Flexible And Part Load Operation & Strategies Of Coal Based Units W.R.T Growing Renewable Power

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Abstract

Generation sector in India is in the midst of a paradigm shift – one which has never been seen before in India. Govt of India has announced massive plan for renewable energy – 100 GW from Solar and 60 GW from Wind by 2022. Moreover, all these renewable plants have been classified as 'must run' plant. The consequence is the base load fossil fired power plant shall be forced to operate in cyclic manner and with frequent shut downs. Also, most of the fossil fired plants are forced to operate at part load for sustained period. This has serious implications for life and robustness of performance of our energy generation assets requiring in depth research and development.

This also calls for new developments at the 3 power system level. Apart from adequate storage capacity in the system, capability to ensure regulation and stability of the power system would be a serious challenge. Working together of centralized and decentralized generation with a sizeable capacity located at the user end is also a new paradigm we must prepare for. All these indicate that we are at the cusp of a new age where we will have to devise technologies and strategies to extract maximum from both renewable as well as conventional plant in a sustainable manner. Apart from development at system level, we need to focus on components and equipment level also.

NTPC needs to strategize and realign its focus over the next 5-10 years with the sector dynamics changing—environment and climate change commitments, energy mix and renewable getting played up, regulatory scrutiny and performance-linked regulations, customers demanding flexible tariff structures and retail competition in the offing. The landscape will surely change. Dependence on regulated returns and taking up non-economic activities which reduce managerial bandwidth may not be useful going forward.

Also, as part of the government's green energy push, NTPC plans to supply electricity from 10,000 MW of solar power capacity that it is setting up on its own at Rs.3.20 per unit by bundling it with unallocated power to bring tariffs down. In addition, there are plans to sell electricity at around Rs.5 per unit for 15,000MW that it is buying on behalf of the ministry of new and renewable energy and earn 7 paise per unit in return.

This paper will focus on all the challenges and strategies to operate NTPC thermal units in the coming dynamic scenario of Indian power sector in near future.

Introduction

Coal-fired power plants are required to balance power grids by compensating for the intermittent electricity supply available from ever increasing renewable energy sources in country. High flexibility is needed to achieving frequent start-ups, meeting major and rapid load changes, and providing frequency control duties. The effect will be to force coal units to become swing suppliers, since they have to deliver widely varying output so that total system supply matches load at all times. Also, they are required to provide frequency control for grids because renewable power sources tend to be less well-suited to such duty.

The expectation is that the challenges presented by this situation will only increase and become more widespread in the future, which will impact both on existing plants through retrofit requirements and on new plant through significant design modifications. In such a scenario in India there much is to be done to establish a viable grid system and dispatch method that can best handle large quantities of intermittent renewable power through the inclusion of coal based systems.

In India as power demand is not increasing at par with capacity addition, coal based power producers are forced to cut down their generation. Capacity addition in the form of solar and wind power are placing additional pressure on thermal power plants to follow load. Thermal power plants which were originally designed to operate as base load units are asked to back down to meet grid requirements. However, when coal-fired plants operate in part load, heat rate and auxiliary power increases, leading to increased cost of generation.

Therefore to stay competitive, optimization of operation and maintenance practices has become essential. This paper presents operation strategy that would reduce cost of generation at low load factor while complying with stringent environment norms.

660 MW units, design to operate with sliding pressure operation mode, has advantage of having better efficiency and heat even at part load operation. What could be a strategy for part load operation. Sipat 660 MW experience is given below.

SIPAT STAGE-I (3X660 MW) UNIT#1, UNIT#2 AND UNIT#3

STRATEGY TO OPERATE 660 MW SIPAT AT LESS THAN TECHNICAL MINIMUM SG

Case I: **FOR SG > 1120 MW**

Effort should be made to run all 3 units at > 396 MW load without oil support. Ensure that scanners are sensing good flame. Both TDBFP in service. 5 mill in service.

