

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

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1 Introduction

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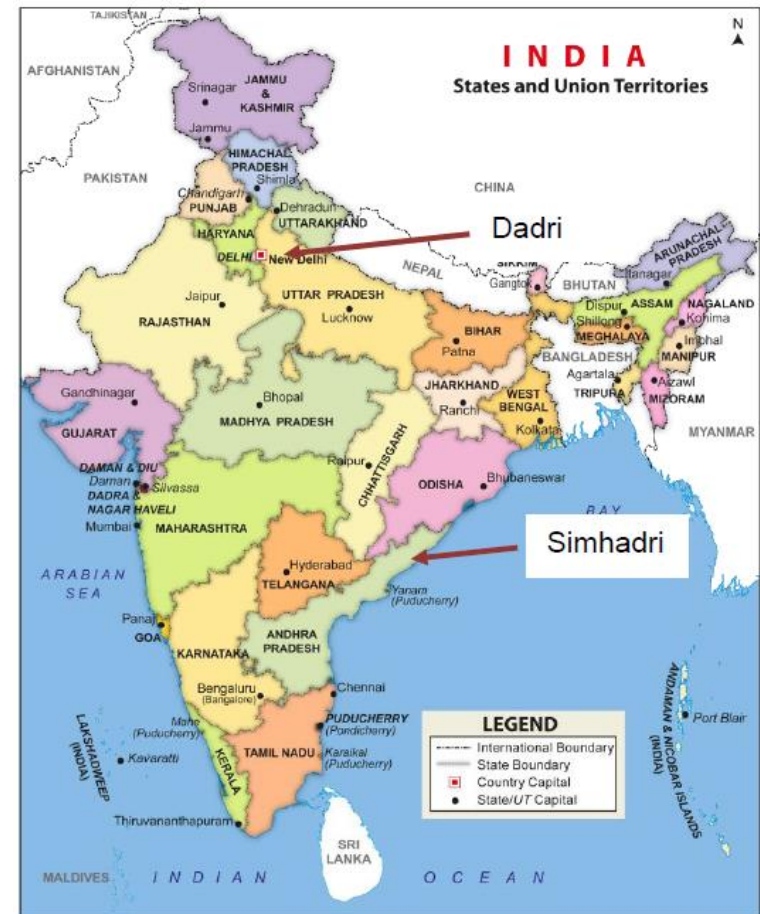
Goal of the study

- 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

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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.

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 <u>COLD</u> (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**

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 |

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.

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.

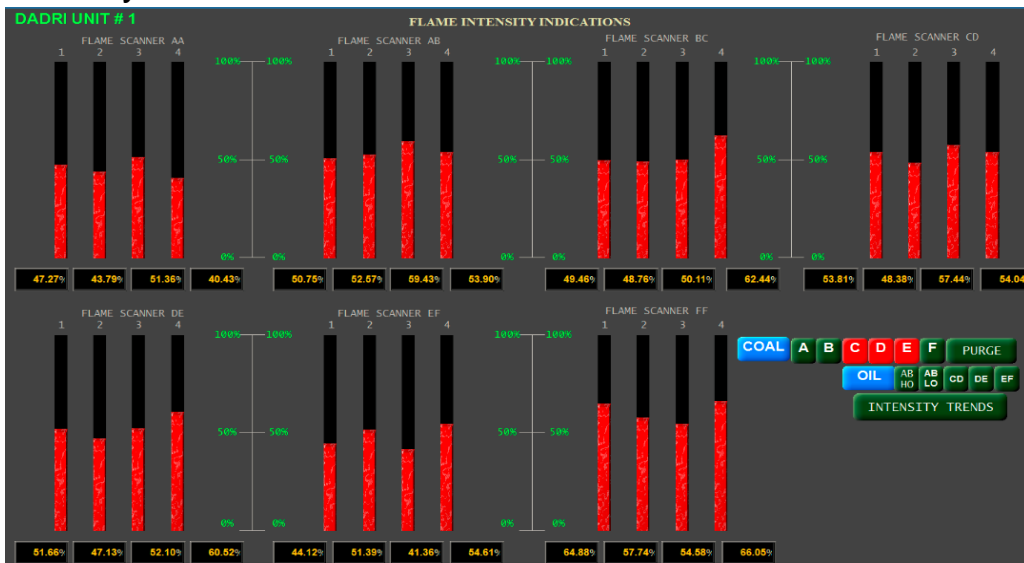
In addition, this measure might require modifications of the boiler safety system.

