Flexibilization of Coal Plants

A study on flexibilization requirements to manage renewables integration in Andhra Pradesh

Doug Waters (C.Eng, MBA, M.Eng & MAN, MIMechE, MEI), Animesh Kumar
Uniper Kraftwerke GmbH
Dusseldorf, Germany
Email: doug.waters@uniper.energy

Manas Majumdar, Rohit Pepalla, Anusha Rajagopalan
KPMG
India
Email: manasm@kpmg.com

*Abstract***— As India moves towards its target of 175GW power supply from renewable energy (RE) sources by 2022, it is imperative to have flexible power supply to balance intermittency in RE generation. A large part of this balancing capacity needs to come from Indian coal plants along with other solutions such as large scale energy storage, demand side management efforts etc. There is also a need for an enabling regulatory & market environment to incentivize power plants to invest and operate in a flexible manner. The current work is aimed at understanding the technical intervention and enablers required to achieve the required level of flexibility for thermal plants in the Indian context. The work has been funded under the Technical Assistance program "Supporting Structural Reforms in the Indian Power Sector" (Power Sector Reforms Programme) by the UK Government's Department for International Development (DFID) in partnership with the Ministry of Power, Government of India.**

Keywords-flexibilization, thermal plants, RE integration

I. INTRODUCTION

The Government of India's 175GW renewable energy (RE) target (by 2022), will need sufficient balancing capacity to manage intermittency that is inherent with RE generation. A multipronged approach is needed to introduce flexibility and safely integrate this energy into the grid.

Some of the measures which can provide this balancing capacity include coordinated scheduling and dispatch at country level, addressing congestion issues in transmission infrastructure to enable export of RE from high RE potential states to low potential RE states and having flexible generation sources. Flexible generation can be provided through a variety of generation sources like Hydro, gas fired power plants, storage solutions like battery, pumped storage etc. However in the Indian context these solutions have their limitations in providing sufficient balancing capacity. For example, gas based power plants have historically suffered from non-availability of affordable gas. Hydel generation is largely driven by irrigation needs and is also dependent on weather. Energy storage solutions are still being implemented only at a pilot scale. Considering this scenario, conventional coal fire plants shall be increasingly called upon to smoothen intermittencies in RE generation. This would require enabling flexible operation of thermal plants.

II. OBJECTIVES OF FLEXIBILIZATION

As per International Energy Agency (IEA), flexibility is defined as the extent to which a power system can modify electricity production or consumption in response to variability, expected or otherwise. Flexibilization of conventional power plants involves retrofitting of certain physical and digital components, making operational, procedural modifications along with a holistic change management program in order to achieve the following objectives as examples:

a) ***Lower technical minimum power output****:* Reduce the capacity at which the thermal plant can be reliably operated
b) ***Multiple start-up and shut- down cycles in a day***: Enable the plant to start from various shut-down conditions multiple times in a day
c) ***Higher ramp rate***: Increase the speed at which plant can respond to changes in demand by increasing or reducing generation
d) ***Shorter start-up time***: Reduce the time taken for a plant to start from no load condition and achieve the required generation output
e) ***Widening of ancillary services provision***: Improving reactive power and frequency response capabilities to the grid

All of the above needs to be done at low cost and considering process and plant safety, as well as, in the context of increased environmental performance

III. NEED FOR FLEXIBILIZAATION IN INDIA

The plant load factors of thermal power plants have been declining with increase in generation from RE sources. The average Plant Load Factor (PLF) of coal-based power stations has reduced from 69.9 per cent in FY 2013 to around 60.72 per cent in FY 2018 [1]. The PLF is expected to deteriorate as RE integration increases. The average PLF could reduce to 50% [2] in a scenario with 100GW solar and 60GW wind installed capacity (in 2022). Reduction in the PLF of thermal plants would hurt the economics of both the thermal units as well as the state of Distribution Companies (DISCOM)

According to the draft National Electricity Plan (NEP) - 2016, during 2017-22, a total of 56GW coal-based power plant capacity is expected to be commissioned. With 175 GW renewable energy target, the net load curve will exhibit strong 'duck curve' characteristics with a maximum ramp-up capacity requirement of ~22 GW/hour (9 per cent of installed capacity) against the current required ramp-up of 10

GW/hour (5.3 per cent of installed capacity). Fig. 1 shows India's projected net load curve with 100GW solar capacity.

