Flexible Power for integration of renewable generation

Solar & Wind capacity (GW)

	As on September, 2019	Expected in Year, 2021-22
Solar	31.10	100
Wind	36.93	60
Biomass	9.95	10
Small hydro	4.61	5
Total	**82.59**	**175**

Statewise renewable capacity (MW) in year,2021-22

State/UTs	Solar Power (MW)	Wind (MW)	SHP (MW)	Biomass	Total
Maharashtra	11926	7600	50	2469	22045
Tamil Nadu	8884	11900	75	649	21508
Andhra Pradesh	9834	8100		543	18477
Gujarat	8020	8800	25	288	17133
Karnataka	5697	6200	1500	1420	14817
Rajasthan	5762	8600			14362
Uttar Pradesh	10697		25	3499	14221
Madhya Pradesh	5675	6200	25	118	12018
West Bengal	5336		50		5386
Punjab	4772		50	244	5066
Haryana	4142		25	209	4376

Installed capacity

	As on 30.09.2019		As on 31.03.2022		As on 31.03.2030	
	(GW)	(%)	(GW)	(%)	(GW)	(%)
Thermal:	203.0	56.00	217.0	**45.30**	266.8	**32.1**
Hydro:	45.0	12.45	51.0	10.65	73.4	8.8
Gas:	25.0	6.90	26.0	5.43	25.0	3.0
Nuclear:	6.8	1.87	10.0	2.09	16.8	2.0
Renewable:	82.5	22.78	175.0	**36.53**	450.0	**54.1**
Total:	362.30	100.00	479.00	100.00	832.00	100.00

Demand & Generation Analysis

Year,2021-22

Hourly Generation prediction, year,2021-22

1. **Solar, Wind, Nuclear & Hydro:** The generation of Solar, Wind, Nuclear & Hydro are predicted on the basis of their past generation trend and the capacity considered in the year 2021-22.

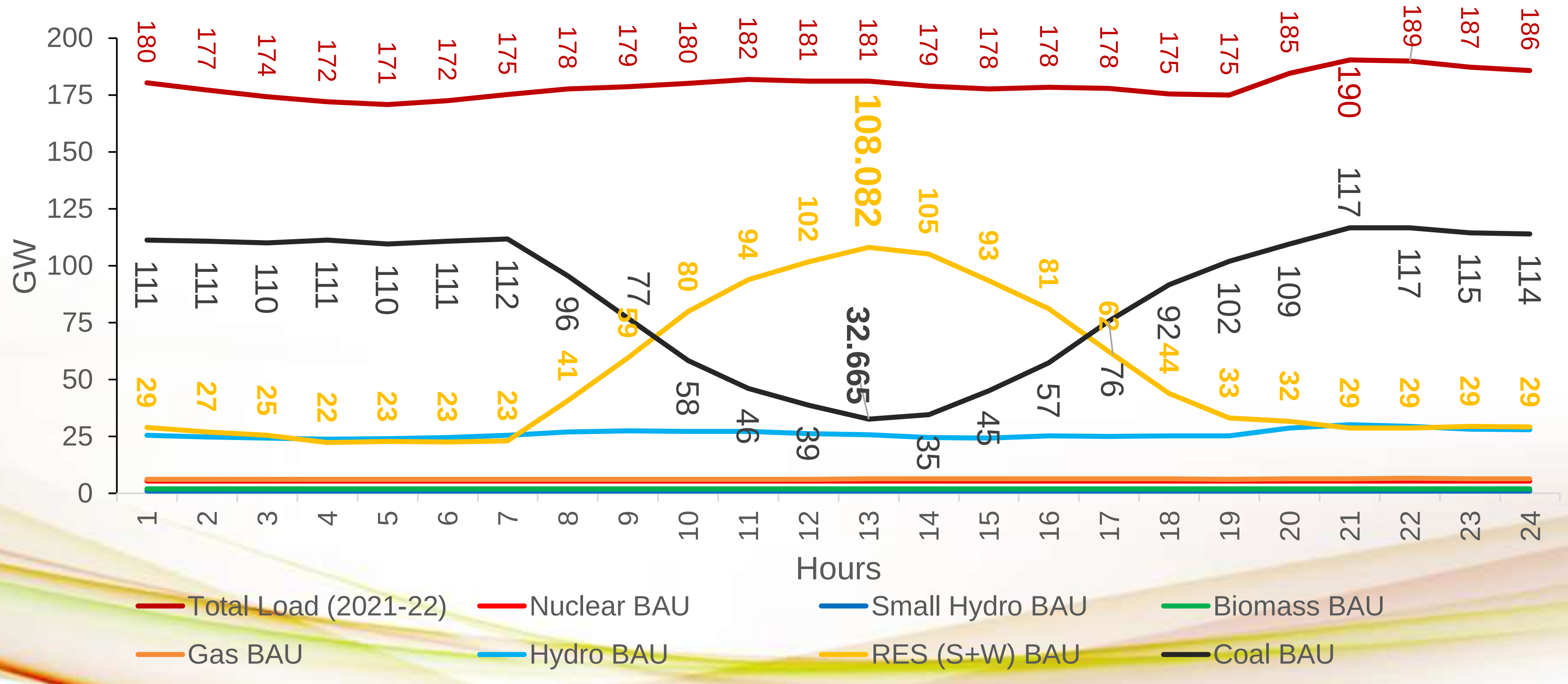
2. **Gas:** The gas generation data has been taken from CEA.