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.



MD4 – Combustion stability – Online management system:

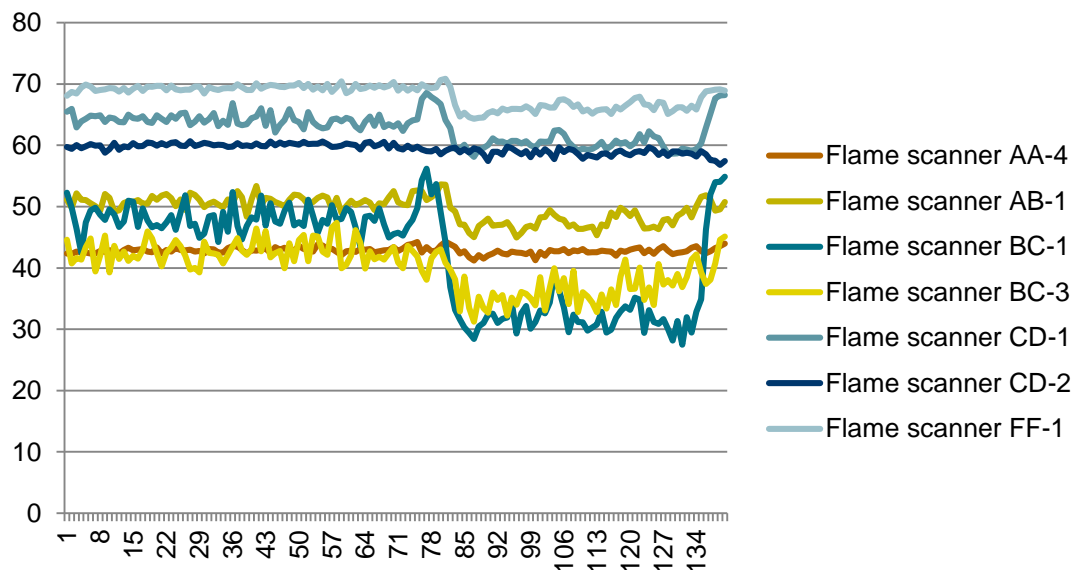
Combustion stability is the main limitation. The precondition of this low load operation is the use of real washed coal. It is recommended installing an online pulverized coal (PC) and air distribution management system to measure the air/fuel ratio to the coal burners in each PC pipe to the coal burners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

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.

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 weighing system shall be discussed with the respective OEM.

Adjustments shall be performed by the OEM during the implementation.

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.

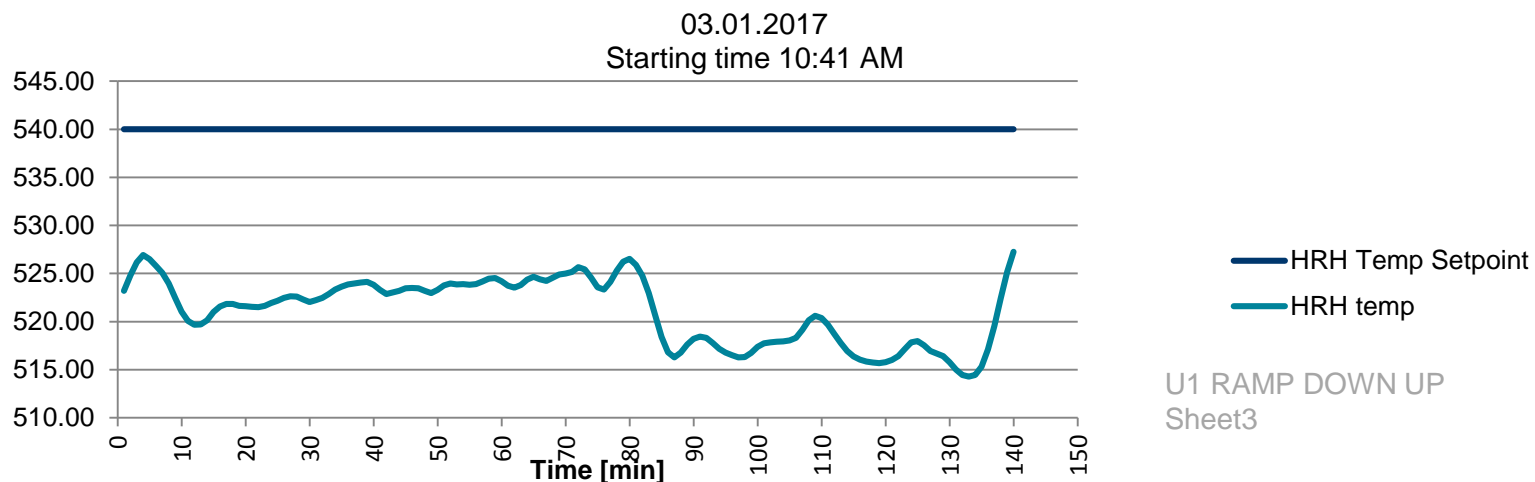
A manual sliding pressure operation is currently implemented. However, the turbine valves are already severely throttled. Therefore, it would be beneficial for low load operation to optimize the sliding pressure mode and to implement an automatic operation.