Figure 1 India's projected net load curve in Jan 2022

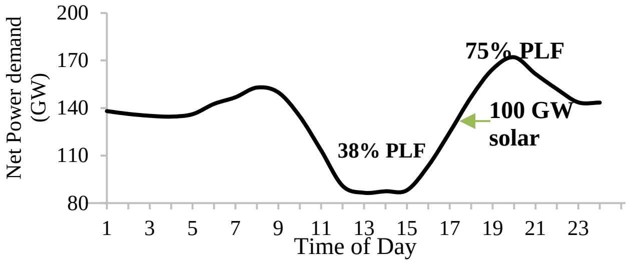
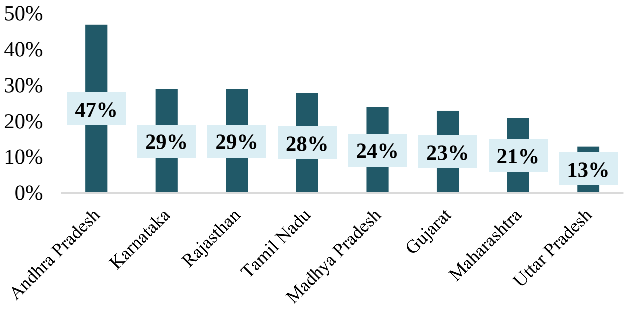


Figure 2 Projected share of RE in power supply by 2022



Thermal plants would require steep ramp rates during morning and evening hours to complement solar generation. Considering merit order dispatch, plants with high variable cost will be required to frequently operate flexibly with increased ramp rates and also undertake multiple cycles of start-up and shut-down. These plants will have to shut-down operation during times of low demand or high renewable penetrations and operate at high capacity during time of high demand. This could also result in some plants never starting up during the normal working day. When the target of 160 GW (100 GW solar and 60 GW wind) is achieved, nearly 20 GW of thermal capacity will never start and 65 GW of capacity experiences plant load factors below 30%. For such plants to remain economical and contribute to grid stability, they should be able to operate with greater flexibility [2].

Further, existing installed capacity and expected growth in RE capacity is concentrated among a few states. Ten states viz., Andhra Pradesh, Tamil Nadu, Gujarat, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Karnataka, Uttar Pradesh and Telangana contribute to about 93% of total RE capacity in India. Nearly 77% of 175 GW target of RE by 2022 is to be achieved by 8 states viz., Andhra Pradesh, Tamil Nadu, Gujarat, Madhya Pradesh, Maharashtra, Rajasthan, Karnataka and Uttar Pradesh. Even though RE is picking up fast, most of the states in India are primarily dependent on thermal based (coal & gas) power generation. Hence the likelihood of RE deployment pressure on these 8 states would be much higher. The projected share of renewable energy in total energy available for each of these 8 states by 2022 is shown in Fig. 2 above.

Based on the analysis, it is highly likely that Andhra Pradesh, Karnataka, Rajasthan and Tamil Nadu will have over 25% of their total energy demand available from RE sources. Since Andhra Pradesh is expected to have the highest share of RE in its supply, the state was selected as a test case for evaluating the need for flexible operation and initiatives to enable flexible operation. A summary of the analysis and conclusions are described in the following sections.