3. **Small Hydro, Biomass:** Since no reliable data is available for these small renewable sources, straight line assumptions has been used. Small Hydro is taken as 1000 MW and Biomass as 2000 MW as constant values.

4. **Demand**: The national electricity demand for the year 2021-22 has been collected from 19th EPS, CEA

5. **Coal:** It is calculated figure. Added hourly generation of all generation sources except coal and subtracted from hourly demand and the result is the required hourly generation from coal.

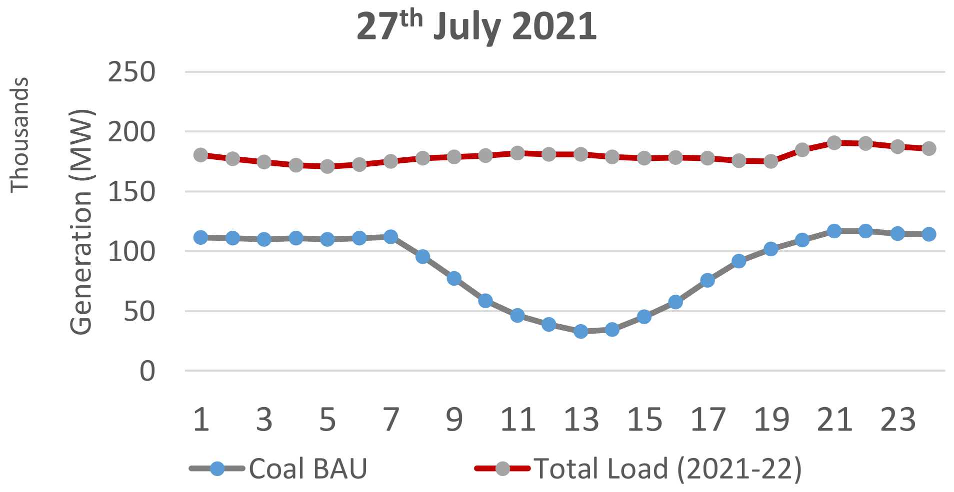
Demand & Generation on the day 27th July,2021



MTL on significant days

S.No.	Day	Date	Max Total Demand	Max RES Generation	MTL	Max. Ramp Rate (MW/min)
1	Highest Demand Day	7th October 2021	225751	52421	62.65%	-216
2	Lowest Demand Day	13th March 2022	185585	74684.5	48.21%	-422
3	Highest RE Day	1st July 2021	201723	108926	33.39%	-332
4	Highest Ramp Down Day	13th March 2022	185585	74684	48.21%	-422
5	Highest Ramp Up Day	3rd Feb 2022	200364	74701	53.02%	379
6	Lowest MTL Day	27th July 2021	190480	108082	25.73%	-310

Ramp Rate - Requirement



Ramp Rate:
-310 MW/min. at 900 hrs.
+305 MW/min. at 1600 hrs.

