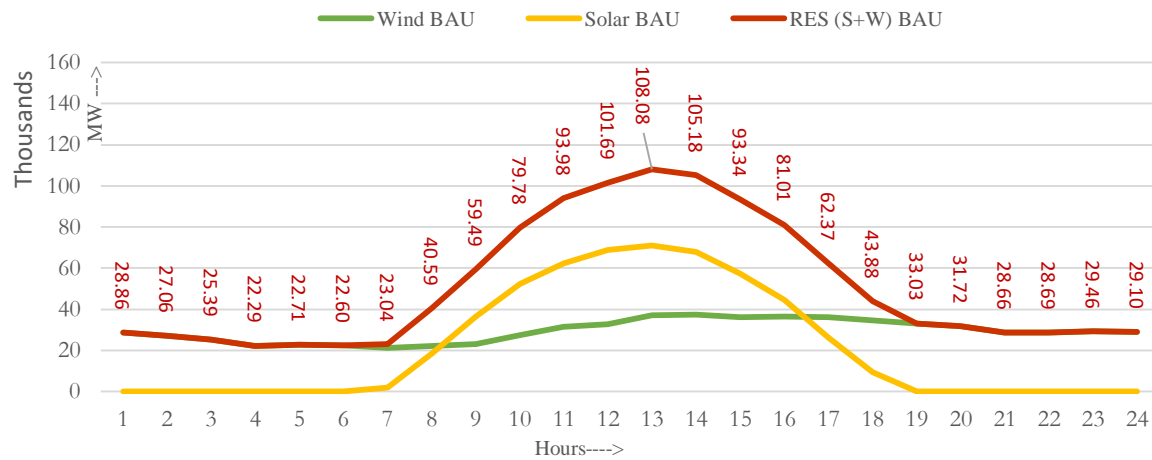
CEA-REPORT,2019-“FLEXIBLE OPERATION OF THERMAL MPOWER PLANTS FOR ITEGRATION OF RENEWABLE GENERATION”

Target 175 GW RES: Target of setting up of 100 GW solar and 60 GW wind capacity by December 2022.

1. Wind power: The wind generation prediction: 15 GW to 37.37 GW (peak)

2. Solar power: Solar generation prediction: Increasing from 0 GW (7 am) to 70.9 GW (1 pm) and decreasing to 0 GW (7 pm)

Solar and Wind capacity (160 GW): 28.86 GW at 1 am decreasing to 23 GW at 7 am, increasing to 108 GW at 1 pm, decreasing to 33 GW at 7 pm, decreasing to 29.1 GW at 12 am



Coal capacity need to be synchronized : 139 GW

(Assumption spinning reserve, APC etc.)

Average min. technical load of coal plants :25.6% (very difficult)

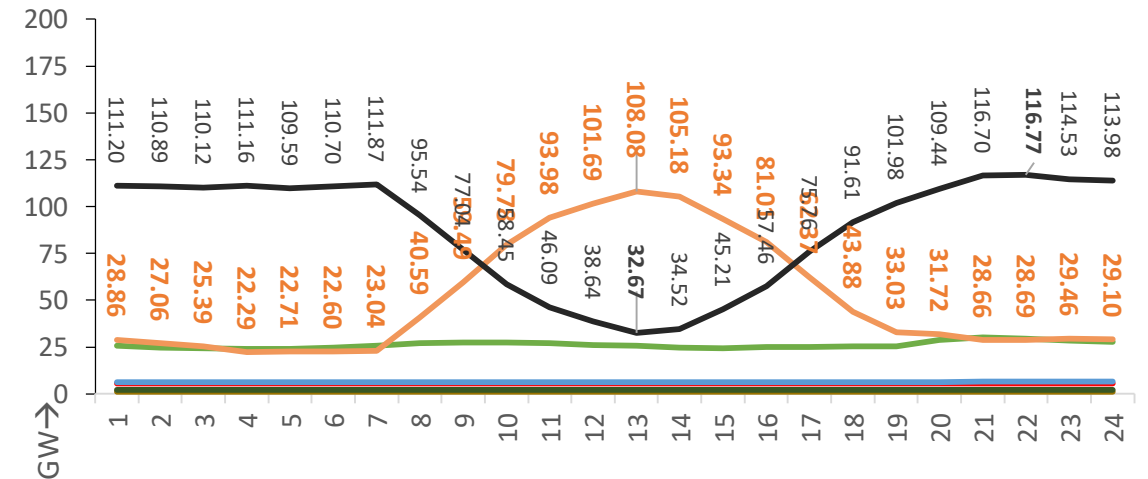
3. All flexing done by Coal

No flexing generation : Gas, Hydro, Nuclear, Small RES

Zero RES Curtailment : Solar and Wind generation

Minimum gen. needed from coal plants: 33 GW (ex-bus)