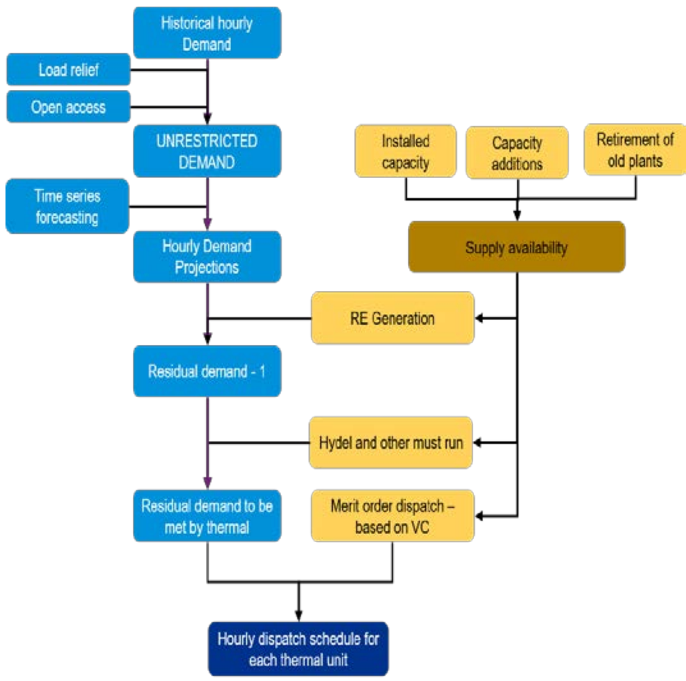
IV. Flexibilization Requirement in Andhra Pradesh

Andhra Pradesh's total generation capacity (not including solar & wind) available to meet demand at bus level is expected to increase marginally from 12.1 GW in 2018 to 13.8 GW in 2022. The state has a large installed capacity of thermal and gas based stations to manage RE additions. However, since gas availability is limited, most of the balancing requirement should be met by thermal sources. In terms of RE generation, the state has set a target of achieving 18GW of installed capacity by 2022. The state met its RE installation target for 2018 and the state has over 6GW of installed RE capacity.

A. Demand Projection

The flexibility requirement for Andhra Pradesh was computed by projecting demand, identifying demand to be met by thermal plants (after adjusting for RE generation) and using merit order dispatch to assess plant-wise flexibility requirement. The flowchart in Fig. 3 shows steps involved in estimating hourly dispatch schedule for each thermal unit. An analytical model was developed to identify the demand to be met by thermal plants and the flexibility requirements for these plants. Hourly demand in the state for each day in 2017-22 was projected using time series forecasting and adjusted for seasonal variation. Historical hourly demand data from FY 14-15 to H1 FY 17-18 was used as input for time series modelling to obtain forecasts.

Figure 3 Flowchart for estimating hourly dispatch schedule



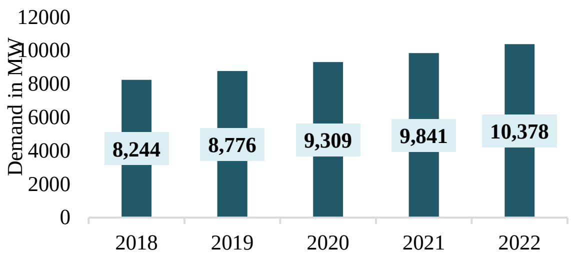
The time series model was built as follows:

$$\textbf{Demand (MW)} = \textbf{(a + b*time) x Seasonality Index};$$

- Factors a, b were computed using linear regression as intercept and slope of the demand equation respectively.
- Seasonality index was constructed based on actual demand data of last 3 years
- Demand (MW) was adjusted to be in line with total energy requirement in a year (as per resource plan)

The projected peak demand from 2018 to 2022 is shown in Figure 3 below. Peak demand is projected to increase from 8.2GW in 2018 to 10.3GW in 2022.

Figure 4 Projected peak demand 2018-22



B. Supply Projection

Total supply available from 2018-2022 was calculated based on existing capacity and expected capacity additions as per the latest resource plan submitted by the DISCOMs. The Plant Load Factor (PLF) / Capacity Utilization Factor (CUF) assumptions for various types of generation is shown in Table 1.