Ex-bus generation of TPP: 117 GW
139 GW thermal capacity on Bar
Ramp capability: 1390 MW/min

The highest ramp down: - 422 MW/min. 13th Mar,2022
Ex-bus generation of TPP: 140 GW,
Thermal capacity to be synchronized: 167 GW.
Ramp capability: 1670 MW/min.

The highest ramp up: 379 MW/min. 3rd Feb,2022
Ex-bus generation of TPP: 154 GW,
Thermal capacity to be synchronized: 184 GW.
Ramp capability: 1840 MW/min.

Renewal generation integration into grid

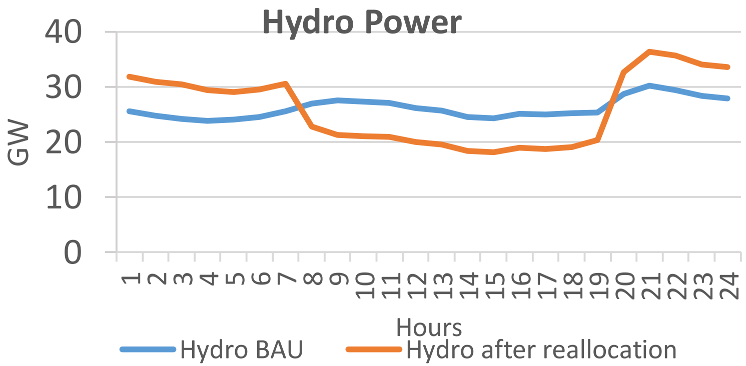
Most critical day	:	27th July,2021
Renewable gen.	:	108 GW
Peak thermal ex-bus/ gross gen.	:	116.7 GW / 139.5 GW
Min. thermal ex-bus/gross gen.	:	32.6 GW / 35.9 GW
Average MTL	:	25.7%
Flexible power required	:	39 GW (considering 55% MTL)

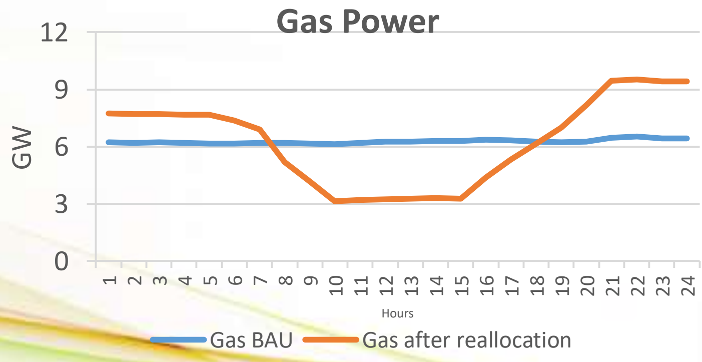
Coordinated Effort

- Step I: Hydro & Gas Reallocation
- Step II: Two Shift Operation of Thermal units+ Pump/ Battery Storage

Step 1: Hydro, PS Flexing &Gas Flexing

- Additional **6200 MW hydro gen. flexing including 4785 MW running & 1205 MW of under construction PS.**
- Regulatory intervention is proposed for:
  - **Lucrative tariff /incentives**
  - **Revision of grid code,**
  - **Implementation of 2-part tariff**



