



**Dr.BS Babji and Tarun Mathur, ABB Corporate Research, Bangalore**

# Enhanced Performance of Boilers through Advanced Monitoring & Control

# Outline

- Introduction
- Advanced Control of Boiler
- Advanced Performance Monitoring of Recovery Boiler
- Conclusions

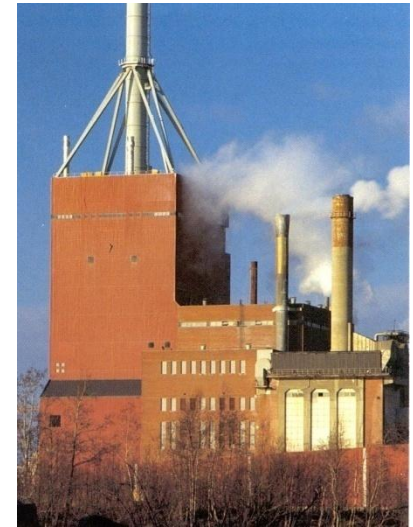
# Introduction

## Boilers

- Play major role in the operation of pulp & paper mill
- Generate steam for process heat and power generation and recovery of cooking chemicals

## Operational Objectives:

- Reduce process variability
  - Steam temperatures
  - Steam pressures
- Stable operation & chemicals recovery
- **Maintain process variables within constraints**
  - Boiler steam flows, pressures, and temperatures
  - Combustion air flows, feedwater flow rate
  - Turbine-generator power output
- **Respond quickly to process upsets**
- **Monitoring of performance parameters**



# Introduction - Advanced Control

Traditional single loop PID control – not satisfactory for processes with

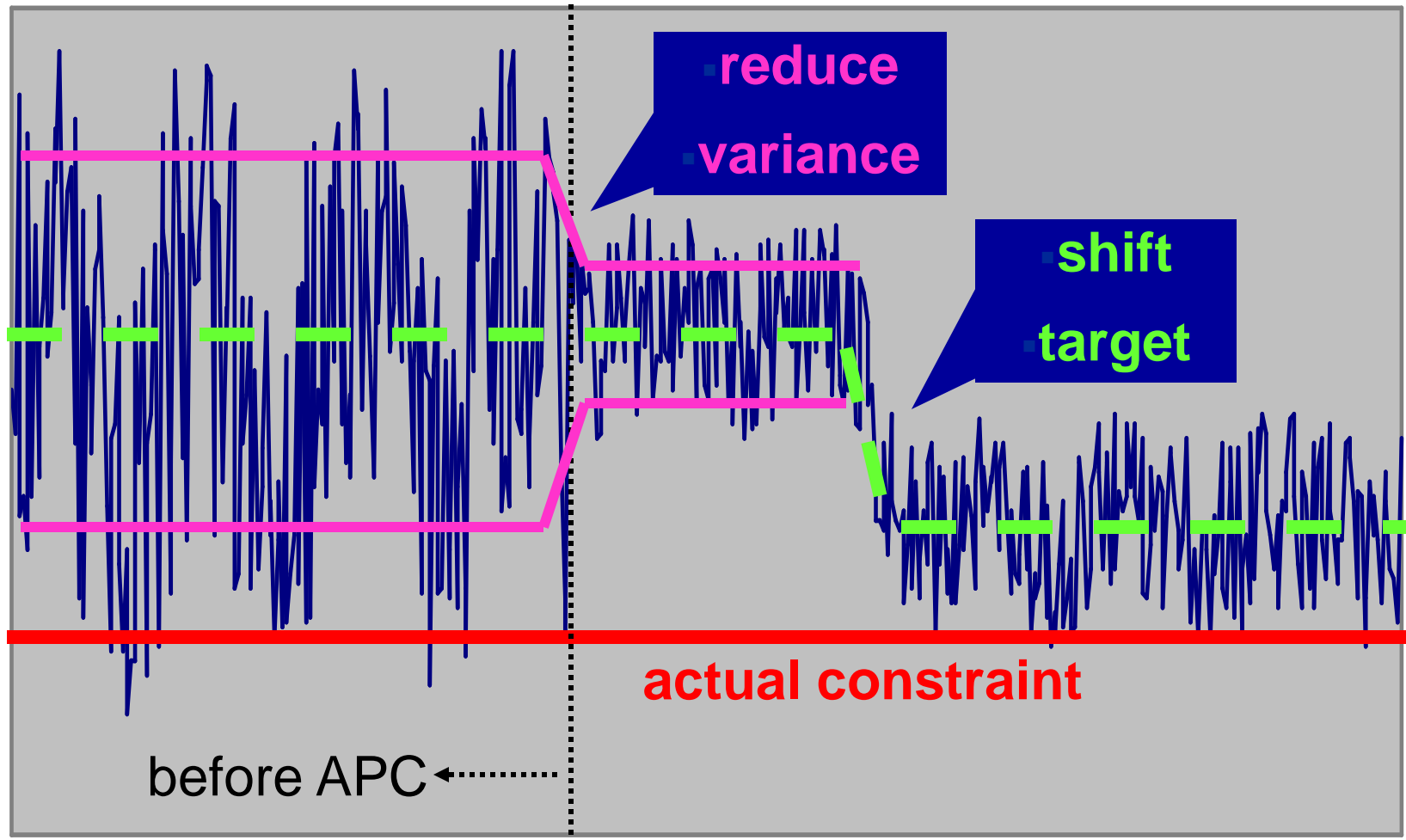
- Interactions among process variables
- Long delay times
- Large time constants
- Process disturbances