Table 1 PLF/CUF for supply projection

Type of plant	Basis for PLF/CUF projection
Thermal	Flat supply curve for the year at available MW (adjusted for aux consumption)
Solar	Actual hourly CUF for 365 days was calculated based on historical data and same has been considered for projections (Avg. PLF: 18.94%)
Wind	Actual hourly PLF for 365 days was calculated based on historical performance and the same has been considered for projections (Avg. PLF: 23.56%)
Other NCE	A flat supply curve assumed for 365 days
Hydro power	Based on historical data, hydel generation is assumed to occur at 4:00 AM to 9:00 AM and at 4:00 PM to 11:00 PM
Gas	Assumed to be used only as peaking plant

Note: Other short-term purchases or market purchases have not been considered. Modelling is based on 18GW [3] of installed RE capacity in 2022 comprising 10 GW Solar and 8 GW Wind

C. Assessment of flexibilization requirement

After scheduling each plant, the flexibility requirement for each plant was calculated for the following parameters:

- Number of start-stops during the day,
- % operation time below Minimum Technical Limit (MTL) for each plant.
- Maximum ramp-up/ramp-down requirements

The flexibility requirement was estimated under the following two scenarios:

a) Constrained scenario:

In the constrained scenario, all thermal plants will be scheduled at minimum technical limit and excess renewable energy generated will be curtailed. Projected RE curtailment at various levels of MTL is as shown in table 2 below

Table 2 Projected RE curtailment under constrained scenario

MTL of thermal plants	Projected RE curtailment in 2022
70%	Overall 40%, with over 80% curtailment projected in June – Sep 2022
55%	Overall 20%, with over 50% curtailment projected in August 2022
30%	<2%

b) Unconstrained scenario

In unconstrained scenario, all generation from RE will be absorbed and thermal plants will be scheduled only to meet the residual demand. This will result in reduced PLF and require faster ramping rates for thermal plants. The results are shown in table 3 below

Table 3 Impact on thermal plants' in unconstrained scenario

Parameter	Current (2018)	Projected (2022)
Impact on PLF	74%	58%
Impact on ramp rate	1,272 MW/hour	2,089 MW/hour

D. Flexibility requirement at plant level in 2022

Due to merit order dispatch, plants with high marginal cost would need to bear most of this flexibility requirement. Hourly dispatch schedule for thermal plants was developed based on hourly demand profile and merit order dispatch. The plant-wise flexibility requirements in AP, across key parameters are described in the following paragraphs.

1) Average PLFs of marginal plants:

Rayalaseema Thermal Power Project (RTPP) units consistently operate at low PLF during the entire evaluation period, with yearly PLF's consistently below 40%. Krishnapatnam Stage-I unit 2 will see its PLF's fall from 77% in 2018 to 54% in 2022.

2) % operation time below MTL

The % of time for which the plant will be dispatched below its MTL (i.e. 55% of rated capacity) would be highest for RTPP and Krishnapatnam. For instance, in July 2022, Krishnapatnam's Unit – II is expected to have a PLF of 20% and operate 73% of that time below MTL.

3) No. of start-stops during the day

Thermal plants will be required to shut-down during periods of high RE generation and start-up as RE generation tapers. In Krishnapatnam, for 11 out of 12 months at least 1 start-up/shut-down per day will be required. However, RTPP units would face the most number of start-up/shut-down cycles with 4 full cycles of start-up/shut-down, every day in November.

4) Ramp rate requirement

Almost all units would experience scenarios where they would have to achieve ramp rates of > 1% of rated capacity/min. Middle of the merit order plants would face consistent need for achieving high ramping rates unlike other cases where high variable cost plants were the most affected. Since low cost plants would always be scheduled at maximum capacity and mid-merit order plants would be called in for additional power, these plants would require higher ramping capacity. On the other hand, high variable cost plants would be unscheduled most of the time or forced to operate at MTL levels.

As a plant with high marginal cost, the Sri Damodaram Sanjeevaiah Thermal Power Station (SDSTPS) at Krishnapatnam would require to be operated flexibly by 2022. A diagnostic study was conducted at the plant to identify initiatives/modifications required to meet future flexibility requirements.

V. Diagnostic Study At Sri Damodaram Sanjeevaiah Thermal Power Station (SDSTPS), Krishnapatnam

An expert team comprising of senior technical experts from Uniper visited SDSTPS, followed by presentation of findings to senior management & team members at Andhra Pradesh Power Generation Corporation (APGENCO) Head Office at Vijayawada. The site visit comprised discussions with key staff, analysis of plant design, and operating conditions to understand the current status and potential issues regarding flexible operation at the site.