Maximum gen. needed from coal plants: 117 GW (ex-bus)



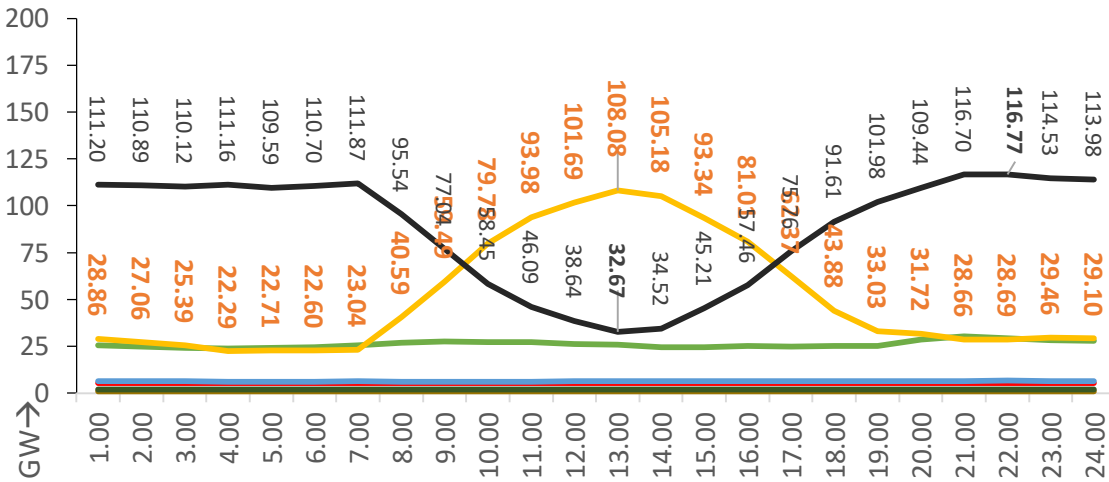
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Minimum Technical Load- On most critical day

Coal flexing alone

Renewable gen. : 108 GW
 Peak thermal **ex-bus/ gross gen.** : 116.7 GW / 139.5 GW
 Min. thermal **ex-bus/ gross gen.** : 32.6 GW / 35.9 GW
 (Assumption spinning reserve = 10%, APC = 8% at peak load and 9% at part load)

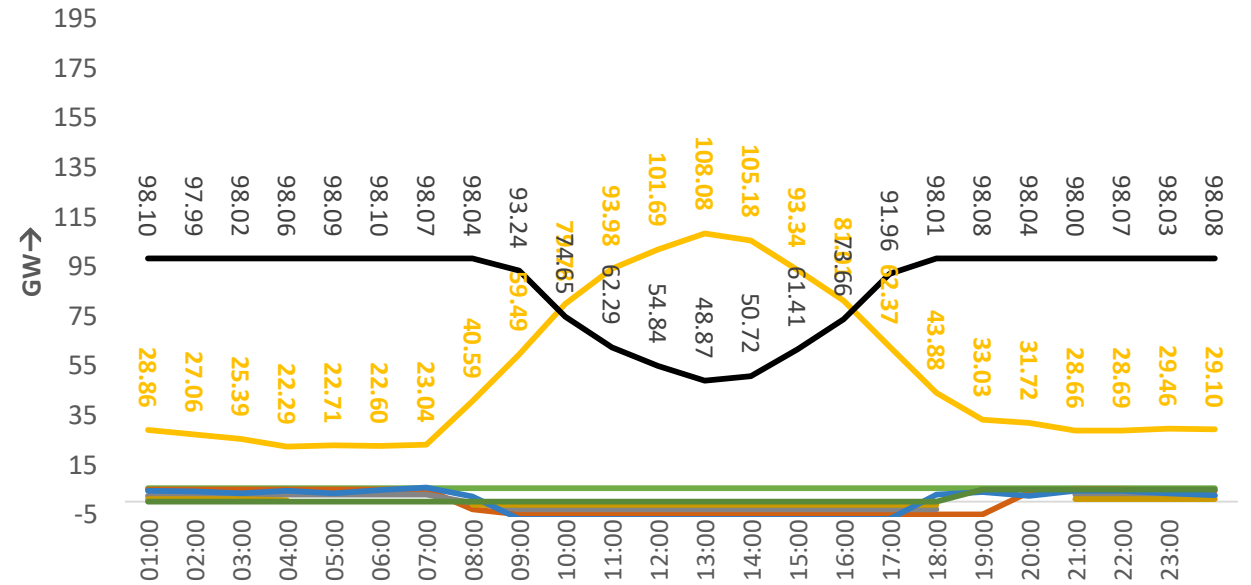
Flexible power required from coal based plants : 84 GW
 Average MTL : 25.7%



