







Indo-German Energy Forum:
Flexibility Case Study at Dadri and Simhadri
Boiler, Combustion and Coal

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Outline

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Outline

Introduction

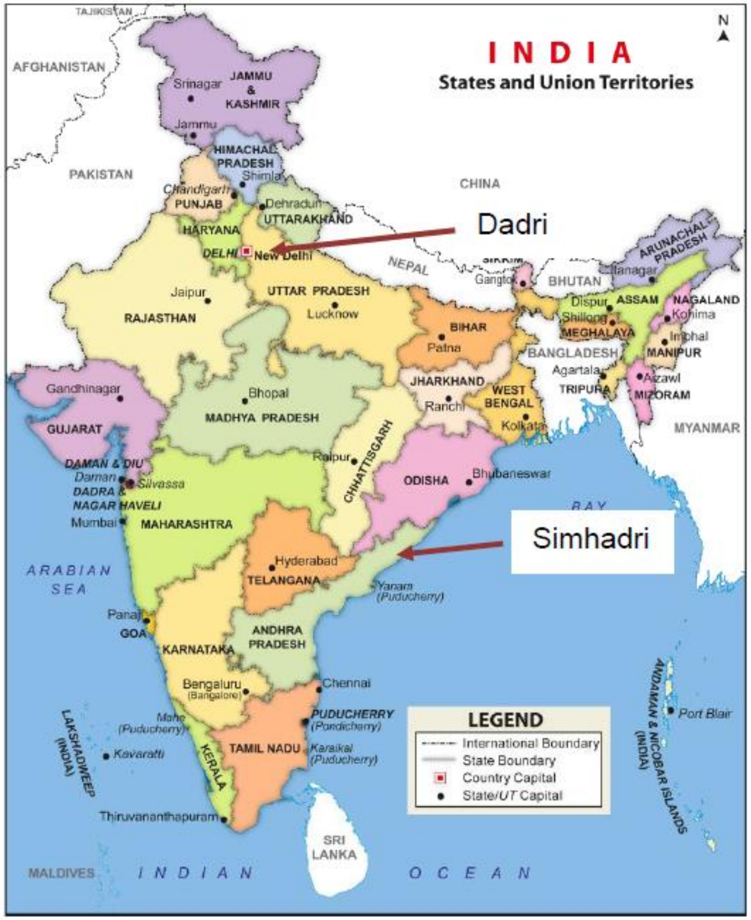
Goal of the study

- Identification of specific measures for flexible operation for the two reference power plants
- Evaluation of the potential based on a cost-benefit analysis

Plants were selected that are constructed in a similar fashion as many power plants operated in India:

- Coal-fired 210 MW_{el} units in Dadri (State of Uttar Pradesh)
- Coal-fired 500 MW_{el} units in Simhadri (State of Andhra Pradesh)

Both power plants are operated by NTPC



Source of the map: www.embassyindia.es

Outline

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Measures for Dadri power plant

Main findings concerning boiler

Based on the documents received, the described components generally appear to be in good condition. General boiler design features are:

- The boilers are provided with tilting burners, tangentially arranged as a corner firing design.
- An oil firing system (each burner was provided by one oil gun) for start-up and low load operation is available in all coal burner elevations.
- Each boiler is equipped with six coal mills, each feeding its own burner level (six levels exist). 6 mills are required for base load.
- The Dadri boiler units are equipped with a de-dusting flue gas cleaning equipment only. All other technologies to meet SO_x, NO_x and heavy metals requirements need to be added in near future.
- Mostly washed coal is used at the Dadri Power Plant but problems with stones still appear.
- It has been stated that combustion stability is the most limiting factor for not further reducing the minimum load but no “two mills” tests have been conducted so far.