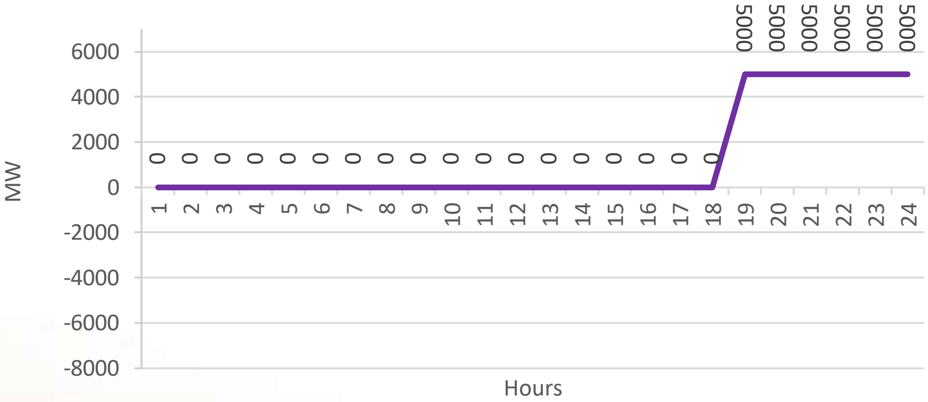


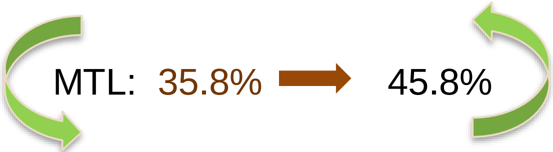
Gas plants do not flex much as of today, we need **3000 MW generation flexibility** from Gas plant by start/stop

MTL: 25.7% → 35.8%

Step 2: Two shift Operation of thermal units & Battery/PS

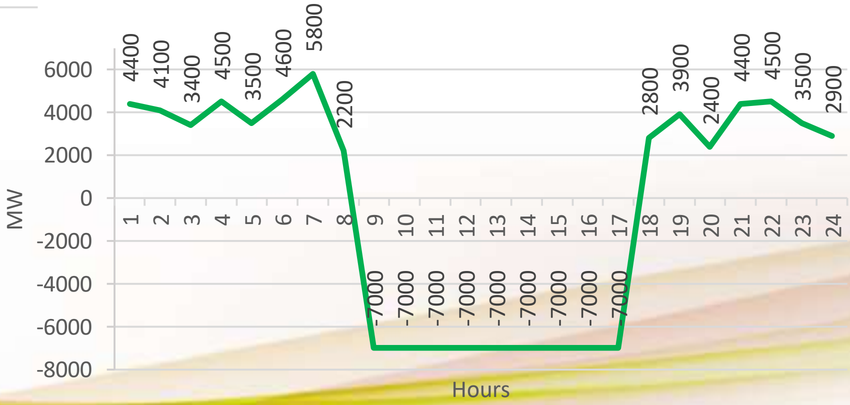
a) Two shift Operation of thermal units





Peak thermal: Ex-bus 98 GW
capacity on bar: 117 GW

b) Battery/PS



Step III: Demand side Management

Demand Side Management

Demand-Side Management (DSM) refers to initiatives that help end-users to optimize their energy use. With DSM, consumers can reduce their electricity costs by adjusting their time and quantity of use. Following measures are expected to contribute in improving the flexible power scenario from the demand side.

1. Time of Day Tariff,
2. Open Electricity Market,
3. Demand response from High Voltage industrial consumers,
4. Supply of electricity to agriculture sector by dedicated feeders**,**
   - Agricultural consumption = 173185 MU
   - Agricultural consumption = 17.30 %
   - Connected load = 108834529 kW
   - Nos. of consumers = 20918824

   2000 MW load is shifted from night hours to peak solar gen. hour it will improve 2% MTL.

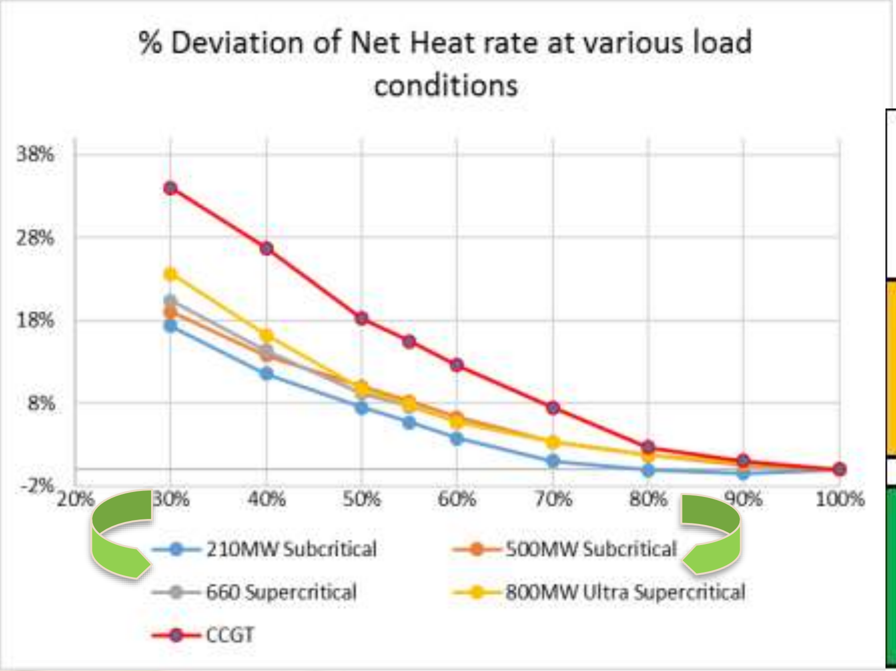
5. Charging of Electric vehicle when solar generation is available – this will also improve MTL.

