Indo-German Energy Forum: Flexibility Case Study at Dadri and Simhadri –

An overview

Dr. Claudia Weise, December 1, 2017, Delhi

Agenda

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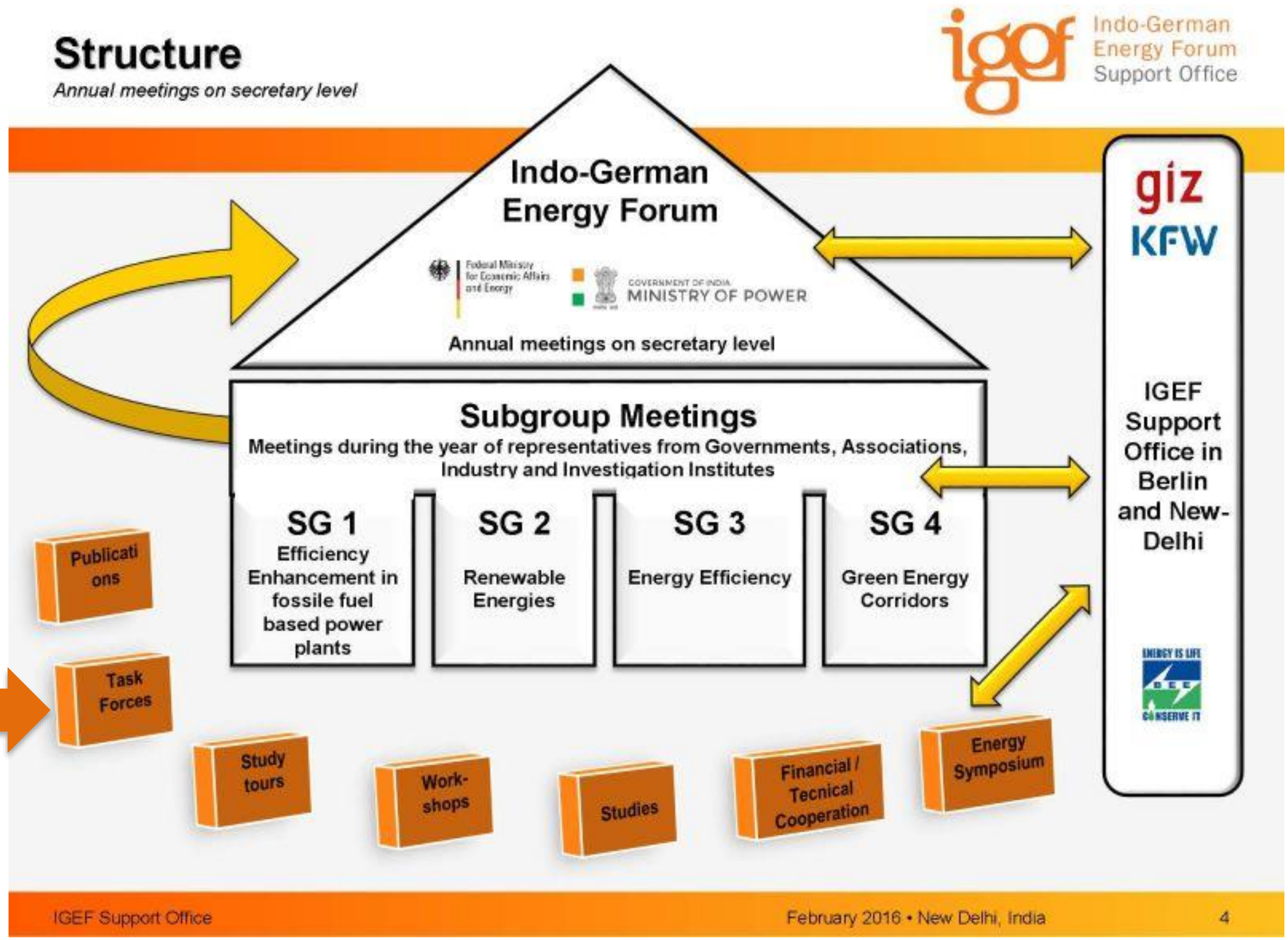
1. Indo-German Energy Forum: Task Force Flexibility