Coal flexing along with other resources

Renewable gen. : 108 GW
 Peak thermal **ex-bus/ gross gen.** : 98.07 GW / 117.26 GW
 Min. thermal **ex-bus/ gross gen.** : 48.87 GW / 53.69 GW
 (Assumption spinning reserve = 10%, APC = 8% at peak load and 9% at part load)

Flexible power required from coal based plants : 49 GW
 Average MTL : 45.88%



CEA-REPORT,2019-“FLEXIBLE OPERATION OF THERMAL MPOWER PLANTS FOR ITEGRATION OF RENEWABLE GENERATION”

Critical day–Coal based plants
Operation

Category	Evening Load on each category based on MOD (MW)	No. of units	Average MTL of each category as a whole	ECR range of the category	MTL range of the category
Low Flexible (X)	52380	75	50.00%	0.84 to 2.38	45% to 55%
Flexible (Y)	41890	78	44.00%	1.20 to 2.36	40% to 50%
Very Flexible (Z)	23280	90	40.00%	1.10 to 2.30	35% to 45%
Total	117550	243	45.88%	0.84 to 2.38	45.88%

Maximum flexible power from coal based power plants

Lowering the technical minimum load of 217 GW

70% of available capacity:	152 GW
55% generation (Ex-bus):	76.92 GW (APC 8%)
40% generation: (EX-bus):	55.32 GW (APC 9%)

Additional 21.60 GW flexible power will be available

Lowering the MTL of 217 GW capacity from 55% to 40% shall provide additional **21.60 GW flexible power equivalent to battery storage capacity**