Measures for Dadri power plant

Overview of Flexibility Parameters at the Dadri Power Plant

	Current value	Value according to design	Potential
Minimum load [MW]	134 – 147	126	30 – 50*
Exemplarily COLD (exemplarily) [h]	6	4	3 – 4**
Ramp rate	3.5 %/min	---	4 – 5 %/min

*** Note that in this load range it is not possible to provide frequency control**

**** Note that due to oil consumption savings a reduction of start-up costs of up to 30% could be possible**

Measures for Dadri power plant

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Overview of suggested flexibility measures at the Dadri power plant

No.	Measure	Flexibility option
MD1	Evaluation of process limitations (in particular boiler and turbine)	General
MD2	Steam coil air pre-heaters (SCAPH)	Minimum load, Start-up
MD3	Combustion stability – Stable two mills operation	Minimum load
MD4	Combustion stability – Online management system	General
MD5	Reliable flame detection	Minimum load, Start-up
MD6	Online coal analysis	General
MD7	Optimization of automation and controls	General
MD8	Re-heater – Investigation of the deviation between actual behavior and design / temperature control	General
MD9	Advanced frequency control	Minimum load, Ramp rate
MD10	Optimization and automation of start-up sequence	Start-up
MD11	Replacement of start-up related temperature measurements	Start-up
MD12	FEM analysis of the limiting components	Start-up
MD13	Plant condition monitoring system	General

Measures for Dadri power plant

MD2 – Steam coil air pre-heaters (SCAPH):

If SCAPH are still installed without being used, the VGB team highly recommends re-commissioning this equipment to protect the so-called cold end. In this way, serious blockages in the cold end of the regenerative air pre-heaters (RAPH) caused by “wet” fly ash sticking can be avoided. The fly ash will become wet if the flue gas temperature drops below the sulfuric acid dew point. Steam coil air pre-heaters will be also applied to increase the flue gas temperature above the sulfuric acid dew point at low load operations. Furthermore, SCAPH should also be operated to increase flue gas temperature at the cold end of the RAPH, as an increase of air leakages into the regenerative air pre-heaters is unavoidable. Regular maintenance after the RAPH sealing is overhauled will reduce the air ingress, but not avoid this impact.

Measures for Dadri power plant

MD3 – Combustion stability – Stable two mills operation:

Having six mills in total the power plant has good prerequisites for being operated at loads between 10 and 20 percent of nominal load. In particular, the operation with two mills should improve combustion stability since the resulting load for each mill increases to a normal/stable range. The precondition for such low load operation is the use of real washed coal, i.e. coal without stones, rocks or other hard impurities.

To ensure the maximum possible re-heater outlet temperature during the planned low load operation in future, mills E and F should be investigated as they serve the upper burner levels.

In addition, this measure might require modifications of the boiler safety system.

Measures for Dadri power plant

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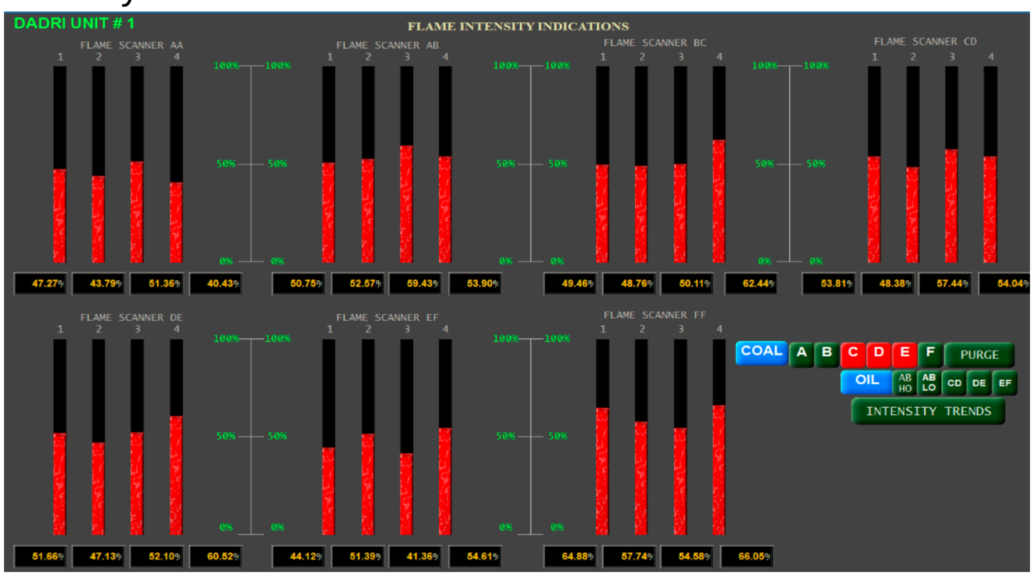
MD3 – Combustion stability – Stable two mills operation:

The stable two mill operation requires further discussion with the OEM. From VGB team experience, this will benefit combustion stability due to the increased load of each mill. In order to stabilize the steam temperatures, it is recommended that the upper burner level be operated.