2. Introduction into the Case Study

3. Status quo of the Reference Plants

4. Key findings and way forward

Task Force Flexibility
Assignment „Adaptation of existing steam power plants to fluctuating renewable energies“



1. Work Programme of the Task Force

	Technical Study	Capacity Building	Framework
Modules	Technical Study	Capacity Building	Framework
Tasks (Phase 1: 2016/2017)	Reference plant assessment	Study tour of Indian delegation to Germany	Compile today's frame-work conditions in India
	Study on flexibility potential and accord. Measures	Flexibility workshop for dissemination	Study on an optimized regulatory framework for India
	Toolbox compiling ex-pertise and best practices	Training concepts on flexibility	
Tasks (Phase 2: 2017+)	Implementation of measures	Trainings / seminars on flexibility	
	Verification and synopsis of results	Long-term-secondment for a flexibility expert	
Results	**Ph 1:** Flexibility Ac-tion Plan + Toolbox **Ph 2:** Flexibility Reference Book	Group of Indian flexibility experts from various institutions	Regulatory Handbook

Phase 1: 2016/2017

Phase 2: 2017+

Indian members	**German members**
NTPC (K.K. Sharma, Director Operations = Chairman), EEC, CEA, POSOCO, BHEL	GIZ, VGB, KWS

4. What does flexible operation mean?

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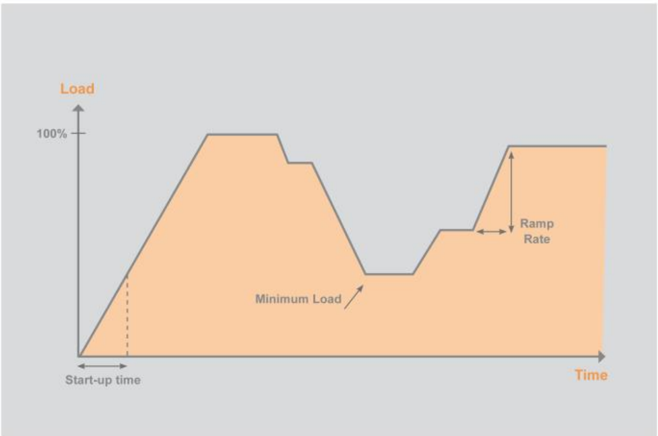

Minimum load operation

- important for the provision of residual load and for fast start up in case of high demand (e.g. two-shifting)
- more economic than shut-down of the whole plant

Advanced dynamics by high ramp rates

- high ramp rates ensure a fast reaction to changed market condition
- power plants with dynamic cycling abilities can participate in different markets

Short start-up and shut-down

- Short start-up and show-down times are beneficial to quickly respond to according market requirements (e.g. two-shifting)
- thermal stress during start and stop are most severe and causes life time consumption

Flexible operation aims at achieving low minimum load, high ramp rates and fast start and stop time. According measures might contribute to one or more targets.