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.

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.



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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.

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**

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 | |

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.

MS3 – Combustion stability –Online management system:

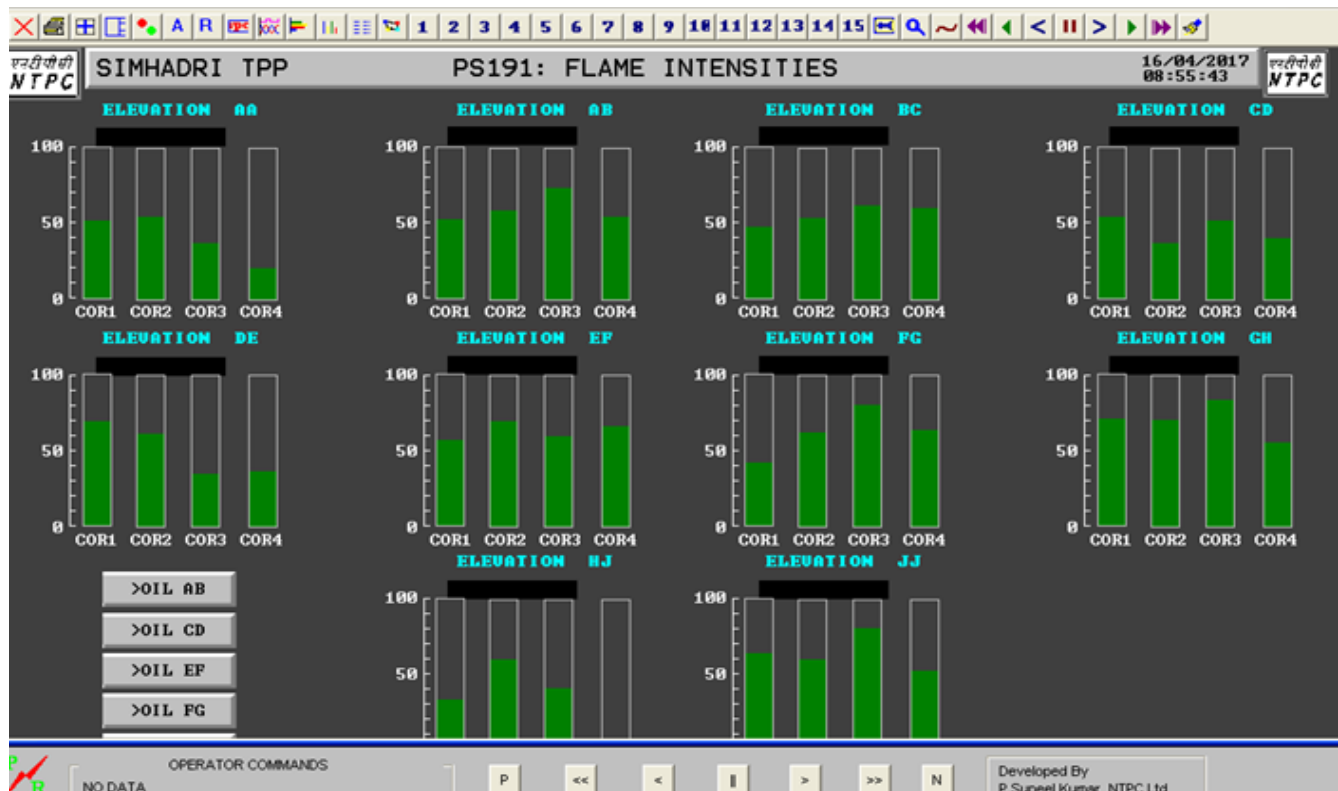
Combustion stability is the main limitation. The precondition of this low load operation is the use of real washed coal. It is recommended installing an online pulverized coal and air distribution management system to measure the air/fuel ratio to the coal burners in each PC pipe to the coal burners 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.