Implementing a two mills operation usually requires boiler safety system modifications to allow a continuous two mill operation. This also requires reliable flame detection.

The mimics show that even at the current minimum load (three mills active) all sensors detect some intensity.



Measures for Dadri power plant

MD4 – Combustion stability – Online management system:

Combustion stability is the main limitation. The precondition of this low load operation is the use of real washed coal. It is recommended installing an online pulverized coal (PC) and air distribution management system to measure the air/fuel ratio to the coal burners in each PC pipe to the coal burners in real time. This can be optimized automatically according to the received coal quality.

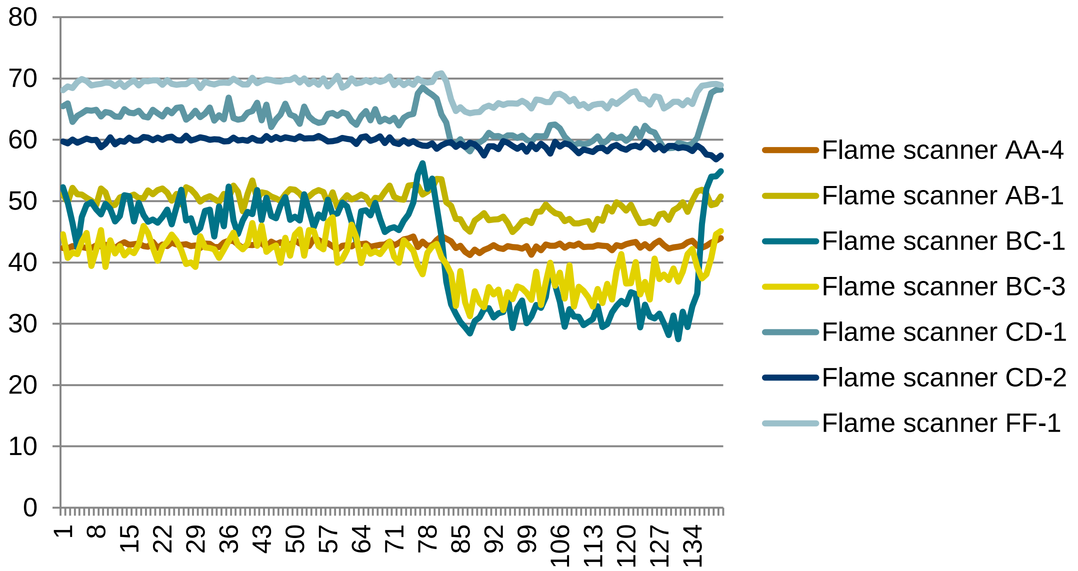
Details with respect to the online pulverized coal and air distribution monitoring management system shall be discussed with the respective OEM, e.g. Promecon.

Adjustments shall be performed by the OEM during the implementation.

Measures for Dadri power plant

MD5 – Reliable flame detection:

As proper flame detection plays a major role in guaranteeing a reliable minimum load operation and in terms of avoiding trips during start-up, the current hardware needs to be considered for potential replacement.



Situation in Germany:

For clearer and more reliable determination, many German plants have introduced direct on/off (100 / 0 per cent) measurements with good results.

Measures for Dadri power plant

MD6 – Online coal analysis:

It is recommendable to install an online coal analysis and weighing system at the Dadri power plant unloading area to check that the incoming coal quality complies with the required quality for low load operation.

Details with respect to the online coal analyser and weighting system shall be discussed with the respective OEM.

Adjustments shall be performed by the OEM during the implementation.

Measures for Dadri power plant

MD7 – Optimization of automation and controls

The optimization of the underlying control loops, i.e. coal supply, drum level, pressure, temperature, air control is a basic requirement for stable operation of the power plant at nominal load and low load as well as load changes, and provision of control power.

Moreover, even though a proper coordinated unit control seems to be implemented, it needs to be optimized if the usual load range is left unchanged, e.g. by a reduced minimum load. Moreover, manual interventions should be reduced to a minimum.

