

Steam Power Plants / Steam Generator

Enabling flexibility: thermal feasibility studies and condition monitoring

Unrestricted © Siemens AG 2018

EEC Conference, New Delhi, 30th Nov 2018

Contact page





Denis Tschetschik

Head of Mods & Upgrade Group Mechanical Engineering: HRSG/Fired Boiler, Balance of Plant

PG SO EN MTEC Tel: +49 1525 53 14 370

Freyeslebenstrasse 1 D-91058 Erlangen Germany

Unrestricted © Siemens AG 2018 Page 2 11/30/2018

Overview – Topics





- 1. Partload Issues for fired Steam Boiler
- 2. Part Load Test in Dadri 6 (NTPC Plant)
- 3. Results and recommendation
- 3.1 Thermal Feasibility Study
- 3.2 Boiler/BOP Fatigue Analysis
- 3.3 Optimization of Existing Controls

Condition Monitoring incl.

Boiler Fatigue Monitoring System (FMS)

1. Partload Issues for fired Steam Boiler







Part Load Challenges:

- 1. Fuel Composition (knowledge of the fuel composition and of the fuel properties incl. ash is very important for the steam generator design)
- 2. Fuel supply system (Mill operation diagram, Mill operation concept, Pressure drop, Air bypass flap, Control system, Mill classifier behavior, Mechanical restrictions of mill etc.)
- 3. Combustion (Fuel composition stability, Temperature/O₂/Concentration inturbulances, Symmetry of flame, Aerodynamics, Combustion efficiency, Emissivity, Support fuel)
- 4. Evaporator Stability (at first Benson Evaporator, Activated Burner Level) / ECO Stability for possible ECO outlet steaming
- 5. Boiler Outlet Parameters (HP/RH Temperature, Control system, Flue gas damper, Activated Burner Level, Attemperator)
- 6. APH (Water/Sulphur dew point), Flue gas pollution (ESP efficiency)
- 7. SCR (Operation temperature window)

Example of mill operation diagram (4 mills, Once- through boiler)

Low-NOx Vortex Coal Burner







Unrestricted © Siemens AG 2018 Page 6 11/30/2018 SIEMENS

Mass Flux Range in Drum- and Once-through (Benson) Boilers







Denis Tschetschik / Power and Gas

Page 7

Possible Solutions for pressure part (Evaporator/ECO/Superheater)



Measures	Effect
Design optimization of heating surfaces in heat flux critical zone Rifled tubes	 Reduction of thermal stress Increase of allowable heat flux Prevention of boiling crisis (DNB – Departure from Nucleate Boiling)
Retrofit / Re-design of attemperators	Improvement- / Increase of spray water mass flow Better water mixing (evaporation distance)
Orifice at Inlet / Outlet ECO, ECO Recirculation	Establishment of smooth and uniform flow distribution in the tubes
Orifice at Evaporator Inlet	Improvement of dynamic stability
Pressure compensation header in Evaporator	Improvement of dynamic stability
Upgrade of Superheater drains	Effective removal of condensate during start-up
Increase of RH outlet temperature for Part Load	Implementation of RH slide pressure curve, Activation of upper burner level, Activation of positive tilting of burner

2. Part Load Test in Dadri 6 (NTPC Plant)





Unrestricted © Siemens AG 2018 Page 9 11/30/2018

Part Load Test in Dadri 6 (NTPC Plant)

In 2006 the Indian Prime Minister and the German Chancellor established the Indo-German Energy Forum (IGEF) to promote an energy dialogue.

Various initiative and efforts were suggested and implemented in cooperation with the **Excellence Enhancement Centre (EEC)** – promoting Energy Efficiency and Energy Security in the Indian Power Sector.

As a part of this effort, NTPC aims at reducing minimum load in several power plants, including Dadri units 5 & 6.

A **team of EEC/VGB/Siemens representatives** were given the opportunity to test minimum load in **Dadri unit 6** on June 21st and June 22nd, 2018.



Unrestricted © Siemens AG 2018 Page 10 11/30/2018

Test for Boiler part stable load reduction Load regime during the minimum load tests





Page 11 11/30/2018

Test for faster load Ramp up / Ramp down between min and base loads Load regime during the ramp tests





3. Results and recommendation



Unrestricted © Siemens AG 2018 Page 13 11/30/2018

Results and recommendation



During the both tests, there were **no major thermal/mechanical restrictions** of the mills, combustion, air flow and flue gas, main steam/RH pressures and temperatures, drum level and economizer.