The site visit highlighted that both units operated as a base load unit with operation mainly at high loads, determined by coal quality issues and reducing to minimum load of 440MW for periods. No planned two shift (off-on cycle) operations had been performed during commissioning or commercial operation. Operation below design minimum load was limited to a short duration at 280MW to conserve coal until new supplies arrived and current ramp rates are below designed rates. The design parameters and the current operation status are shown in table 4.

Table 4 Design and Achieved operation parameters SDSTPS

Parameter	Design	Achieved
Rated capacity	800MW	630MW; Generation was limited by coal throughput at 380 tonnes/hour. The throughput was limited due to high ash content (>30%) in input coal.
Minimum load	Design minimum load - 440MW Capable of operating at 330MW with no oil support	Operated at 280MW during one instance for conserving coal until next delivery
Ramp rate	2%	0.8-1%

The original design of the plant assumed a continuous operational duty with few starts per year. Unit-1 of the plant had 8 starts in 2017-18 while Unit-2 had 9 starts during the year. Issues in coal supply led to reduced availability of the units during the year. Unit-1 had an availability of 55% while Unit-2 had availability of 56% during the year.

With high RE integration, the initial expectation for flexibility from the plant is likely to be cycling between maximum and the minimum load, and the need to reduce the minimum load to an ultra-low load. Additionally, higher ramp rates would be required to provide quicker response to changes in supply/demand. Two-shifting (stop/start) ability will be required at a later stage after achieving reduction in minimum load and increase in ramp rates. The plant staff highlighted certain technical issues that could arise with flexible operation and expressed concerns at operating beyond design limits. Some of the key issues that were identified and recommended actions for SDSTPS are shown in table 5 below.

Process/Digital Improvements

Flexible operations may introduce new and increase existing stress /damage on systems and in turn increase risk of premature failure and maintenance costs. Therefore, there is an increased need for maintenance and monitoring systems to ensure equipment reliability. The volume of data being generated means that big data techniques such as machine learning and artificial intelligence should be considered in order to provide real time decision relevant information to plant operators and management

In addition to the above mentioned solutions, it is necessary to ensure equipment reliability for flexible operation. A condition monitoring system is necessary which can provide the maintenance team information about timely detection and rectification of issues. Also, a computerized maintenance management system (CMMS) can be installed for ensuring tracking and completion of all maintenance works. The above mentioned initiatives will help in reducing minimum load from 440-320MW @ 4 mills to 120MW @1 mill. Initiatives to enable two-shifting can shall be taken up after successfully reducing minimum load and increasing ramp rates.

The enabler actions designed based on plant conditions should be first implemented for a short period and test runs should be conducted. Impact of the flexibility measure can be analyzed by comparing the plant's performance during test runs with its historical performance. The final list of flexibility measures to be implemented shall be arrived at based on a cost-benefit analysis.

VI. Implementation Programme

Flexibilization initiatives should be implemented in a phased manner. A typical program would contain four main phases:

1) A more detailed technical assessment of potential risk areas and specifications of additional instrumentation needed to monitor all high-risk plant areas.
2) The installation of instrumentation and monitoring equipment to allow rapid in-depth analysis of specified plant parameters under the test conditions of low load or start-up operations.
3) Operational trials including the analysis of monitored data, the preliminary review of component lives and the establishment of revised operating procedures.

4) After a period of flexible operation, an in-depth analysis of the impact of flexible operation on the life of selected components, allowing a damage cost to be established.

Capacity building of employees is imperative for successful implementation of solution and enabling flexible operation of thermal plants. Compared to operating the plant at steady load levels, operating at ultra-low loads, increasing load ramp rates or two shifting the plant, all require a significant additional level of competence from the operating staff. Capacity building programs should also be implemented in a structured manner as follows:

- Creating a flexible operator team from selected staff to undertake any trials to develop the procedures that optimize flexible performance. These procedures can then be formalized and included within the station procedures.
- Training of the staff to allow each of the staff to undertake the additional activities they need to perform flexible operation. The training can be a mixture of classroom, initially using Uniper training personnel, then using a 'train the trainer' approach to broaden the training to all required staff. In addition, simulator training and on the job training would be used to increase individuals experience in flexible operation.
- Monitoring the performance and providing feedback to each of the shift operations teams is an essential part of the learning curve to reduce the shift to shift variations that, from experience, will exist at any site, even when following the same operating procedures.