Balancing of Grid

- The installed capacity of renewables may vary from one state to another state.
- The State like Maharashtra, Tamil Nadu, Andhra Pradesh, Gujrat, Karnataka, Rajasthan, have huge capacity of renewable and they need large amount of flexible power.
- On the other hand, many states have small capacity of renewables and practically they need small amount of flexible power.
- Thus, the requirement of additional flexible power of RE rich states can easily be met from surplus flexible power available in other states.
- Thus, curtailment of renewable generation can be avoided in RE rich state if their system balancing is done with the support from other states.

Identification of thermal units for flexible operation

1. Increase in tariff due to increase in Net Heat Rate



2. Life Consumption reflected in increased O&M cost

MW	Event	O&M Cost (INR-Lakh)			% Addl. / event
		Per Event	Per MW	Per MW (Current level) As allowed by CERC 2017	
200	Cold Start	91.3	0.46	28.70	1.59%
	Warm Start	51.4	0.26		0.90%
	Hot Start	38.0	0.19		0.66%
	Significant load following	0.5	0.01		0.01%
500	Cold Start	262.2	0.52	19.22	2.73%
	Warm Start	151.6	0.30		1.58%
	Hot Start	123.0	0.25		1.28%
	Significant load following	2.7	0.01		0.03%

Pilot test

Test/study conducted

1. Dadri, 500 MW unit# 6, NTPC
2. Mouda, 500 MW unit# 2, NTPC
3. Sagardighi, 500 MW unit# 3 , WBPDCL
4. Vindhyachal,500 MW unit# 11, NTPC
5. Anpara B, 500 MW unit# 4 & 5, UPRVNL

Measures Identified

- Thermo-Mechanical Assessment
- Condition Monitoring
- Fine tuning of Existing CMC Logic
- Steam temperature Controls
- Flue Gas Temperature Controls
- Fuel firing system optimization
- Automatic startup & shutdown of Mills
- BFP Operation at Low Load
- Primary Frequency Control
- Turbine Blade Vibration Monitoring

Regulatory intervention

1. Capex: Implementation of measures for flexible operation

   Capex: actual basis after examination

1. Opex:

- Increase in Net Heat Rate at low load
- Life Consumption reflected in increased O&M cost

Opex: benchmarked costs (compensation) + markup (incentivisation)

Conclusion

1. Balancing shall be done at national level which will reduce the total required balancing power.
2. Hydro power plants are especially suitable for quick supply of flexible generation. Coordination with state owned hydro plants would play an important role in re-allocation of hydro generation. Pumped storage, existing and under construction, shall be used exclusively for peaking or balancing of system. To make the peak hour's generation lucrative provision of two-part tariff and revision of grid code are suggested. Regulatory intervention is required.