Recommendations:

- 1. Thermal Feasibility Study
- 2. Fatigue Analysis (FEM calculation)
- 3. Optimization of Existing Controls (Control and Automatic Mill Operation, fans, boiler feed pumps and mills automatically into operation, Main Steam Temperature Control, Reheat Steam Temperature Control, Flue Gas Temperature Control)
- 4. Condition Monitoring incl. Boiler Fatigue Monitoring System (Condition monitoring systems should monitor highly loaded boiler and piping components against creep and fatigue. Such a system monitors the temperature differences, pressure, and signals when the allowable limits during load changes have been exceeded)
 Unrestricted © Siemens AG 2018

Page 14 11/30/2018



A thermal feasibility study of the boiler and the turbine for minimum load based on test data is required in order to avoid long-term damages and limitations to the boiler and turbines systems.

Such a study would involve the evaluation of process limitations and an assessment of the influences of low load operation and temperature- and pressure gradients on the boiler and turbine components and equipment. Thermal and mechanical models of the plant will be constructed, calibrated with test measurement data and applied.

Since other Indian power plants are built with the same setup, these models can be used for the rollout into the 500 MW fleet.

Boiler thermal calculation software DEFOS

The thermal boiler model is constructed by using computer software **DEFOS** (boiler performance calculation tool developed under BENSON license), which permits a detailed representation of the thermodynamic and heat transfer processes across the complete boiler system based on engineering principles and analysis.

Boiler thermal model of flue gas segment:



----Street last have Test-size the sheet by ba-C Birthe The Real Property lies, and Date Sheet 1 100 Intel 1 and Parent's Tenii B Terril 1 ELfanting - Dity In the - 1 M All. Sol. Dot. Tom. No. feet 0 tion of O by fairs of in the lot has 10.1 in his hard be test/ - 101 in-mat Juck has a firmal hold int

Boiler thermal model of water/steam system:



Check of relevant firing boiler components during Feasibility Study

- Heating surface SH (thermodynamical, hydraulical, mechanical)
- > Piping (thermodynamical, hydraulical, mechanical)
- Drums/separator and evaporators (thermohydraulic, Benson)
- ECOs (thermodynamic, hydraulic, bypass)
- Flue gas part (slaging, fouling, velocities, abrasion, pressure drop)
- ID/FD/PD- fans and other components
- Water desuperheaters, temperature control
- Casing; casing insulation
- > APH
- Control valves, Safety valves
- ≻ I&C
- Pumps
- Flashtank





3.2 Boiler/BOP Fatigie Analyses Two origins of boiler fatigue



Fatigue from cyclic operation

- During Start / Shutdown / Loadchanges: Changing steam pressure and steam temperature
- Result: Alternating Stresses at boiler pressure parts
- Cracks occur after a certain number of cycles depending on Stress variation range

Creep fatigue

- Material strength reduces during steady state operation at high temperature and at high pressure
- Cracks occur after a certain operation time



Unrestricted © Siemens AG 2018 Page 18 11/30/2018 At Siemens MTEC we calculate the percentage of fatigue with

FEM-Simulations



Denis Tschetschik / Power and Gas

What are FEM-Simulations?

Boiler/BOP Fatigue Analysis

FEM = <u>Finite Element Method</u>

- FEM is a numerical method to compute the physical
- The system is split into small sections, which "Finite Elements"

General fields of application

- Mechanical Simulation: Stresses, deformations, ...
- Thermal Simulation: Heat conduction, temp. fields,
- Fluid Dynamics: Flow distribution, flow velocities,
- Modal Analysis: Resonance frequencies,
- Electromagnetic Analysis: Magnetic fields,
- etc.

Page 19



11/30/2018







Our Approach and Advantages of FEM-Simulations



Our Approach	
Thermal-Transient Simulation to calculate the temperature	
distribution during Start & Shutdown	
Static-Mechanical Simulation to calculate stress trends from	
thermal and mechanical stress	
Evaluation of stress variation range according to DIN EN 12952-3	
to calculate the fatigue of one loadcycle in %	
Calculation of creep fatigue according to DIN EN 12952-4 with	
⁴ the software Probad	
Extrapolation of current and future component fatigue based on	Calculate Integra of HBSG compositor.
Startup-counting and future load regime	

Advantages compared to simplified method

- More accurate boundary conditions
- More precise stress calculation

- Assessment of welds possible
- "Complicated geometries" possible

Selection of SPPA-P3000 References Profitable, reliable and flexible plants - worldwide