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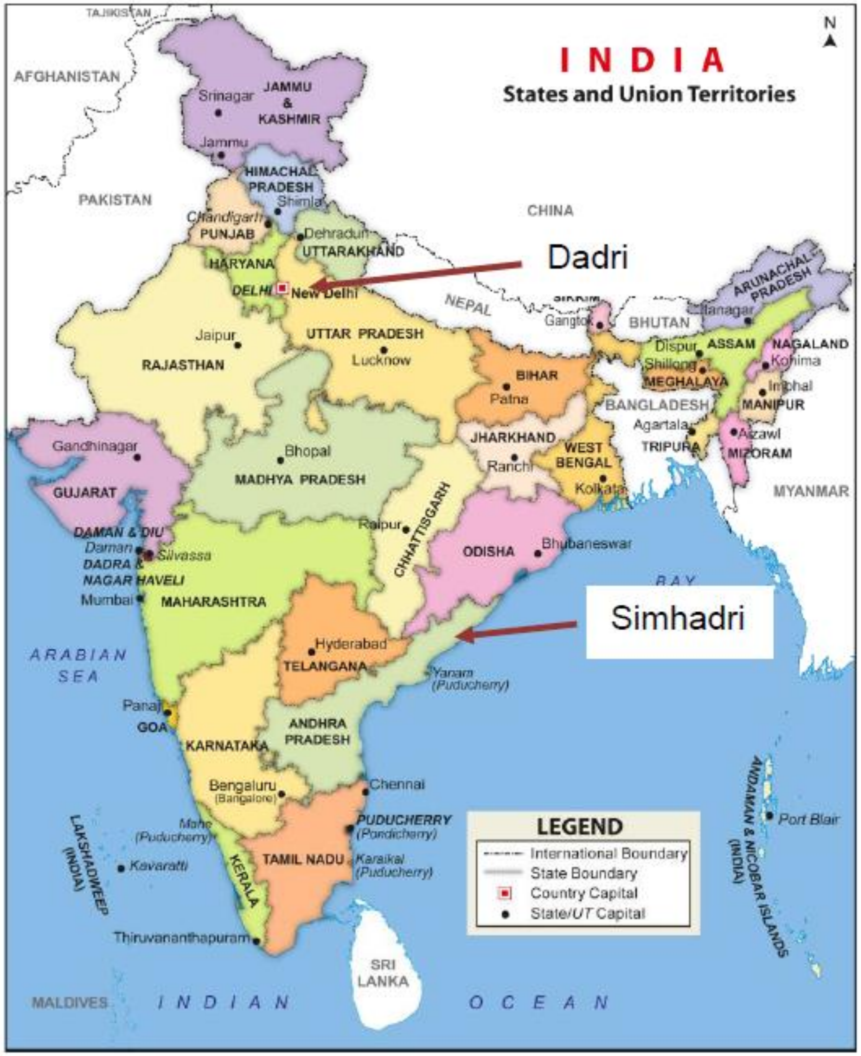
2. Case Study at the Reference Plants – Overview

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 MWel units in Dadri (State of Uttar Pradesh)
  - Coal-fired 500 MWel units in Simhadri (State of Andhra Pradesh)

  Both power plants are operated by NTPC



Source of the map: www.embassyindia.es

2. Case Study Methodology

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Step 1

Examination of the status quo of the plants

The operational data formed essential input for the study.

Step 2

Flexibility examination for the reference plants

Analysis of strengths, weaknesses and limitations of flexible operation – form the basis for deriving measures to enhance the flexibility of the plants.

Step 3

Assessment of the flexibility measures

Assessment of the flexibility measures based on operating experiences and best practices gained in German and European power plants.

Prioritization of flexibility measures related to their benefits and cost impacts.

Step 4

Proposal for an action plan for both plants

Based on the assessment, recommendations furnished for flexibility action plan.

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3. Status Quo of Dadri Power Plant – Key Figures

Capacity	Four units – 840 MW_{el} in total, 210 MW_{el} each unit
Start of operation	1991 to 1994 – unit I to unit IV
Boiler	▪ Natural circulation with single drum ▪ Directly fired by pulverized coal ▪ Six mills ▪ Manufactured by BHEL ▪ Tilting tangential firing
Fuel	Indian coal from different sources (partly washed coal)
Turbine	▪ Nominal rating 210 MW_{el} ▪ Single-flow HP turbine, double-flow IP- and LP turbine ▪ Manufactured by BHEL – KWU design
Cooling	Closed cycle with natural draft cooling tower

3. Status Quo of Dadri Power Plant – Main Process Parameters

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Auxiliary consumption	Approx. 5 %
Live steam parameters	151 bar, 537°C
Live steam flow	700 t/h at BMCR 645 t/h at 210 MW_{el}
Hot reheat steam parameters	38 bar, 537°C
Boiler efficiency at 210 MW_{el}	87.28 %
Feed water inlet temperature	246 °C
Turbine	Nominal rating 210 MW_{el} Peak load 229 MW_{el}
Design back pressure	0.1 bar
Generator	MVA rating: 247 Efficiency: 98.55 %