In terms of load reduction there might also be interlocks coming from logics. However, these interlocks are usually relatively simple to identify and eliminate with test runs.

A manual sliding pressure operation is currently implemented. However, the turbine valves are already severely throttled. Therefore, it would be beneficial for low load operation to optimize the sliding pressure mode and to implement an automatic operation.

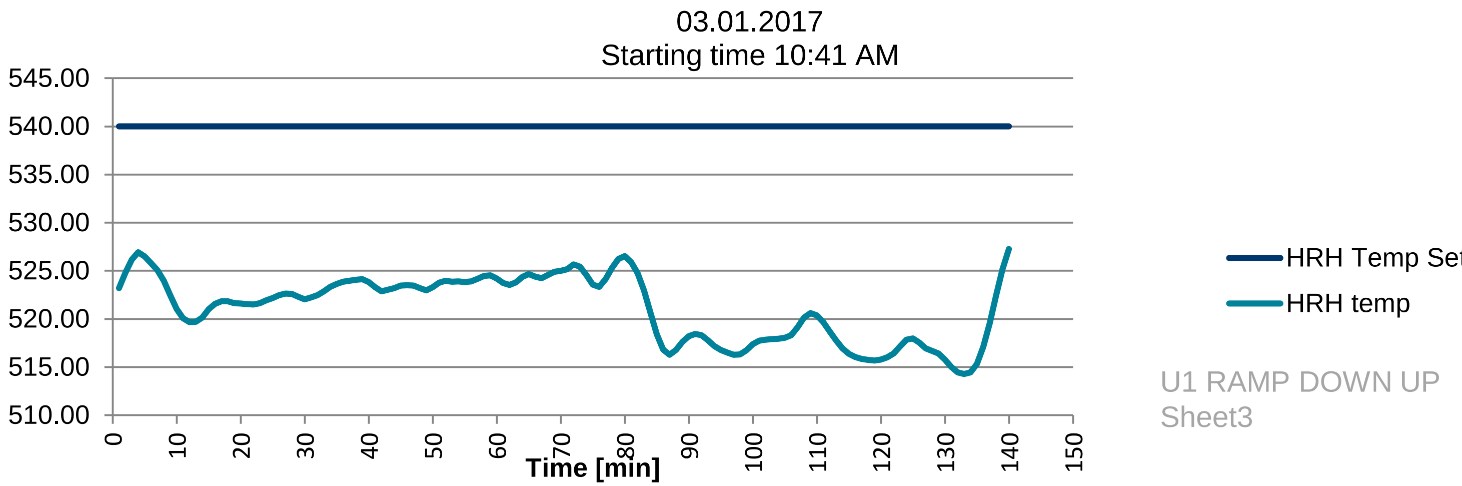
In order to increase part load efficiency "single device" approaches (e.g. single FW pump, PA fan, etc. in operation) should be considered. However, this strategy requires a reliable implementation with respect to bump-less switch-over to stand-by equipment in order to not force trips.

Measures for Dadri power plant

MD8 – Re-heater – Investigation of the deviation between actual behavior and design / temperature control

The deviation between actual behavior and design needs to be investigated. In particular, the interaction of the tilting burners in conjunction with the spray type (water) attemperators, especially between the re-heater heating bundles, should be thoroughly investigated and modified, if applicable.

Moreover, control strategies (such as coordinated set point control for the temperatures of the superheated steam and reheated steam) need to be implemented to keep the steam temperatures in an admissible and controllable range.



Outline

1. Introduction
2. Measures for PP Dadri – Boiler, combustion and coal
3. Measures for PP Simhadri – Boiler, combustion and coal
4. Cost-benefit analysis
5. Summary

Measures for Simhadri power plant

Main findings concerning boiler

On the basis of the documents received, the described components mostly appear to be in a good condition. General boiler design features are:

- The boiler at Simhadri stage 1 is equipped with nine coal mills, each feeding its own burner level (nine levels). The pulverized system is designed to ensure BMCR operation by seven coal mills in operation.
- The boiler at Simhadri stage 2 is equipped with ten coal mills, each feeding its own burner level (ten). Nine of ten mills are able to provide the required fuel to the burners if poor quality coal is applied.
- The received documents state that four of the boilers' coal mills for both stages are able to feed the required coal during 50 percent BMCR load.
- The Simhadri boilers used in both stages are provided with tilting burners, tangentially arranged as a corner firing design.
- The Simhadri boiler units used in both stages have de-dusting flue gas cleaning equipment only. All other technologies to meet SO_x, NO_x and heavy metals requirements need to be added in the near future.
- An oil firing system (20 heavy oil burners and four diesel oil burners in the lowest level) for start-up and low load operation is available in all coal burner elevations.