Parish, USA

- Low Loss Start
- Minimum Load Reduction
- Fast Ramp



ValesPoint, Australia

- Fast Ramp
- Temperature Optimizer
- Minimum Load Reduction
- Low Throttling



Callide, Australia

- Fast Ramp
- Maximum Load Plus
- Temperature Optimizer
- Dispatch Control



Neurath, Germany

- Frequency Control
- Dispatch Control
- Low Throttling
- Minimum Load Reduction



Elverlingsen, Germany - Combustion Optimizer - NO_x Reduction



Altbach, Germany

- Frequency Control
- Sootblower Optimizer
- Lifetime Plus



Dingzhou, China

- Dispatch Control
- Temperature Optimizer
- Lifetime Plus



Cottam, UK - NO_x Reduction





To obtain further information, please contact: denis.tschetschik@siemens.com

This document contains forward-looking statements and information – that is, statements related to future, not past, events. These statements may be identified either orally or in writing by words as "expects", "anticipates", "intends", "plans", "believes", "seeks", "estimates", "will or words of similar meaning. Such statements are based on our current expectations and certain assumptions, and are, therefore, subject to certain risks and uncertainties. A variety of factors, many of which are beyond Siemens' control, affect its operations, performance, business strategy and results and could cause the actual results, performance or achievements of Siemens worldwide to be materially different from any future results, performance or achievements that may be expressed or implied by such forward-looking statements. For us, particular uncertainties arise, among others, from changes in general economic and business conditions, changes in currency exchange rates and interest rates, introduction of competing products or technologies by other companies, lack of acceptance of new products or services by customers targeted by Siemens worldwide, changes in business strategy and various other factors. More detailed information about certain of these factors is contained in Siemens" fillings with the SEC, which are available on the Siemens website, www.siemens.com and on the SEC's website, www.sec.gov. Should one or more of these risks or uncertainties materialize, or should underlying assumptions prove incorrect, actual results may vary materially from those described in the relevant forward-looking statement as anticipated, believed, estimated, expected, intended, planned or projected. Siemens does not intend or assume any obligation to update or revise these forward-looking statements in light of developments which differ from those anticipated.

Trademarks mentioned in this document are the property of Siemens AG, it's affiliates or their respective owners.

Editor and Copyright 2018:

Denis Tschetschik

Head of Mods & Upgrade Group Mechanical Engineering: HRSG/Fired Boiler, Balance of Plant

PG SO EN MTEC Tel: +49 1525 53 14 370 Freyeslebenstrasse 1 D-91058 Erlangen Germany

Subject to change without prior notice.

The information in this document contains general descriptions of the technical options available which do not always have to be present in individual cases. The required features should therefore be specified n each individual case at the time of closing the contract.

Unrestricted © Siemens AG 2018

Page 22 11/30/2018

3.3 Optimization of Existing Controls Condition Monitoring incl. Boiler Fatigue Monitoring System (FMS)

The situation:

A power plant unit needs to be operated at the most profitable operating point at all times. This generally calls for greater **flexibility**, higher **efficiency**, better **availability** and lower **emissions**.



Our solution: SPPA-P3000 Process Optimization solutions

SIEMENS

Ingenuity for life

SPPA-P3000 Minimum Load Reduction Reduced minimum load level



Task

To upgrade the plant so that the specified minimum load level can be reduced and to make the plant capable of fast and low-stress load increases on demand in accordance with market requirements.

Solution

- · Use of robust state space controller for unit control
- Adaptation, optimization and setting of lower-level controls for new minimum load level
- Adaptation or addition of control sequences, burner and mill scheduler
- Provision of additional instrumentation where necessary

Benefit e.g. 500,000 €/a → Benefit calculation

- Reduced financial losses during off-peak periods
- Faster response to increased load demands as unit does not need to be shut down
- Avoidance of unnecessary startups and shutdowns

Minimum Load Reduction



The Minimum Load Reduction solution results in savings for minimum load operation through optimization of lower-level controls.