3. Current Flexibility Parameters of the Dadri Power Plant

	Current value	Value according to design	Potential
Minimum load [MW]	134 – 147	126	50*
Exemplarily COLD start-up time [h]	6	4	3 – 4**
Ramp rate	2.0 – 3.5 %/min (test runs)	---	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

3. Status Quo of Simhadri Power Plant – Key Figures

Capacity	Four units – 2,000 MW_{el} in total, 500 MW_{el} each unit
Start of operation	2001 – unit I and II, 2011 to 2012 – unit III to unit IV
Boiler	▪ Controlled circulation with single drum ▪ Directly fired by pulverized coal ▪ Nine / ten mills ▪ Manufactured by BHEL ▪ Tilting tangential firing
Fuel	Indian coal from different sources as well as imported coal
Turbine	▪ Nominal rating 500 MW_{el} ▪ Single-flow HP turbine, double-flow IP- and LP turbine ▪ Manufactured by BHEL – KWU design
Cooling	Closed cycle with natural draft cooling tower

3. Status Quo of Simhadri Power Plant – Main Process Parameters

Live steam parameters	166.7 bar, 537°C
Live steam flow	369 kg/s
Hot reheat steam parameters	Stage 1: 39.6 bar, 537 °C Stage 2: 39.6 bar, 565 °C
Boiler efficiency at 500 MW_{el}	84.85%
Feed water inlet temperature	253 °C
Turbine	Nominal rating 500 MW_{el} Max. load 524.2 MW_{el} (VWO – valves wide open)
Design back pressure	Stage 1: 0.1026 bar Stage 2: 0.1027 bar
Generator	588 MVA

3. Current Flexibility Parameters of the Simhadri Power Plant

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	Current value	Value according to design	Potential
Minimum load [MW]	350 (275 test run)	250	125*
Exemplarily WARM 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

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4. Key Findings

- 14 measures have been identified to increase flexibility in operation for both plants
  - Prioritized based on a cost-benefit analysis
  - Divided into **different load scenarios 50%, 40% and 25% minimum load** – low load (up to 25%) requires a certain coal quality
- Training programs should be set-up in parallel

There is a realistic potential to achieve minimum load levels up to 40% for both reference plants with technology and O&M adaptations.

Benefit

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

Cost

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

4. Action plan to reach minimum load of 50%

No	Measure	Scope
1	Re-assessment of O&M procedures	▪ Strict compliance to O&M requirements is mandatory. ▪ Enhancements of maintenance strategy – special focus on critical equipment. ▪ Awareness and competency of power plant personnel is important – training programs should be executed.
3	Test runs to evaluate the plant flexibility potential	▪ Transparency about the plant performance with respect to minimal load, start-up and cycling behavior with current set-up. ▪ Identification of constraints and process limitations as well as potential for improvements.
2	Optimization of automation and controls – main and underlying control loops	▪ Smooth control of major power plant processes is a flexibility enabler; e.g. precise steam temperature control. ▪ Optimization of the underlying control loops, i.e. coal supply, drum level and air control, is a basic requirement. ▪ Consideration of interlocks coming from logics.
4	Operation with a reduced number of mills	▪ Test runs, verification of accuracy of all relevant measurements and defined coal quality are pre-requisite. ▪ Comprehensive adaptation of the emergency shut-down system is likely to be required.