Measures for Simhadri power plant

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Overview of Flexibility Parameters at the Dadri Power Plant

	Current value	Value according to design	Potential
Minimum load [MW]	350 (275 test run)	250 (150)	75 – 125*
Exemplarily <u>WARM</u> start-up time [h]	7 – 8	2	2**
Ramp rate	<0.5 %/min	---	4 – 5 %/min

*** Note that in this load range it is not possible to provide frequency control**

**** Note that due to oil consumption savings a reduction of start-up cost of up to 30% could be possible**

Measures for Simhadri power plant

Overview of suggested flexibility measures at the Simhadri power plant

No.	Measure	Flexibility option
MS1	Evaluation of process limitations (in particular boiler and turbine)	General
MS2	Combustion stability – Stable two/three mills operation	Minimum load
MS3	Combustion stability –Online management system	General
MS4	Reliable flame detection	Minimum load, Start-up
MS5	Online coal analysis	General
MS6	Optimization of automation and controls	General
MS7	Re-heater - Investigation of the deviation between actual behavior and design/temperature control	General
MS8	Advanced frequency control	Minimum load, Ramp rate
MS9	Optimization and automation of start-up sequence	Start-up
MS10	Replacement of start-up related temperature measurements	Start-up
MS11	FEM analysis of the limiting components	Start-up
MS12	Plant condition monitoring system	

Measures for Simhadri power plant

MS2 – Combustion stability – Stable two/three mills operation:

Having nine mills (Simhadri stage 1) and ten mills (Simhadri stage 2) in total, both stages provide good prerequisites for being operated at loads between 10 and 20 percent of nominal load. In particular, the operation with two (three) mills should improve combustion stability since the resulting load for each mill increases to a normal/ stable range. The precondition of the described low load operation above is the use of real washed coal, i.e. coal without stones, rocks or other hard impurities. The use of two or three mills needs a route cause investigation.

To ensure the maximum possible re-heater outlet temperature during the planned low load operation in future, the upper burner levels should be investigated.

In addition, this measure might require modifications of the boiler safety system.

Measures for Simhadri power plant

MS3 – Combustion stability –Online management system:

Combustion stability is the main limitation. The precondition of this low load operation is the use of real washed coal. It is recommended installing an online pulverized coal and air distribution management system to measure the air/fuel ratio to the coal burners in each PC pipe to the coal burners in real time, which can be optimized automatically based on the received coal quality.

Details with respect to the online pulverized coal and air distribution monitoring management system shall be discussed with the respective OEM.

Adjustments shall be performed by the OEM during the implementation.