Table 5 Issues and Solutions to enables flexible operation of SDSTPS

Objective	**Risks/Issues**	**Potential Solutions**
Minimum load operation	Poor quality of coal	• Sampling of delivered coal • Fuel evaluation tool to evaluate impact of various qualities of coal • Ensure installed coal crusher is always in operation for crushing large coal pieces to avoid feeder blockages • Install a proper coal blending system to ensure homogenous supply of coal
Minimum load operation	Control system tuning	• Control system should be tuned to operate at current minimum load. Multiple test runs and trials should be conducted to enable tuning
Minimum load operation, increasing ramp rates	Main boiler feed pump (MBFP) suffers from induced vibration at low loads due to poor pressure control. Currently, electric driven feed pump is used at low loads to avoid this issue but switching back to MBFP at higher loads takes more than an hour	• Change the configuration so that the flow control valve that is present for the electric driven feed pump is moved so that it also covers operation of the two steam driven feed pumps enabling these pumps to operate at low loads • Avoiding switch over of feed pumps during ramping up will help in faster ramp up
Minimum load operation, Improve start-up/shut-down times	Start-up system has not been fully installed	• Start-up system should be installed after a full design review of the proposed modification
Minimum load operation	Mill trips at low loads due to flame stability	• Current flame detection hardware should be considered for replacement to ensure good quality flame detection
Minimum load operation	Risk of overheating the upper furnace walls and platen super heater due to low water / steam flow	• Over-fire air could be used to reduce temperatures in upper furnace walls, platen super heaters and support back end temperatures
Improve start-up/shut-down times	Control system not capable of achieving design ramp rates	• Station is working on upgrading its DCS to achieve ramp rates of 5%
Improve start-up/shut-down times	Current level of automation is a concern for the site to start and stop the unit	• Control systems should be tuned to operate correctly below 60% load • Automation of start-up sequence can also be undertaken for enabling multiple start/stops
Enable shift operators to handle flexible operation	Lack of confidence among shift operators	• Training programs to ensure all shift operators are competent in managing flexible operations

		• Implement computerized maintenance & monitoring systems to ensure proper functioning of plant components

VII. Key Enablers For Incentivizing Flexibilization

Enabling flexible operation of thermal plants requires incentives in the form of regulatory, policy and market design. Such improvements are necessary for creating an ecosystem that supports investment in flexibilization of thermal plants. Some of the key factors to enable flexible operation are described in the following paragraphs.

A. Regulations defining technical minimum for coal plants

In 2016, the Central Electricity Authority (CEA), lowered the technical minimum of Central Generating Stations (CGS) or Inter-State Generating Stations (ISGS) to 55% of total installed capacity. The regulation includes mechanisms for compensation as part of tariff for operating the plant at technical minimum, which could be below the plant's normative capacity. In future, the minimum load could be further lowered to 40% in order to increase the level of flexibility in the system. However, currently, these regulations do not apply to state level power generating stations and hence plants serving only the local market do not have any such compensation mechanism for flexible generation. Further, the compensation mechanisms are designed to only account for increase in operation and maintenance expenditure. Tariff mechanisms to compensate for fixed costs incurred to retrofit plants for complying with lowered minimum load should be designed.

B. Ancillary services

Ancillary services, important for ensuring power system reliability, include frequency support, voltage support and system restoration. Primary, secondary and tertiary reserves are required for balancing variability in RE generation. The Indian Electricity Grid Code has already mandated several generators to maintain primary reserves for frequency control. Additionally, slow tertiary frequency control as an ancillary service for manually changing schedules of thermal generators was introduced in 2016.

C. Market design for flexible operation

Efficient market design enables unlocking of existing flexibility in generation as well as incentivizing investments in flexibilization of thermal plants. Real time electricity markets exist in several developed power markets across the world as integrated markets or exchange based market. Considering that India has already adopted power exchange model for day ahead and intra-day trading, it would be efficient to adopt the exchange based market model for balancing services, which is also practiced in European markets. The Central Electricity Regulatory Commission's (CERC) roadmap for implementation of reserves also suggests moving to a market mechanism for procuring balancing services. An exchange based balancing market would enable better price discovery compared to bilateral agreements. For the generating stations, especially the stations ranked lower on merit order dispatch, participating in real time electricity market could lead to improved revenues thereby encouraging investment in flexibilization initiatives.