SOLAR AND WIND GENERATION PREDICTION ,2030

Installed capacity: Wind -100 GW, Solar-292 GW

Max. Solar Gen.: 241 GW

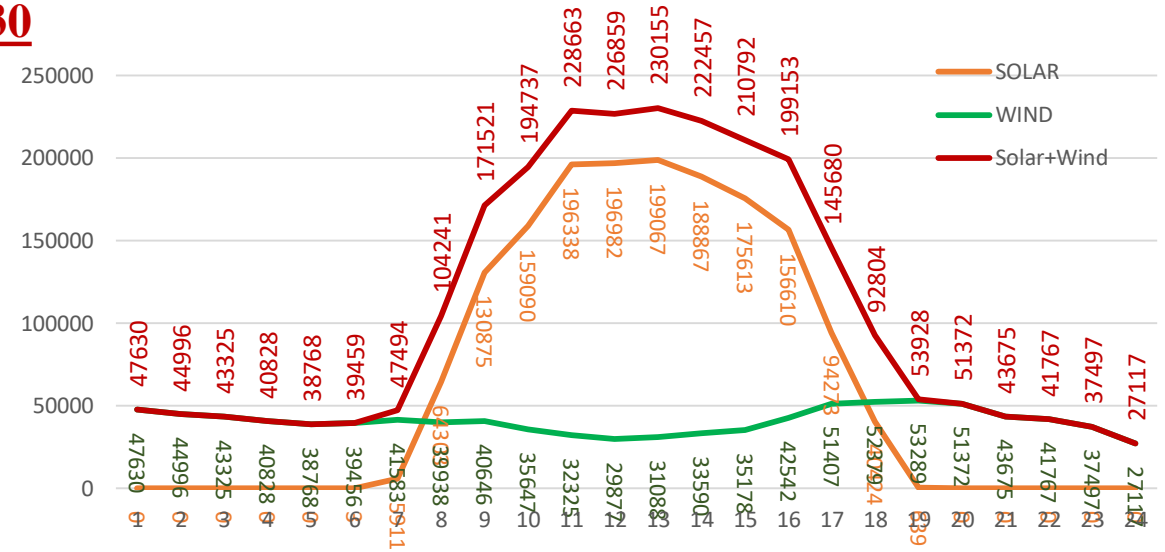
Max. Wind Gen.: 72 GW

Max. Solar + Wind: 247 GW

BSS proposed: 41.65 GW

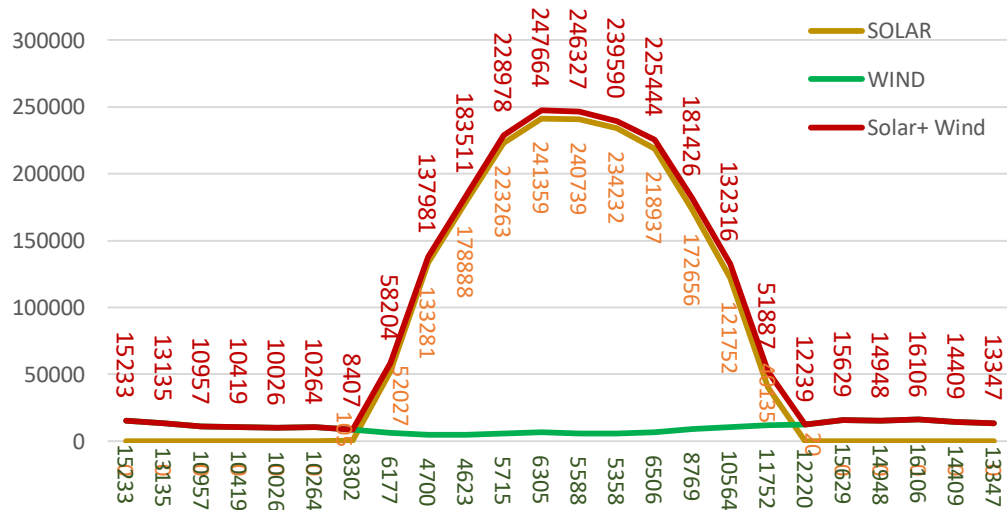
Hydro - 59.22 GW

PSP- 18.98 GW

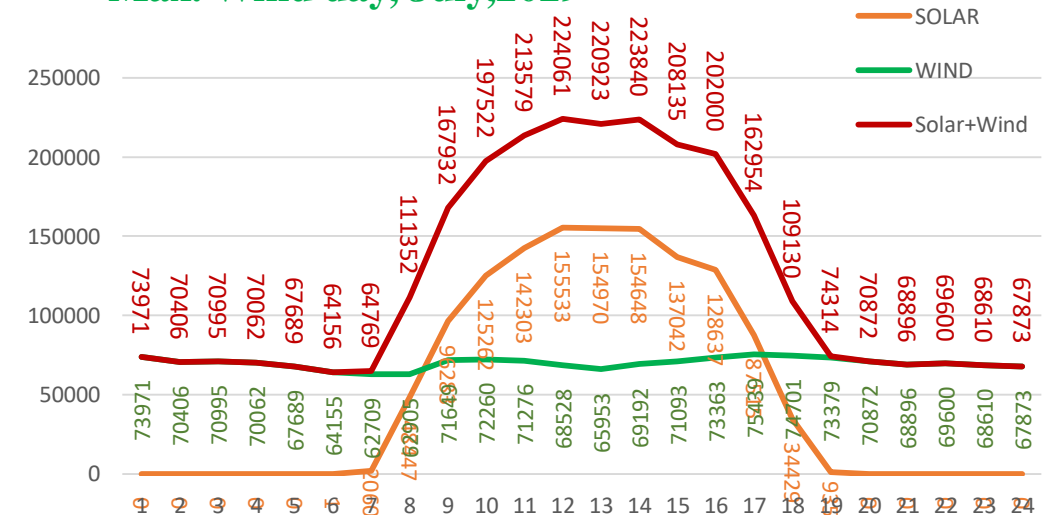


Max. Demand day Solar and Wind Gen., May, 2029

Max. Solar Day, May, 2030



Max. Wind day, July, 2029



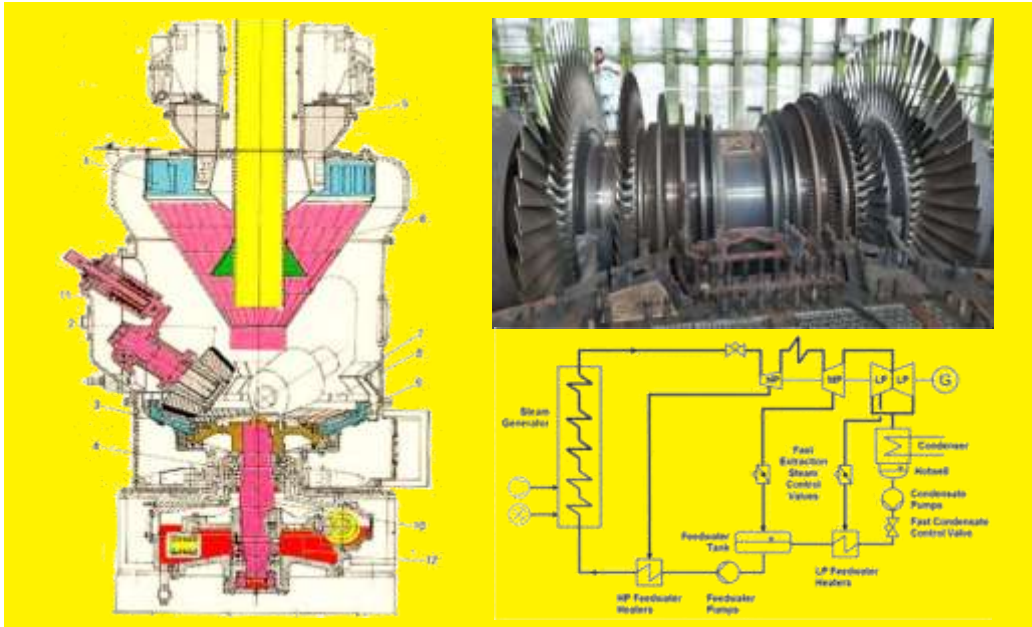


सत्यमेव जयते

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

1. Need for Flexibilisation
2. Key Requirements of Flexibilisation
3. Studies Conducted
4. Challenges of Flexibilisation and Mitigation
5. Procedures for Low Load Tests
6. Modifications Required
7. Cost of Flexible Power
8. Two Shift Operation
9. Flexible Power from Different Sources
10. Roadmap
11. Conclusion & Way Forward