Case II: FOR 800 < SG < 1120 MW
Run one unit at around 250 to 280 MW with oil support (CD or EF elevation, HFO Pr. - 8.5 ksc),
4 consecutive mills (C, D, E, F), both TDBFP in service. Other two units at around 280 MW or more as required without oil support, 4 mills in service (5 mills if required) & both TDBFP in service.
Case III: FOR SG < 800 MW
Run all 3 units at around -260-280 MW with oil support (CD or EF elevation, HFO Pr. - 8.5 ksc), 4 consecutive mills (C, D, E, F), both TDBFP in service.

Case IV: SG FURTHER LOW
One of the unit may be taken to wet mode and may taken under reserve shut down for a period depending on the prevailing grid conditions and techno economic operation of the 660 Mw unit.
Following precautions to be taken at low load operation of units:-

- Keep APH soot blowers in service continuously until oil support is withdrawn.
- In case of any mill tripping take oil support at two elevations CD and EF.
- Ensure Scanner healthiness.
- In case of low flame intensity of scanners, take oil support and inform all concerned people.
- MDBFP to be taken in-service if TDBFPs are not stable at any load. However effort should be made to manage load with both TDBFPs only.
- Maintain average of Flue gas outlet temperature to APH > 90^{0}C (SCAPH may be charged).

Note: ID Fan 3A blade pitch is not increasing >56% and it is going is stalling zone when ID Fan 3B blade pitch is >81 %. ID/PA Fan limitation ,if any, to be kept in mind while load variation is there.

This is one of the example of managing part load in a particular station in today's scenario of thermal and renewable mix where renewable is not big part grid yet. In future where renewable is going to be a big part of Indian grid system also what could be the strategies and challenges that are to be build up.

What Could be The Varying Operating Conditions and how Efficiency can be Managed:

Sl. No.	Unit load	Operating condition	Equipment/system operation	Plant efficiency	Probable time of the day
1.	>90±10% TMCR	Near full load (white zone)	At or near base load condition	Close to design efficiency	Morning & evening peak
2.	70±10% TMCR	Green zone	Optimization of no. of mills, ESP pass isolation if environmental	Can be optimized	Daytime & evening

			parameters within permissible limits		
3	50±10% TMCR	Yellow zone	Single set of auxiliaries with TDBFP in operation	Can be optimized	Daytime & evening
4	30-40% TMCR	Red zone	MDBFP In service, No oil support required	Can be optimized	Night and weekends
5	< 30% TMCR	Near start up condition (black zone)	One or more units to be kept under reserve shutdown	Short shutdown jobs to improve efficiency and reliability	Night and weekends

Based on the above table, we have divided the unit operation into five zones. Significance of this subdivision is as follows:

1. When unit load > 90±10% TMCR:

This is base load operation of unit where unit can be operated at rated parameters. Best coal available in the plant is to be used during operation so that net unit heat rate is minimum.

2. When unit load 70±10% TMCR:

Sliding pressure operation is to be adopted followed by reducing one mill in service.

3. When unit load 50±10% TMCR:

One set of auxiliaries such as FD, ID, ACW and ECW are to be taken out of service, preventive/breakdown maintenance such as TDBFP recirculation valve/NRV passing can be carried out. Condenser backwashing / back flushing to be done to improve vacuum. For prolonged low load operation, one TDBFP and one CW pump (in case of more than one units CW pumps operating in parallel) can be stopped. No of CT fans to be stopped will depend on ambient condition and condenser performance.

4. When unit load 30-40% TMCR:

MDBFP is to be taken I/S. This operation is feasible for short duration and it is beneficial to take one or more units in reserve shutdown with at least one unit in service. Worst quality coal available to be fed.

5. When unit load < 30% TMCR:

It is always advisable to take unit in reserve shutdown rather than operating with oil gun I/S. APH hot water washing and seal setting to be done during reserve shutdown if time permits.

CHALLANGES OF FAST LOAD CHANGE AND LOW LOAD OPERATION:

The operation of large scale power plants has to face the continuously tightening regulations and satisfy more and more demanding performance requirements; either it is defined by a single customer or an electric grid operator. These extended operation modes and challenges involve:

a) Increased operational range by decreasing the minimum achievable load level without boiler or turbine trip (This has emerged due to Fluctuations in supply because of must run renewable power sources creeping into the grid)

b) capability to change load level frequently and in a fast manner within as wide range of load level as possible

c) Primary frequency control requires extremely fast-changing output capability (for example approximately 1% of rated load per second, although it is needed only over short periods of time).

d) Satisfying emissions limitations at steady-state operation and during the transient response, too.