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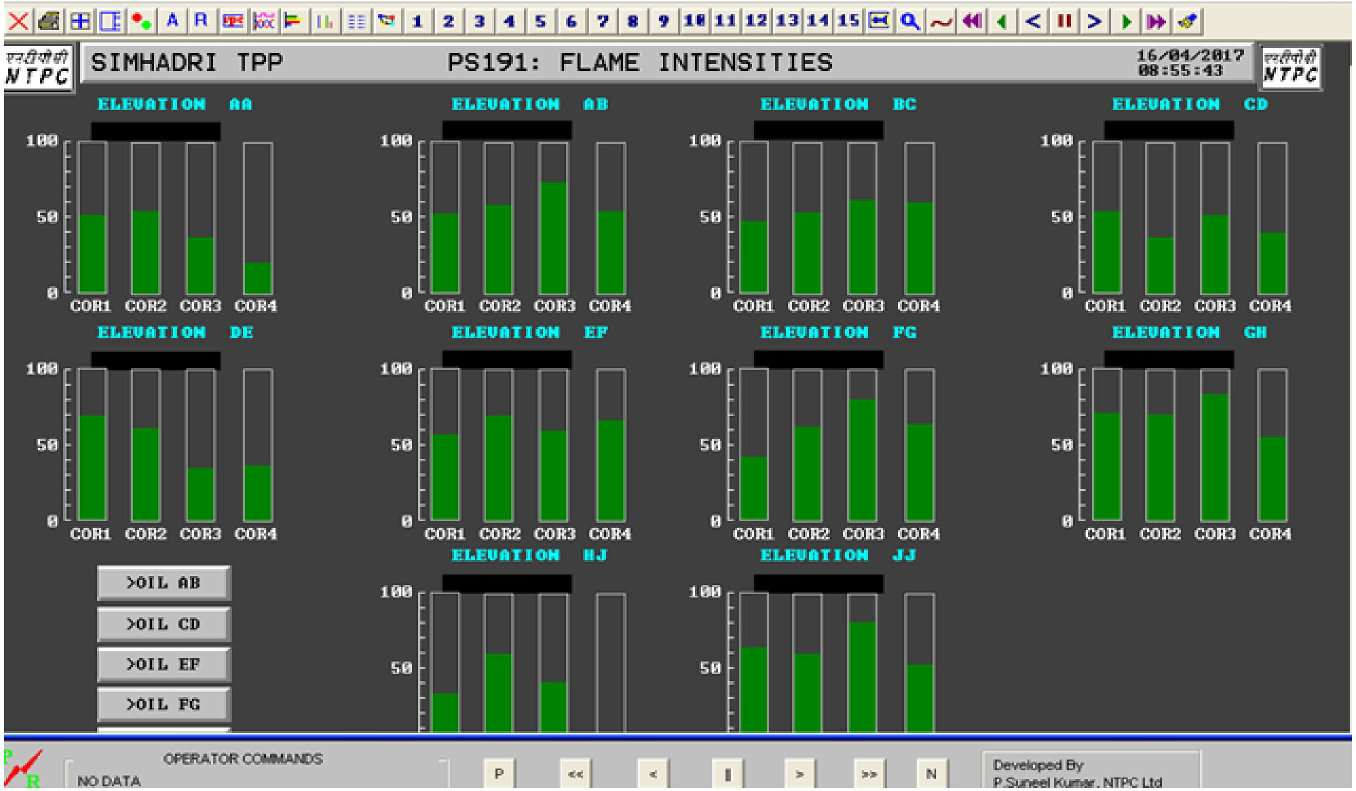
MS4 – Reliable flame detection:

As proper flame detection plays a major role in guaranteeing a reliable minimum load operation and in terms of avoiding trips during start-up, the current hardware needs to be considered for potential replacement.



Measures for Simhadri power plant

MS5 – Online coal analysis:

It is advisable to install an online coal analysis and weighing system at the Simhadri power plant unloading area to check that the incoming coal quality complies with the required quality for low load operation.
Details with respect to the online coal analyser and weighting system shall be discussed with the respective OEM.
Adjustments shall be performed by the OEM during the implementation.

Measures for Simhadri power plant

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MS6 – Optimization of automation and controls:

The optimization of the underlying control loops, i.e. coal supply, drum level, pressure, temperature, air control is a basic requirement for the stable operation of the power plant at nominal load and low load as well as load changes, and provision of control power.
Moreover, even though a proper coordinated unit control seems to be implemented, it needs to be optimized if the usual load range remains unchanged, e.g. by a reduced minimum load. Manual interventions should also be reduced to a minimum.
In terms of load reduction interlocks might be coming from logics. However, these interlocks are usually relatively simple to identify and eliminate using test runs.
A manual sliding pressure operation is currently implemented. However, the turbine valves are already severely throttled. Therefore, it should be beneficial for low load operation to optimize the sliding pressure mode and to implement an automatic operation.
In order to increase part load efficiency “single device” approaches (e.g. single FW pump, PA fan, in operation) should be considered. However, this strategy requires a reliable implementation with respect to a switchover to stand-by equipment without bumps in order to not force trips.