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Sl. no	Name of Plant	Unit Size MW	Unit No.	Utility	Agencies involved	Remarks
1	Dadri TPS	500	2	NTPC	IGEF, BHEL, NTPC,CEA	Conducted in June 2018. Achieved 40% load (2.5 hrs) & 0.86% ramp up and 0.5% ramp down at 40% load
2	Mouda TPS	500	2	NTPC	BHEL, NTPC,CEA	Conducted in May 2019. Achieved 40% load (1hr.) & 0.85% ramp up and 0.9% ramp down
3	Sagardighi TPS	500	3	WBPDC	BHEL, WBPDC, CEA	Conducted in June 2019. Achieved 40% load (1hr.) & 1.1% ramp up and 0.67% ramp down.
4	Ukai TPS	500	6	GSECL	USAID, BHEL, GSECL, CEA	Conducted in March 2020. Achieved 40% load (2.5 hrs) & 1 ramp up and 1.2 ramp down
5	MRB TPS	525	1	MPL	IGEF, BHEL, CEA	Conducted in July,2021. Achieved 40% load & 0.95% ramp up and 0.38% ramp down. 40% load (1hr.)
6	DSTPS	500	1	DVC	IGEF, BHEL, CEA	Conducted in March,22, 40 % achieved (1.5hrs), less than 1% ramp up and ramp down.
7	Ramagundam TPS	500	7	NTPC	DEA, CEA, NTPC	Successfully conducted 27.02.2023 to 02.03.2023, 40% load (2 hrs)
8	Raichur TPS	210	3	KPCL	DEA,CEA, KPCL	Successfully conducted Successfully conducted 27.02.2023 to 02.03.2023, 40% load (2 hrs)

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COMPENSATION METHODOLOGY

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INCREASE IN FIXED COST

- a) Capital Expenditure (CAPEX):** One-time expenditure to be incurred in retrofitting of various measures to make the plant capable of low load operation.
- i. In case of old units (commissioned before 01.01.2004) which have not upgraded their plant control and instrumentation system previously, capex requirement may be around Rs 30 crores for each unit.
 - ii. An estimated capital investment of around Rs 10 crores will be required for each unit commissioned on or after 01.01.2004 and except units covered under para (iii).
 - iii. As per the OEM few measures are required to be implemented for regular 40% load operation of subcritical units though the same (40%) was demonstrated during PG test. Considering above it is proposed a capital investment of Rs.6 crores may be allowed to the subcritical generating units where investment approval received on or after 01.01.2011
 - iv. Unit will be eligible for increased fixed tariff irrespective of actual operation once measures are implemented and exhibits desired low load operation. Considering five (5) years payback period the impact has been estimated.
 - v. Power plant may be penalized proportionally (Fixed cost) for not exhibiting low load operation at least 85% of time when asked for.

Unit Size (MW)	Recovery period (years)	Capital cost (Rs Cr)	Increased in fixed charge per annum (Rs. Cr.)	Capital cost (Rs Cr)	Increased in fixed charge per annum (Rs. Cr.)
200	5	30	7.65	10	2.55
500	5	30	7.65	10	2.55
660	5	30	7.65	10	2.55
800	5	30	7.65	10	2.55

Unit Size (MW)	Recovery period (years)	Capital cost (Rs Cr)	Increased in fixed charge per annum (Rs. Cr.)
200/250	5	6	1.53
500	5	6	1.53
600	5	6	1.53