D. Faster scheduling intervals

Time granularity in electricity markets should be increased, with shorter scheduling and dispatch intervals along with shorter gate closure periods in order to utilize existing flexibility of thermal plants. With shorter span between gate closure and actual transactions, the forecast accuracy for RE generation also improves, thereby reducing the amount of conventional capacity that should be held as reserves.

E. Pan-India code for flexibilization

The extent of flexible operation required at thermal plants will vary based on technical factors and commercial parameters such as its variable costs. There is a need to develop flexibilization guidelines and standard operating procedures (SoPs) applicable to different types of coal fired power plants across India. In order to develop these guidelines, pilot studies should be conducted at different types of plants across India. Learnings from these pilots should be incorporated in a database for developing a holistic flexibilization code that can be implemented by thermal plants.

F. Economic incentives influencing plant operation

The terms and conditions of supply, maintenance and tariff contracts impact the economics of plant operations.

1) Contract terms

The terms of various contracts between coal power plants and other associated stakeholders have a strong influence on the ability of power plants to operate flexibly. Although these terms are designed to help in risk mitigation or an assurance of minimum revenue, it could also dis-incentivise flexible operation of thermal plants. For example, fuel contracts are often structured as 'take-or-pay' contracts. This incentivizes the plant operators to run the plant irrespective of market requirements to avoid making payments for non-consumption of fuel. Another example is maintenance contracts which are structured based on number of starts. Flexible operation may require measures such as two-shifting (multiple start/stops) and such maintenance contracts can prevent thermal plants from responding to market needs.

2) Tariff structures

Tariff structures can prevent a plant from operating flexibly as per market requirements. In India, most of the coal fired generating stations have a long-term power purchase agreement with the distribution companies. These PPAs are based on a two-part tariff mechanism where the plants recover their fixed cost for being available, regardless of their actual power generation. Such tariff structures do not incentivize flexible operation. Instead, tariff structures should be designed to reflect the generating stations' contribution to the grid requirements. A tariff mechanism for valuation of flexibility services should be developed in order to drive plants towards investing in enabling flexible operation.

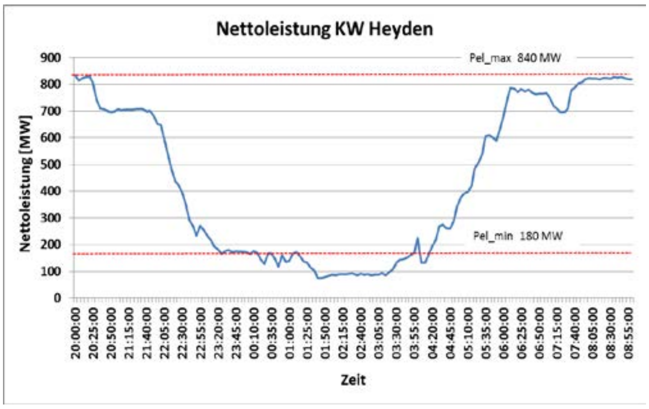
VIII. Uniper's Experience In Flexibilization

A. Low Minimum Load Experience at Heyden, Germany

Uniper's Heyden Power Plant is a single unit supercritical plant first commissioned in 1987 with an installed capacity of 800

MW and was later increased to 875MW. With increased requirements for flexible operation, the plant had to maintain its commercial operation without incurring accelerated life reduction due to increasing unit starts. Also, start-up costs due to oil consumption had to be avoided while taking advantage of summer and night time opportunities in the market. The work conducted to understand the impacts of increased starts and identify the solutions required to prevent them resulted in revisions to the boiler and turbine capabilities such that the minimum stable load was reduced from 180 MW down to 90 MW (~11 % of the rated capacity).