Unrestricted © Siemens AG 2018

Page 24 11/30/2018

SPPA-P3000 Best Point Optimum steady-state plant operation



Task

To ensure fast provision of information about deviations from optimum operation and to calculate consequential costs for detection of improvement potentials

Solution

- Online calculation of key process data on the basis of a thermodynamic process model
- Validation of process data
- Interactive process analysis for "what if?" scenarios for the purposes of optimized operation and investment decisions

Benefit, e.g. 100,000 – 300,000 €/a → Benefit calculation

- Early detection of malfunctions and deviations from optimum operating point
- Reduced maintenance costs through qualified problem analysis
- Reduced power generation costs

Best Point



Rechenstatus OK (Schritt #5 Postpro)

Stationaritat la

Umgebungsdruck 1012.48 mitarabs AUSSENULFT-TEMPERATUR 9.59 °C NOX KAMIN KORR MW 150 71 mg/m² SO2 KAMIN KORR MW 120 71 mg/m² CO M KAMIN KORR 3356 mg/m² DK/W Wkgm netto DK/W Wkgm netto DK/W Wkgm NettaraZahi setta

APRIL PROVIDE HIGHLE



Kessel	hat .	Exp	ΔP	Δn		Luit / Rauchgas	lst	Exp	AP	40	
TEMP Frackdampl LIRE / FD-RUCK ZUE-Austrittatemperatur M ZUE EINSPRATZMENIGE S SPW-TEMP vor ECO LIRE SPW-TEMP vor ECO LIRE	542 12 235 64 538 07 32 33 272 86	545.92 °C 296.97 barg 538.17 °C 32.33 sh 273.80 °C	-0.30 MM -0.29 MM -0.32 MW -0.32 MW -0.49 MM	0.01%	0.05% 0.02% 0.08%	02 GEH KESSEL ENDE F RG-DIFF-DRX LLV 10 RG-DIFF-DRX LLV 20 EF110 Druckverhust REA Druckverhust RG-TEMP H LJ-LUV 10 RG-TEMP H LJ-LUV 10 RG-TEMP H LJ-LUV 20 Loxo10 RG Wriged Luve20 RG Wriged	4 52 14 81 14 21 0 44 1 41 10 69 157 24 190 69 67 24 68 35	4 20 % 13 33 mbarate 12 31 mbarate 2 05 mbarate 2 05 mbarate 16 29 mbar ate 16 29 mbar ate 16 21 % 149 97 °C 66 21 % 70 12 %	0.05 MW 0.30 MW 0.53 MW 2.60 MW 1.07 MW 0.07 MM 1.77 MW 0.07 MM 0.20 MW 0.29 MW 0.29 MW 0.47 MR	0.00% 0.00% 0.33% 0.33% 0.01% 0.22% 0.00% 0.00% 0.00% 0.00%	
Dampiturbine	łat	Exp	40	۵	n .	Kondensator	ist.	Exp	<u>AP</u>	Δn	
OT HD WikGel	87.76	87,71%	0.04 MW	0.01%	0	DRK KONDESATOR MW	-0.9760	-0.9628 berg	0.68 MW	o cers 🖞	
senstig	141	Ēφ	₹₽.	4	η						
SUMME EB	28.84	31.14 MW	2.29 MW	0.25%							

A thermodynamic plant model generates significant indicators for profit-optimized plant operation.

Unrestricted © Siemens AG 2018

Page 25 11/30/2018

SPPA-P3000 Uptime Plus Early detection of emerging damage



Task

Extensive condition monitoring of the plant processes to maximize availability and avoid costly reductions in performance and outages

Solution

- Earliest possible damage detection based on empirical values from plant's operating history
- Rapid and precise localization of an event thanks to alarms in the DCS
- Monitoring of all plant components and processes, also in quasisteady-state conditions
- Individual model generation for your plant

Benefit, e.g. 180,000 €/a → Benefit calculation

- Prevent unscheduled downtime
- Shorten scheduled outage times
- Plan maintenance and repair work in a proactive and anticipatory manner
- Minimize load on machines and components

Unrestricted © Siemens AG 2018

Page 26 11/30/2018

Uptime Plus



Condition monitoring with Uptime Plus detects possible damage at the earliest possible moment and thus creates more time for proactive measures

Boiler Fatigue Monitoring System (FMS)



Customer Challenge:

 Ensure maximum lifetime of HRSG and adapt operating modes to accordingly Calculation of the total theoretical lifetime of highly stressed components based on creep fatigue and low-cycle fatigue



Solution

- Determination of creep and low-cycle fatigue
- Component specific calculation acc to EN 12952
- Online calculation
- Long-term data storage

- > Transparency in relation to impact of operating mode on residual life
- Detection and prevention of high-wear operating modes
- > Optimum selection of point in time for requisite overhaul and inspection
- Cost-effective in-service monitoring and analysis
- Integrated into "T3000"