In order to achieve these goals – from systems engineering point of view – the dynamic response of the large power plants has to be improved. It requires flexible operation from the firing system, the water-steam system, the turbine system as well as the emission removal system. Increasing dynamic performance also results in faster and larger changes in pressure and temperature conditions, therefore larger attention must be given to the potential detrimental effect on pressure components.

The challenge is even more complex since not only the new, green field plants have to be designed up to these requirements, but also the existing ones – which are fundamentally designed for constant load operation – have to meet the new requirements.

Growing capacity of renewable energy plants around the world and the effects of their intermittent and highly variable output on the operation of coal-fired plants. In the absence of sufficient large-scale electricity storage capability, the effect has been to force coal (and gas) fired units in some countries to deliver greatly varying output to enable the grid system to meet load at all times. The challenges presented by this situation will only increase and become more widespread in the future.

Table 1 Some design and reported plant load ramp rates for coal-fired units (Lindsay and Dragoon, 2010)

		Ramp rate, %/min	
Subcritical	Design	3–5	
Supercritical	Design	7–8	
Reported (EPRI)		Average	Maximum
Subcritical	180 MW	1.8	3.6
	300 MW	2.0	3.1
	420 MW	1.1	2.9
	540 MW	1.7	2.8
	660 MW	1.3	3.7
Supercritical	420 MW	1.3	4.3
	540 MW	1.1	3.6
	660 MW	1.2	2.0
	780 MW	0.9	3.5
	900 MW	1.0	2.0

EPRI data (from IEA Clean Coal Centre – Increasing the flexibility of coal-fired power plants) shows that there is considerable differences between maximum and average plant ramping rates for supercritical plants, probably indicating a desire to limit plant wear, although there may be other influencing factors.

Table 2 Flexibility features of power plants (Domenichini and others, 2013)

	Turndown	Cycling capability, start-up to full load	Ramp rate
USC PCC	Minimum boiler load: 25–30%	Very hot start-up: <1h Hot start-up: 1.5–2.5 h Warm start-up: 3-5 h Cold start-up: 6-7 h	30-50% load: 2–3%/min 50-90% load: 4–8%/min 90-100% load: 3–5%/min
IGCC	Minimum environmental GT load: 60%. Process unit/air separation unit (ASU) cold box minimum load: 50%. ASU compressor minimum load: 70%	Cold start-up: 80-90 h Gasification hot start-up: 6-8 h ASU hot start-up: 6 h	Gasification ramp rate: 3–5%/min ASU ramp rate: 3%/min

Flexibility characteristics of modern USC PCC and IGCC plants is (extracted from a table in a paper based on a study by Foster-Wheeler for the IEA Greenhouse Gas R&D Programme). From the above review that units can be supplied that can provide higher ramp rates than might commonly be supposed.

Power grids have to maintain their alternating current frequency within defined limits. The synchronous capacity (coal, gas and nuclear) on a grid forms an inertial mass that provides a natural resistance to changes in that frequency when step changes in load or generator trips occur. However, the system also has to have active support to re-match supply to demand within seconds so that the system frequency can be quickly restored after it has begun to change. This primary frequency support function is provided by requiring some plants to be designed and operated in a manner to allow the supply of increased or reduced power on a very short-term reactive basis.

Apart from these higher level challenges ,presently there are other small challenges which are also needs to be taken up for gearing up to the new grid environment

1. FW Flow control: At low load operation, flow control by TDBFP becomes difficult due to low extraction pressure and simultaneous opening of both TDBFP recirculation valve. As such when load is reduced below 350 MW, alternate source of steam from MS TDBFP PRDS to be charged at 15 ksc pressure. Before charging steam from MS, extraction line drains to be kept open and steam temp at 4500C to be ensured before changeover. Also One TDBFP R/C to be opened at 350 MW load and second one at 300 MW for smooth control of FW flow. FW flow may be increased by DT control during opening of R/C valve and thereafter DT controller should be kept in AUTO.