MS7 – Re-heater - Investigation of the deviation between actual behavior and design/temperature control:

At low load, the deviation between actual behavior and design needs to be investigated. In particular, the interaction of the tilting burners in conjunction with the spray type (water) attemperators, especially between the re-heater heating bundles, should be thoroughly investigated and modified, if applicable.
Moreover, control strategies (such as a coordinated set point control for the temperatures of the superheated steam and reheated steam) need to be implemented to keep the steam temperatures in an admissible and controllable range.

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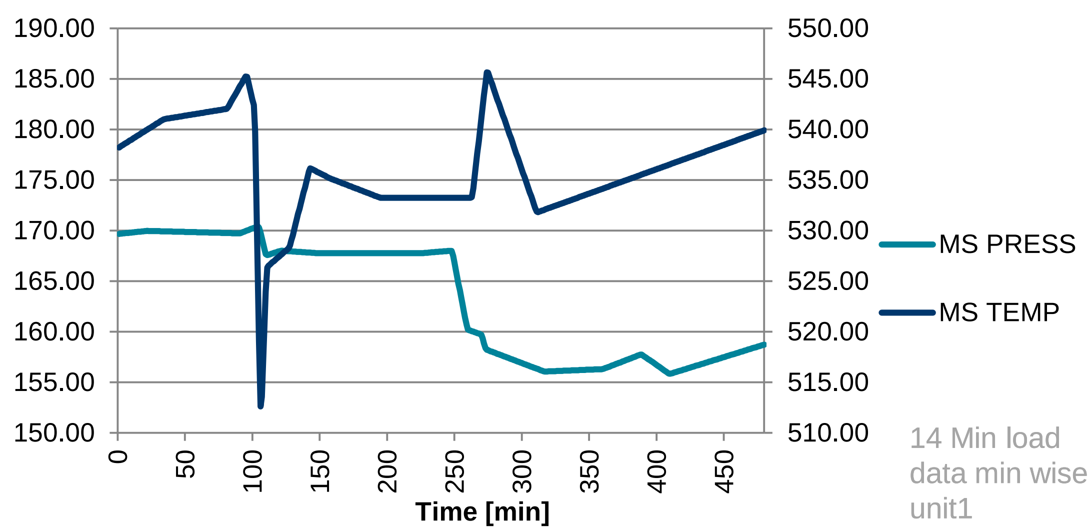

Outline

Cost-benefit analysis

Assessment of the flexibility measures

In order to support the prioritization of the measures, each measure was assigned a level of estimated benefit, namely:

1 = the benefit is estimated as having rather low improvement potential with respect to flexibility
2 = the benefit is estimated as having medium improvement potential with respect to flexibility
3 = the benefit is estimated as having high improvement potential with respect to flexibility

The exact benefit is difficult to quantify without performing a detailed technical impact assessment based on more test runs in flexible operation mode. **Test runs are indispensable and therefore strongly recommended for both plants.**

Similarly, the estimated costs associated with implementing a measure is categorized as follows:

A = cost estimated at less than $100,000
B = cost estimated between $100,000 and $300,000
C = cost estimated between $300,000 and $600,000

Cost-benefit analysis

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Assessment of the flexibility measures for Dadri power plant 1/2

ID	Measure	Flexibility impact	Est. cost (cat. A – C)	Est. benefit (cat. 1 – 3)	Time for impleme ntation
MD1	Evaluation of process limitations (in particular boiler and turbine)	General	A – B	N/A Precondition for further measures	1 month
MD2	Steam coil air pre-heaters (SCAPH)	Min. load	C	1 – 2	
		Start-up		1 – 2	
MD3	Combustion stability – Stable two mills operation	Min. load	B – C Precondition washed coal usage	3	6 to 12 months
MD4	Combustion stability – On-line management system	General	B	3	6 to 12 months
MD5	Reliable flame detection	Min. load	C	2 – 3 Precondition for further measures	1 to 2 months
		Start-up		N/A Precondition for further measures	
MD6	Online coal analysis	General	C	2	up to 6 months