4. Action plan to reach minimum load of 40% and to fasten start-up

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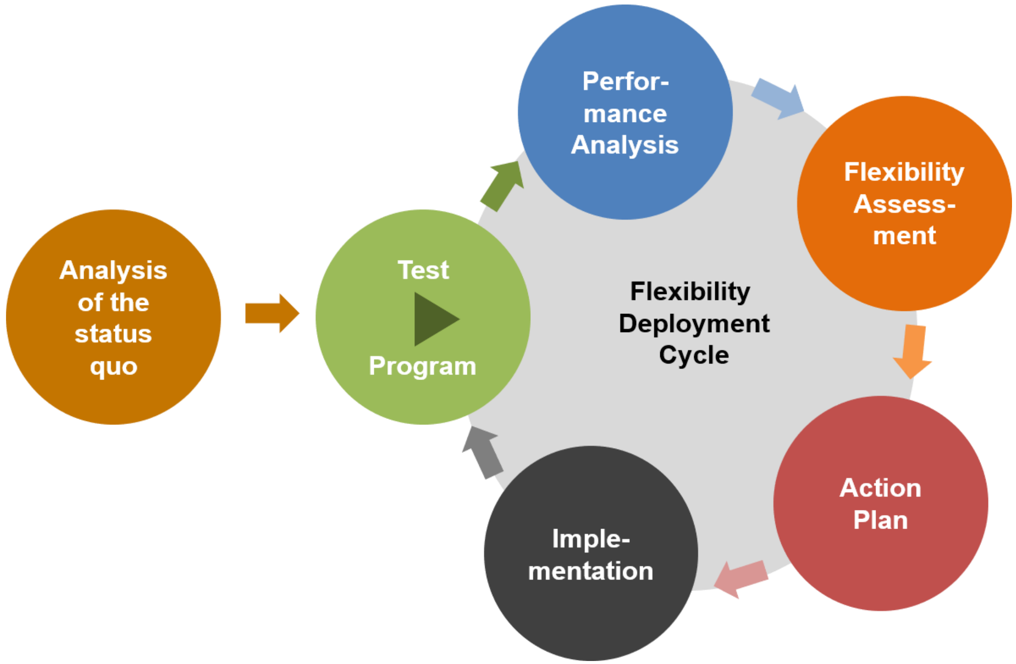
No	Measure	Scope
5	Reliable flame detection for each burner individually	▪ As proper flame detection plays a major role in guaranteeing a reliable minimum load operation and in terms of avoiding trips during start-up, the current hardware needs to be considered for potential replacement. ▪ This measure is essential to ensure proper combustion control.
6	Advanced frequency control resp. unit control (if frequency control is to be provided at 40% load)	▪ Manual interventions should be reduced to a minimum. ▪ Enhances the dynamic behavior of the plant and positively contributes minimum load and cycling operation (to provide 5% frequency control power). ▪ The main options are condensate throttling and throttling of the extraction steam for the HP pre-heater.
7	Check and potential replacement of start-up related temperature measurements	▪ The temperature measurements are crucial to optimize the start-up and shut down procedure and to manage life time monitoring in a most efficient way. ▪ FEM analysis would be beneficial for the re-assessment of admissible temperature limitations.



- **Implementation stage 1:** The measures 1 to 4 – to achieve 50% load – are to be implemented near term. The timeline comprises up to 6 months.
- **Implementation stage 2:** The next phase – measures to achieve 40% load and start-up optimization – will be initiated after stage 1. The duration of these activities is 12 months.
- Strong involvement of OEMs as well as training programs are essential.

धन्यवाद

Thank you
for your interest!

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1. Installed Capacity in India and Germany

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Install. Cap. [GW]	Total	Renewables				Thermal				Nuclear
		Solar	Wind	Hydro*	Bio-mass	Gas	Diesel	Coal	Lig-nite	
India**	314.6	9.0	28.7	48.5	8.0	25.3	0.8	188.5	-	5.8
		94.2				214.6				
Germa-ny***	197.3	40.9	49.6	5.6	7.1	29.9	4.2	28.3	20.9	10.8
		103.2				83.3				

*including all hydro; **as of January 31, 2017; ***as of December 31, 2016

Type of coal	Calorific value [kJ/kg]	Ash content [%]	Water content [%]	Sulphur content [%]
Indian coal	11,715 – 20,900	25.0 – 50.0	10 – 20	0.30 – 0.80
German lignite	7,800 – 11,300	2.5 – 20.0	40 – 60	0.15 – 3.00
Imported hard coal applied in Germany	~25,000	7.0 – 15.0	9.0 – 12.0	< 1.0