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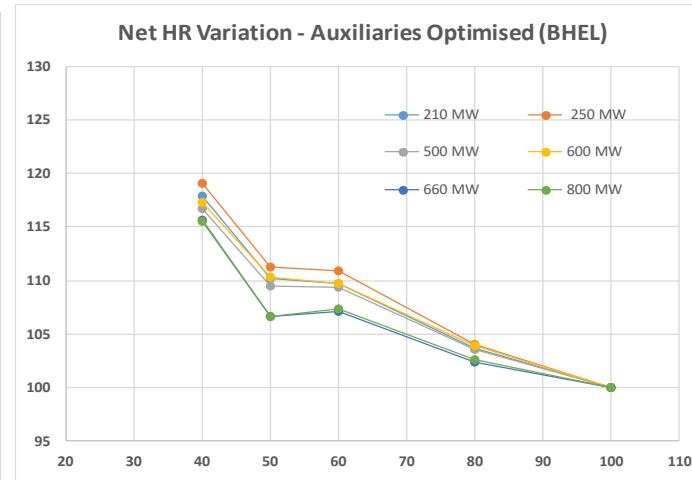
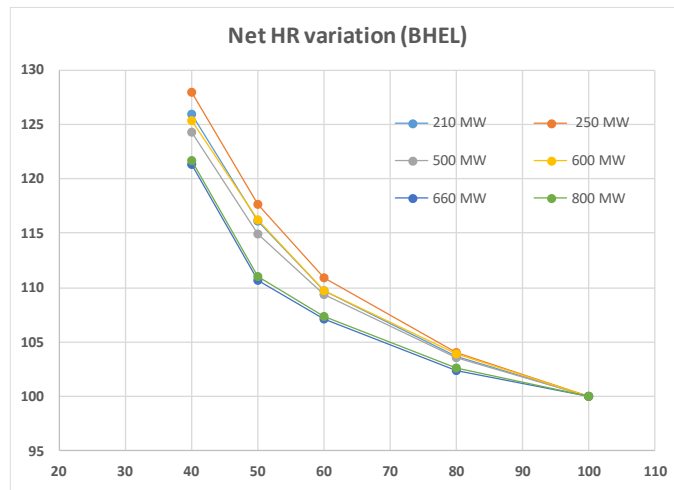
Operational Expenditure (OPEX):

- i. Cost due to increase in Net Heat Rate
- ii. Cost due to Increased Life Consumption (damage costs)
- iii. Cost due to additional oil consumption for additional EFOR

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i). INCREASE HEAT RATE

Heat Balance study



After analyzing the HBD report of major OEMs (BHEL/GE/Siemens) and actual test report of low load operation unit size wise NHR degradation is given in table.

The study conducted by CEA indicates the impact of low load operation at 40% on variable part of tariff is around 16% for subcritical units (200/500MW) and around 15% for supercritical units(660/800MW).

Capacity (MW)	Loading (%)	Net Heat Rate Increase (%)
200	<55 to 50	10.00
	<50 to 45	13.00
	<45 to 40	16.00
500	<55 to 50	10.90
	<50 to 45	13.60
	<45 to 40	16.00
660	<55 to 50	8.70
	<50 to 45	11.90
	<45 to 40	14.60
800	<55 to 50	8.60
	<50 to 45	12.00
	<45 to 40	15.00

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ii). **INCREASED O&M** : Flexible operation also leads to a higher rate of deterioration of plant’s components

i. As flexible operation is new in India no reliable data is available regarding actual life consumption or damaged. In other country also no such assessment has been done as cost of flexible power is being kept under ancillary services and price is market based which may be high or less compared to actual.

ii. USAID-Intertek Study: An estimate of the increase in O&M Cost due to reduction in life of components 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). No two units have the same costs due to variation in factors affecting the costs like coal, age of plant, operating practices, operator’s skill and design.

iii. Engie Lab estimates: the capital expenditures and additional maintenance result in a 0.3% to 4.3% cost impact versus the total costs of a unit. The absolute non-fuel costs over a 10-year period are approximately But this estimate is based on the current level of flexibilization,(55% and above).

iv. Considering above the increase in annual O&M cost has been proposed as 9%, 14% and 20% at 50%, 45%, 40% loading respectively as increase in O&M costs shall depend on level of flexibilisation.

Capacity (MW)	Loading (%)	O&M cost Increase (%)
200	<55 to 50	9.00
	<50 to 45	14.00
	<45 to 40	20.00
500	<55 to 50	9.00
	<50 to 45	14.00
	<45 to 40	20.00
660	<55 to 50	9.00
	<50 to 45	14.00
	<45 to 40	20.00
800	<55 to 50	9.00
	<50 to 45	14.00
	<45 to 40	20.00

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iii). ADDITIONAL OIL CONSUMPTION

Based on the increased EFOR the norms for specific oil consumption and increased compensation may be allowed as per the Table.

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 (40-50% load)	3.5
3	At 0.8 ml/kWh (30-40% load)	4.0

In addition, due to flexible operation there would be loss of availability on account of increased maintenance requirements and increased EFOR which will make it difficult for the generator to recover full capacity charges.