Cost-benefit analysis

Assessment of the flexibility measures for Dadri power plant 2/2

ID	Measure	Flexibility impact	Est. cost (cat. A – C)	Est. benefit (cat. 1 – 3)	Time for impleme ntation
MD7	Optimization of automation and controls	General	C	2 – 3	up to 12 months
MD8	Re-heater – Investigation of the deviation between actual behavior and design/temperature control	General	A	N/A Precondition for further measures	3 months
MD9	Advanced frequency control	Min. load Ramp rate	C	1 – 3 depending on requirements on frequency control provisions	up to 12 months
MD10	Optimization and automation of start-up sequence	Start-up	C	2 – 3	at least 12 months
MD11	Replacement of start-up related temperature measurements	Start-up	B	1 – 2	up to 4 months
MD12	FEM analysis of the limiting components	Start-up	A	2	2 to 3 months
MD13	Plant condition monitoring system	General	B – C	1 – 2	3 to 4 months

Cost-benefit analysis

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Assessment of the flexibility measures for Simhadri power plant 1/2

ID	Measure	Flexibility impact	Est. cost (cat. A – C)	Est. benefit (cat. 1 – 3)	Time for implementation
MS1	Evaluation of process limitations (in particular boiler and turbine)	General	A – B	N/A Precondition for further measures	1 month
MS2	Combustion stability – Stable two/three mills operation	Min. load	B – C Precondition washed coal usage	3	6 to 12 months
MS3	Combustion stability – Online management system	General	B-C	3	6 to 12 months
MS4	Reliable flame detection	Min. load	C	2 – 3 Precondition for further measures	1 to 2 months
		Start-up		N/A Precondition for further measures	
MS5	Online coal analysis	General	C	2	up to 6 months
MS6	Optimization of automation and controls	General	C	2 – 3	up to 12 months

Cost-benefit analysis

Assessment of the flexibility measures for Simhadri power plant 2/2

ID	Measure	Flexibility impact	Est. cost (cat. A – C)	Est. benefit (cat. 1 – 3)	Time for implementation
MS7	Re-heater – Investigation of the deviation between actual behavior and design /temperature control	General	A	N/A Precondition for further measures	3 months
MS8	Advanced frequency control	Min. load Ramp rate	C	1 – 3 depending on requirements on frequency control provisions	up to 12 months
MS9	Optimization and automation of start-up sequence	Start-up	C	2 – 3	at least 12 months
MS10	Replacement of start-up related temperature measurements	Start-up	B	1 – 2	up to 4 months
MS11	FEM analysis of the limiting components	Start-up	A	2	2 to 3 months
MS12	Plant condition monitoring system	General	B-C	1 – 2	3 to 4 months

Cost-benefit analysis

Operating Procedures

Adapting the operating practices to cycling operation is key for improving the plant's reliability and availability. The mitigation measures generally apply as well, but the following points focus on the operational procedures directly. Detailed procedures applying to Dadri or Simhadri can only be devised if the current procedures are known. Generally, however, the following apply:

- Strictly adhering to the plant chemistry guidelines during start-up, shut-down and lay-up. To ensure compliance with quality standards at all operating conditions, e.g. maintain water/steam quality to avoid corrosion, the VGB Standard "Feed Water, Boiler Water and Steam Quality for Power Plants / Industrial Plants" could serve as a guideline.
- Lay-up procedures: Boiler tube failures and other corrosion fatigue effects can be reduced by defining lay-up procedures, depending on the duration of the plant being off line. For implementing suitable preservation procedures to protect equipment, the VGB Standard "Preservation of Power Plants" and "Preservation of Steam Turbo-Generator Set" could serve as a guideline.
- Advanced control and data assessment: New automatic procedures based on suitable instrumentation and monitoring systems need to be operated by knowledgeable plant personnel. This also includes life-time assessment tools.
- Training of O&M staff to improve monitoring and inspection skills required as these activities intensify during cycling operation.
- Introducing various monitoring and inspection programs covering all strained boiler components as well as the generator (e.g. stator end windings) and turbines (e.g. ventilation, vibration protection). The maintenance strategy needs to be adapted to take new market requirements into account.

Outline

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Summary

Main results

The situation for conventional power plants in India is changing. Flexibility will play a substantial role for coal-fired power plants in future.

Two reference power plants from NTPC were chosen, which were investigated in the conducted study.

Flexibility measures were identified for the reference power plants. These measures might serve as a showcase for other coal-fired power plants in India.

In the next step more detailed investigations are necessary before the implementation of the flexibility measures. This includes e.g. test runs.

Thank you very much for your attention!

For further information please visit us at www.steag.com