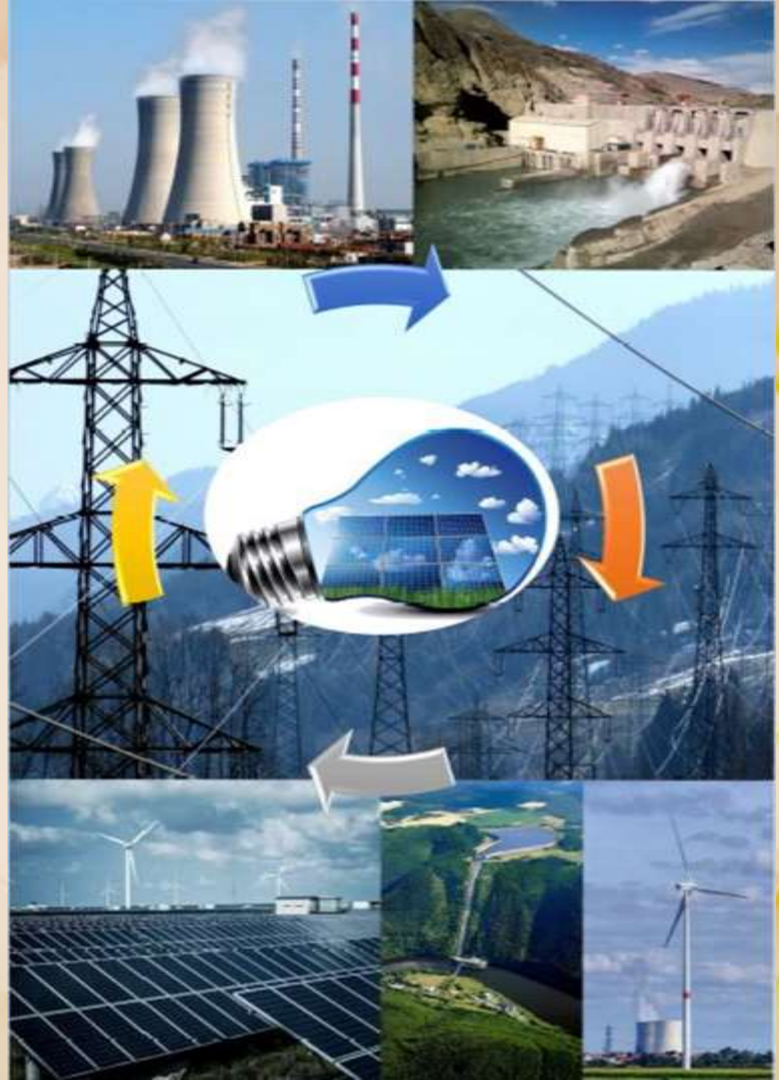
3. Gas power plants have better start stop capability.
4. Establishment of pump or battery storage or combination of both at strategic locations may be explored for energy storage during high solar generation period and utilizing the same during peak demand hours or at the time of need.

5. 210 MW & 500 MW units shall be operated at lower MTL than bigger size unit.
6. Among the fleet of 200 MW, 500/600 MW or 660/800 MW thermal units, which are efficient and have low ECR, should be given preference over other units in terms of generation schedule.

7. Pilot study of thermal units for operation at low load shall be conducted before implementation of measures for flexible operation as the measures are plant specific.
8. Several measures need to be undertaken to make the plants capable of low load operation, (i) Capex to be reimbursed on actual basis after examination, (ii) Opex -based on a benchmarked costs (compensation) + markup (incentivisation). Regulatory intervention is required
9. Capacity building of coal fired power plant operators becomes an important measure in the changing operational regime.

10. Demand side management including measure targeted at domestic, agricultural, industrial and e-mobility sector would enable more rational consumption pattern of electricity.

Thank You



A Scheduling Case Study

Scheduling in flexible regime with all India Merit Order Dispatch based on ECR

Factors considered for selection of a thermal unit:

1. Unit heat rate
2. Load centre unit
3. Pit head unit
4. Old units
5. New units
6. Merit Order/ ECR
7. Super critical/ Sub-critical
8. Size of unit

Categorization of units

Symbol	Category	Capacity Range	Capacity	No. of units
X	Base Load	660 to 800 MW	68160	98
Y	Flexible	490 to 600 MW	70770	133
Z	Very Flexible	195 to 360 MW	67640	285
TSO	Two shift operation	< 151 MW	10564	110
	Total		217134	626

27th July with Step 1 & 2

1	2	3	4	5	6
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
x	52380	75	50.00%	0.84 to 2.38	45% to 55%
y	41890	78	44.00%	1.20 to 2.36	40% to 50%
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%

Units having higher ECR are proposed to run at lower loads than units having lower ECR within the same category.