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Likely increase in tariff considering capital investment of Rs. 30 crores, increase of O&M cost, variable cost and EFOR cost

Unit Size (MW)	Loading (%)	Coal price Rs 2000.00 per ton	Coal price Rs 3300.00 per ton	Fixed Tariff increase (Paisa/kWh)		EFOR compensation (Paisa/kWh)	Total tariff (fixed & variable) increase (Paisa/kWh)	Total tariff (fixed & variable) increase (Paisa/kWh)
		Variable Tariff increase (Paisa/kWh)	Variable Tariff increase (Paisa/kWh)	due to increased O&M cost	due to increased capital cost		Coal price Rs 2000.00 per ton	Coal price Rs 3300.00 per ton
200	<55 to 50	13.68	22.57	6.70	7.68	1	29.06	37.95
	<50 to 45	17.78	29.34	10.42	7.68	1	36.88	48.44
	<45 to 40	21.89	36.11	14.88	7.68	1	45.45	59.67
500	<55 to 50	14.66	24.20	4.57	3.07	1	23.30	32.84
	<50 to 45	18.30	30.19	7.11	3.07	1	29.48	41.37
	<45 to 40	21.53	35.52	10.16	3.07	1	35.76	49.75
660	<55 to 50	11.17	18.42	4.12	2.56	1	18.85	26.10
	<50 to 45	15.27	25.20	6.40	2.56	1	25.23	35.16
	<45 to 40	18.74	30.92	9.14	2.56	1	31.44	43.62
800	<55 to 50	10.65	17.57	3.70	1.92	1	17.27	24.19
	<50 to 45	14.86	24.52	5.76	1.92	1	23.54	33.20
	<45 to 40	18.58	30.65	8.23	1.92	1	29.73	41.80

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Likely incremental tariff (RS 10 crores capital investment)

Unit Size (MW)	Loading (%)	Coal price Rs 2000.00 per ton	Coal price Rs 3300.00 per ton	Fixed Tariff increase (Paisa/kWh)		EFOR compensation (Paisa/kWh)	Total tariff (fixed & variable) increase (Paisa/kWh)	Total tariff (fixed & variable) increase (Paisa/kWh)	Proposed total tariff (fixed & variable) increase (Paisa/kWh)
		Variable Tariff increase (Paisa/kWh)	Variable Tariff increase (Paisa/kWh)	Due to increased O&M cost	Due to increased Capital cost		Coal price Rs 2000.00 per ton	Coal price Rs 3300.00 per ton	
200	<55 to 50	13.68	22.57	6.70	2.56	1.00	23.94	32.83	28.39
	<50 to 45	17.78	29.34	10.42	2.56	1.00	31.76	43.32	37.54
	<45 to 40	21.89	36.11	14.88	2.56	1.00	40.33	54.55	47.44
500	<55 to 50	14.66	24.20	4.57	1.02	1.00	21.25	30.79	26.02
	<50 to 45	18.30	30.19	7.11	1.02	1.00	27.43	39.32	33.38
	<45 to 40	21.53	35.52	10.16	1.02	1.00	33.71	47.70	40.71
660	<55 to 50	11.17	18.42	4.12	0.85	1.00	17.14	24.39	20.77
	<50 to 45	15.27	25.20	6.40	0.85	1.00	23.52	33.45	28.49
	<45 to 40	18.74	30.92	9.14	0.85	1.00	29.73	41.91	35.82
800	<55 to 50	10.65	17.57	3.70	0.64	1.00	15.99	22.91	19.45
	<50 to 45	14.86	24.52	5.76	0.64	1.00	22.26	31.92	27.09
	<45 to 40	18.58	30.65	8.23	0.64	1.00	28.45	40.52	34.49

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Likely Incremental Tariff for units where investment approval received on or after 01.01.2011 (Rs 6 crores capital investment)

Unit Size (MW)	Loading (%)	Coal price Rs 2000.00 per ton	Coal price Rs 3300.00 per ton	Fixed Tariff increase (Paisa/kWh)		EFOR compensation (Paisa/kWh)	Total tariff (fixed & variable) increase (Paisa/kWh)	Total tariff (fixed & variable) increase (Paisa/kWh)	Proposed total tariff (fixed & variable) increase (Paisa/kWh)
		Variable Tariff increase (Paisa/kWh)	Variable Tariff increase (Paisa/kWh)	Due to increased O&M cost	Due to increased Capital cost		Coal price Rs 2000.00 per ton	Coal price Rs 3300.00 per ton	
200	<55 to 50	13.68	22.57	6.70	1.54	1	22.92	31.81	27.37
	<50 to 45	17.78	29.34	10.42	1.54	1	30.74	42.30	36.52
	<45 to 40	21.89	36.11	14.88	1.54	1	39.31	53.53	46.42
500	<55 to 50	14.66	24.20	4.57	0.61	1	20.84	30.38	25.61
	<50 to 45	18.30	30.19	7.11	0.61	1	27.02	38.91	32.97
	<45 to 40	21.53	35.52	10.16	0.61	1	33.30	47.29	40.30
660	<55 to 50	11.17	18.42	4.12	0	1	16.29	23.54	19.92
	<50 to 45	15.27	25.20	6.40	0	1	22.67	32.60	27.64
	<45 to 40	18.74	30.92	9.14	0	1	28.88	41.06	34.97
800	<55 to 50	10.65	17.57	3.70	0	1	15.35	22.27	18.81
	<50 to 45	14.86	24.52	5.76	0	1	21.62	31.28	26.45
	<45 to 40	18.58	30.65	8.23	0	1	27.81	39.88	33.85