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.



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 weighing system shall be discussed with the respective OEM.

Adjustments shall be performed by the OEM during the implementation.

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.

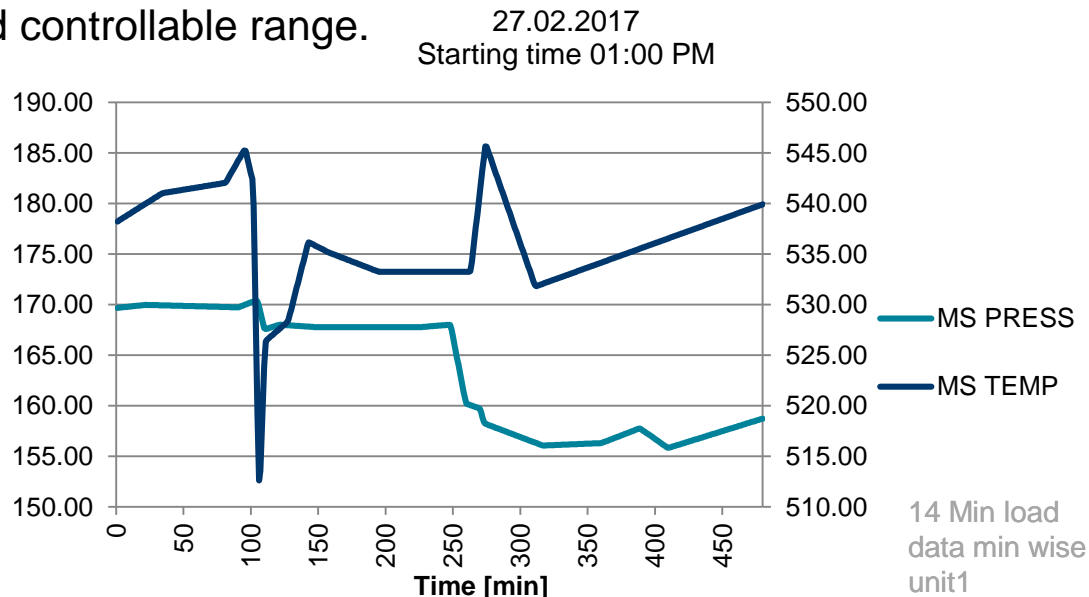
A manual sliding pressure operation is currently implemented. However, the turbine valves are already severely throttled. Therefore, it should be beneficial for low load operation to optimize the sliding pressure mode and to implement an automatic operation.

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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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

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 implementation |
|------------|--|-----------------------|---|--|-------------------------|
| 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 Start-up | C | 1 – 2 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 Start-up | C | 2 – 3 Precondition for further measures N/A Precondition for further measures | 1 to 2 months |
| MD6 | Online coal analysis | General | C | 2 | up to 6 months |

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 implementation |
|-------------|---|------------------------|------------------------|--|-------------------------|
| 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 |

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 <hr/> Start-up | C | 2 – 3 Precondition for further measures N/A Precondition for further measures | 1 to 2 months |
| 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 |

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 |
| | | <u>Min. load</u> | | | |
| MS8 | Advanced frequency control | 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 |

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.

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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!

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