DT set point biasing to be given to maintain MS temp at 5400C, SH spray flow minimum considering metal temp limit and no rise in separator level.

2. Water wall temp control: DT should be kept minimum such that separator level does not rise. Higher burner tilt operation so that average flame height is increased. Maintaining high furnace to WB DP by excess air control to reduce water wall heat flux in the combustion zone. Switchover from CMC to TF2 mode as per requirement. Ramp down rate to be restricted to 3MW/min with frequency influence kept OFF.

3. SH & RH metal temp excursion : Lower consecutive mills to be kept in service. Metal temp excursion to be controlled by SH & RH spray. Due to reduced pressure of TDBFP, spray flow may become saturated. Also Left and Right Temp imbalance becomes high and it becomes difficult to maintain rated parameters. The situation becomes more difficult if sp. coal is less than 0.6 and condenser vacuum is very good. Under these conditions, it is very essential that flame scanners are kept healthy to prevent spurious

tripping. 3 out of 4 oil guns in one elevation to be taken in service if load < 300 MW and charging APH cold end soot blowing. Also throttle pressure to be increased to contain metal temp excursion. Water wall soot blowing to be avoided during low load operation of unit.

4. APH FG O/L temp : If PAPH FG O/L temp cannot be maintained even after throttling SAPH FG O/L dampers, then SCAPH to be charged if ACET <900C. This will prevent acid dew point corrosion and choking of APH baskets.

5. DRY to WET changeover : Below 200 MW load it becomes difficult to control separator level and metal temp excursion. Therefore changing to be done from FW control mode to separator level control mode with gradual increase in set point. After fulfilling wet mode criteria, BRP must be taken in service. FRS 30% line may be taken in service as per requirement.

OPTIONS FOR ACHIEVING FELXIBLE OPERATION OF THE UNITS

a) De-aerator level controller throttling and sudden load raising (study under going at NTPC Dadri)

b) Sudden load raising with the turbine bypass valve

c) HPH bypassing for a short time

These are some of the options by which sudden load raising requirement of the units can be achieved during the flexible operational requirements of the grid. But positive actions may have some negatives associated with it. There are many detrimental effects which are associated with load variation and part loading of the base load thermal units. Some of the detrimental effects are described here.

FLEXIBLE OPERATION: DETRIMENTAL EFFECTS

Affected components:

- High pressure and high temp components:
- Boiler and turbine (maximum adverse effect)
- Auxiliary system
- Emission control system

Principal mechanism for damage in base load plant

- Creep

Cyclic loading:

- Fatigue - thermal & mechanical
- Corrosion
- Creep fatigue interaction
- Differential expansion

The interaction of creep and fatigue effects shortens life in components like turbine, boiler header & other thick walled components.
The residual life sometimes is reduced to 40-60% of original design life

CONCLUSION:

Requirement for increased operational flexibility, especially load following capability, has been increased in the past few years. This is mainly due to the growing need participating in grid frequency control balancing the intermittent energy production based on renewable energy sources. However, it looks obvious that in the future even more flexibility is required.

Normal power plant operation over time results in creep damage to high temperature and pressure components, but flexible operation introduces thermal and mechanical fatigue stresses also. These, together with corrosion, differential expansion, and other effects, often with synergisms, result in a reduction of the expected life of the pressure parts. The residual fatigue-related life of the equipment can be calculated approximately by taking into account the effects of the different types of stress encountered. Many other parts of plants can be affected by plant cycling in the form of either reduction in life, performance or energy efficiency. These include auxiliary systems and emissions control systems. Means to counter these difficulties have been, and are continuing to be, developed.

We need to change ourselves and adopt the systems which are the need of the hour, with the flexibility and right approach , the flexible operation of the thermal power plants can be achieved to the extent it is required.

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References

Best Practices Manual for USAID

Benchmarking Documents for Sipat

Case Studies from Sipat

Learning's from operation of supercritical units

IEA Clean Coal Centre – Increasing the flexibility of coal-fired power plants