Figure 5 Low Load Operation at Heyden



This ultra-low minimum stable load can be achieved and sustained with single mill operation without the need for oil burner support. The objective was to reduce the electrical minimum power to approximately 10 % to 15% of the nominal power plant capacity. The process steps reduce generation costs in periods with low electricity market prices. Stable operation of the boiler, the turbine and all auxiliary plant has been achieved at 15 % of the boiler load, or ~ 10 % of the plant's rated power. Boiler operation was managed and the unit was controlled in single mill operation without oil support and subsequently returned to the conventional two mill operation mode in a safe way. The experiences of ultra-low load operation at Heyden Power Plant have been cascaded to other Uniper plants within Germany and the Netherlands. The plant in the Netherlands is a 1,113MWgen supercritical unit commissioned in 2017. Its steam conditions are final superheater 596 ℃ @ 275 bar and final reheater 619 ℃ @ 58 bar capable of achieving a plant efficiency of 46%. The plant was originally designed for minimum operation at 40% load. However, even though the plant is the latest and the most efficient coal fired unit in Europe, it has already responded to market demands by reducing its minimum load to 19% with two mill operation (without oil support), and plans to progress further reductions towards one mill operation if needed.

B. Stopping & Starting (2-shifting) Experience

The UK energy market, being a smaller, less integrated grid than Central Europe, has seen the requirement for plant to stop and start (2 -shift) regularly. Fig. 6 illustrates Ratcliffe Power Stations journey over the last number of years. Ratcliffe Power Station is a 4 x 500MW coal-fired power station.

Figure 6 Generation at Ratcliffe power station across years

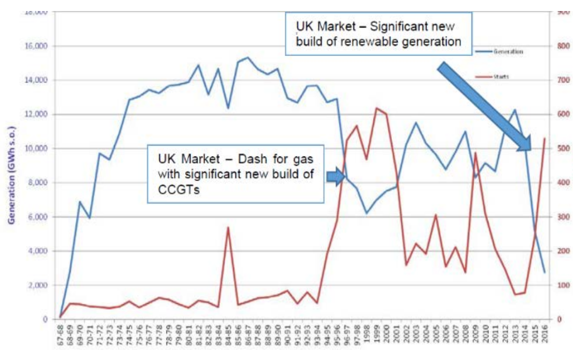


Fig. 6 shows the hours and starts per year for the power plant. This clearly highlights the dash-for-gas period in the 1990's, when a large number of new CCGT plants were built. More recently the penetration of renewables has been increasing the requirement for even more flexibility. To put this in perspective, Ratcliffe Power Station now regularly synchronizes all 4 units concurrently, 18 to 20 times per week during winter operation and flexibility to operate between minimum stable load and full load approximately 60 times per week.

"Views, thoughts and opinions expressed in this publication are of author(s) and may not necessarily reflect the views, thoughts and opinions of KPMG or UNIPER"

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BIOGRAPHICAL INFORMATION

Doug Waters is the Director of Global Energy Services at Uniper. Before this he was the head of Local Fleet Management for EON Espana Generation in Madrid, being responsible for the Local Asset Management team of E.ON's 5GW of thermal and hydro portfolio in Spain. Prior to that he led the fleet wide renegotiation of E.ON's portfolio of long term service agreements contract for the global portfolio of CCGTs. During his nearly 20 years in the power industry, Doug has worked on projects in Europe, India and US. He holds a Master degree in engineering from Birmingham, UK as well an Executive MBA from European School of Management & Technology in Berlin, Germany. He is a board member of India Uniper Power Service Pvt, Uniper India Pvt, Uniper Energy Southern Africa Pty and Uniper Energy Services MENA DMCC

Manas Majumdar is a Partner in KPMG in Energy & Resources. He has around 2 decades of experience in Power, Oil & Gas, Chemicals sectors with expertise in operations improvement and transformation and supply chain. Manas has worked with clients in these domains spread across US, India and in several other countries in the Asia-Pacific region. Manas has led several operations improvement & transformation projects for large utility companies in the power sector. He has also designed and implemented best practices in material and inventory management as part of site level initiatives at power generation utilities in India. Manas holds a Master's degree in Technology in mathematics and computing from Indian Institute of Technology, Delhi and also a Master's degree in Management from Indian Institute of Management, Calcutta