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ASSUMPTIONS

1. General:
 - i. Average PLF: 60%,
 - ii. PAF: 100%,
 - iii. Debt to equity ratio: 70:30,
 - iv. Return on equity: 15.5%,
 - v. Interest on loan:10%,
 - vi. Depreciation rate:5.28%,
 - vii. Specific oil consumption: 0.5 ml/kWh,
 - viii. Price of oil:- Rs 35/lt,
 - ix. GCV of oil: 10000 kcal/lt,
 - x. GCV of Coal:3800 kcal/kg.
 - xi. Landing cost of coal
 - a) Rs.2000.00 per ton (estimated average cost of coal at pithead plants)
 - b) Rs. 3300.00 per ton (estimated average cost of coal at non-pithead plants)
 - xii. Weighted average cost of capital for annuity calculations : 10%
2. Unit size 200 MW O&M Cost Rs 36.56 lakh/MW, Heat rate 2430 kcal/kWh.
3. Unit size 500 MW O&M Cost Rs 24.97lakh/MW, Heat rate 2390 kcal/kWh
4. Unit size 660 MW OO&M Cost Rs 22.47lakh/MW, Heat rate 2280 kcal/kWh.
5. Unit size 800 MW O&M Cost Rs 20.22 lakh/MW, Heat rate 2200 kcal/kWh

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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.

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.

Case study:

- i) 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.
- ii) Another example of two-shift operation of Tamil Nadu where thermal power plants are operating from 5 pm to 11 am, daily hot startup.

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COMPARISON OF FLEXIBLE POWER

Source of flexible Power:

1. Reallocation of Hydro Generation,
2. Pump Storage,
3. Gas Flexing,
4. Demand Side Management
5. Low Load Operation of Thermal Power Plants,
6. 2-Shift operation
7. Battery Storage System,

Low Load Operation of Thermal Power Plants:

Lowering the technical minimum load of 216 GW

Lowering the technical minimum load of 216 GW capacity from 55% to 40% shall provide additional 24.55 GW flexible power in the grid

Capex = 15 Crore per unit (average)

Total no. of Units = 484

Total investment = 484x15 = 7260 Crore

Battery Storage System:

If we consider 24.55 GW BSS with an average cost of 5.6 Crore/MW, total cost will be more than one lakh thirty thousand crore.

Thus BSS will be costly, imported, having less life about 9-10 years and disposal issues.

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ROADMAP

About 25% thermal capacity is newly commissioned, January 2016 onwards. 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 102 units are brought under the purview of flexibilisation operating regime first.

SUMMARY OF PHASING PLAN

		PILOT PHASE	PHASE I	PHASE II	PHASE III	PHASE IV		Total
			July,2024-Jun,2026	July,2026-Jun,2028	July,2028-Dec,2029	Jan,2030-Dec,2030		
		(40%)	(40%)	(40%)	(40%)	(40%)	2-shifting(age>40 yrs)	
CENTRAL	UNITS	5	28	27	11	43	36	150
	CAPACITY(MW)	2490	17510	11850	4730	16850	9910	63340
STATE	UNITS	4	27	23	34	45	49	182
	CAPACITY(MW)	2760	15910	10480	10590	11810	9915	61465
PRIVATE	UNITS	1	41	65	36	14	4	161
	CAPACITY(MW)	600	20960	31035	12055	6420	862	71932
TOTAL	TOTAL (UNITS)	10	96	115	81	102	89	493
	TOTAL (Capacity)	5850	54380	53365	27375	35080	20687	196737

In the pilot phase, 10 units of central/state/pvt sector commissioned from Jan 2016 to December 2022 shall be taken for refurbishment. 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.

BALL & TUBE	UNITS		34
	CAPACITY(MW)		8950
CFBC	UNITS		54
	CAPACITY(MW)		6001
Opted for 2 shift Operation	UNITS		6
	CAPACITY(MW)		377.5
GRAND TOTAL	UNITS		587
	CAPACITY(MW)		212065.5

Thank You

REGULATION ON TECHNICAL MINIMUM LOAD

CEA has also notified a Regulation regarding Flexible operation of coal based Thermal Power Generating Units on 30.1.2023.

1. The 55% minimum load and 2% ramp rate operating requirement shall have to be implemented by all thermal generating units (Central/State/Pvt) within one year of the notification of the regulation.
2. Power plants shall implement measures, if required, as per the phasing plans by the respective power plants owners to operate thermal unit at 40% minimum load with following ramp rate:
 - 1% per minute - 40% to 55% and 55% to 40% load
 - 2% per minute - 55% to 70% and 70% to 55% load
 - 3% per minute - 70% to 100% and 100% to 70% load