## Advanced Control

- Reduces variance in the process variables
- Lower variance keeps operation closer to optimal operating point or allows operation closer to operating limits
- Frequently optimal operating point is beyond the operating limits, so operation at the limits is desired

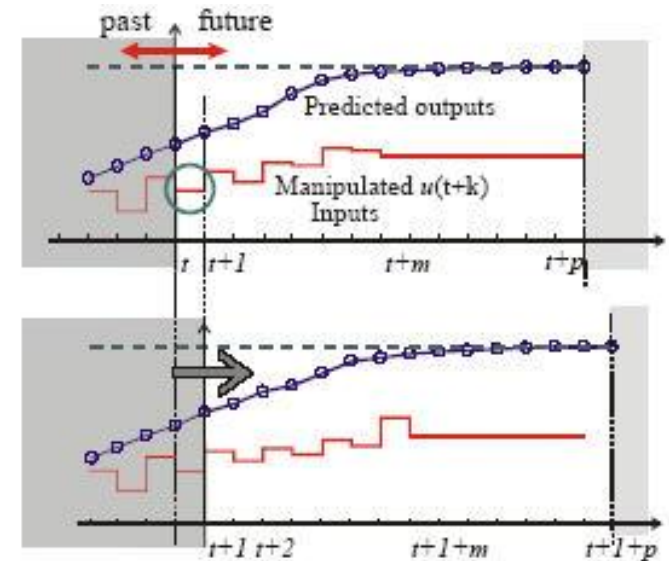
Therefore: **operating closer to the limits increases benefit**

# Introduction : Advanced Control



# Introduction – Multivariable Model Predictive Control

- A Multivariable Model Predictive Controller (MVPC) uses a mathematical model to quantify correlations between variables based on process data
- An empirical process model is developed and is used to predict output process behavior due to disturbances or changes of input variables
- The Controller uses these predictions to take small control actions and maintain output variables at their setpoints or within constraints
- Optimization calculations are performed at every sampling period to generate the required control actions
- Multiple inputs and outputs can be handled simultaneously



# Advanced Control of Boiler

# Advanced Control of Boiler

## Multi-variable model-predictive control

- Minimizes variation in process variables
- Built-in optimizer finds the optimum setpoints
- Brings the plant to the optimum in a graceful, coordinated fashion, without violating any of the numerous constraints
- Greatly simplified control structure
- Smooth transition from between different operating points

## Typical MVPC design

### Manipulated Variables

- Coal Setpoint
- Attemperator Spray Flow
- TG Throttle Valve Demand

### Feed forward variables

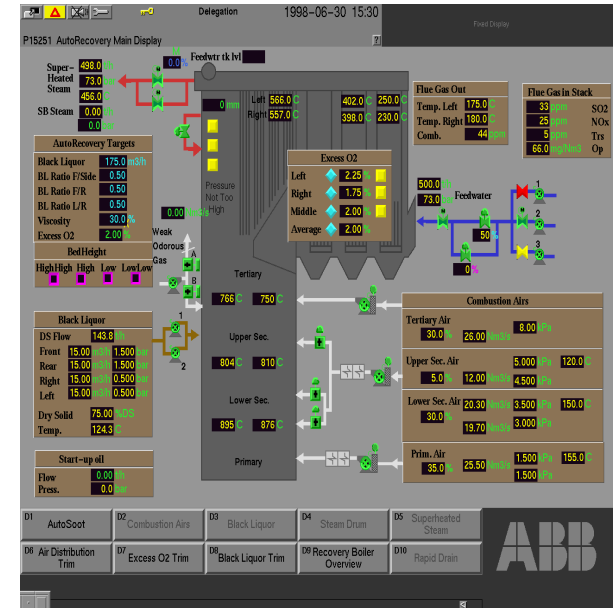
- Steam Flow
- Bark flow

### Controlled Variables

- Steam Temperature
- Steam Pressure

### Constraints

- Boiler Steam Flow
- TG Generator output
- Limits of coal flow
- Limits on attemperator spray flow
- others ...



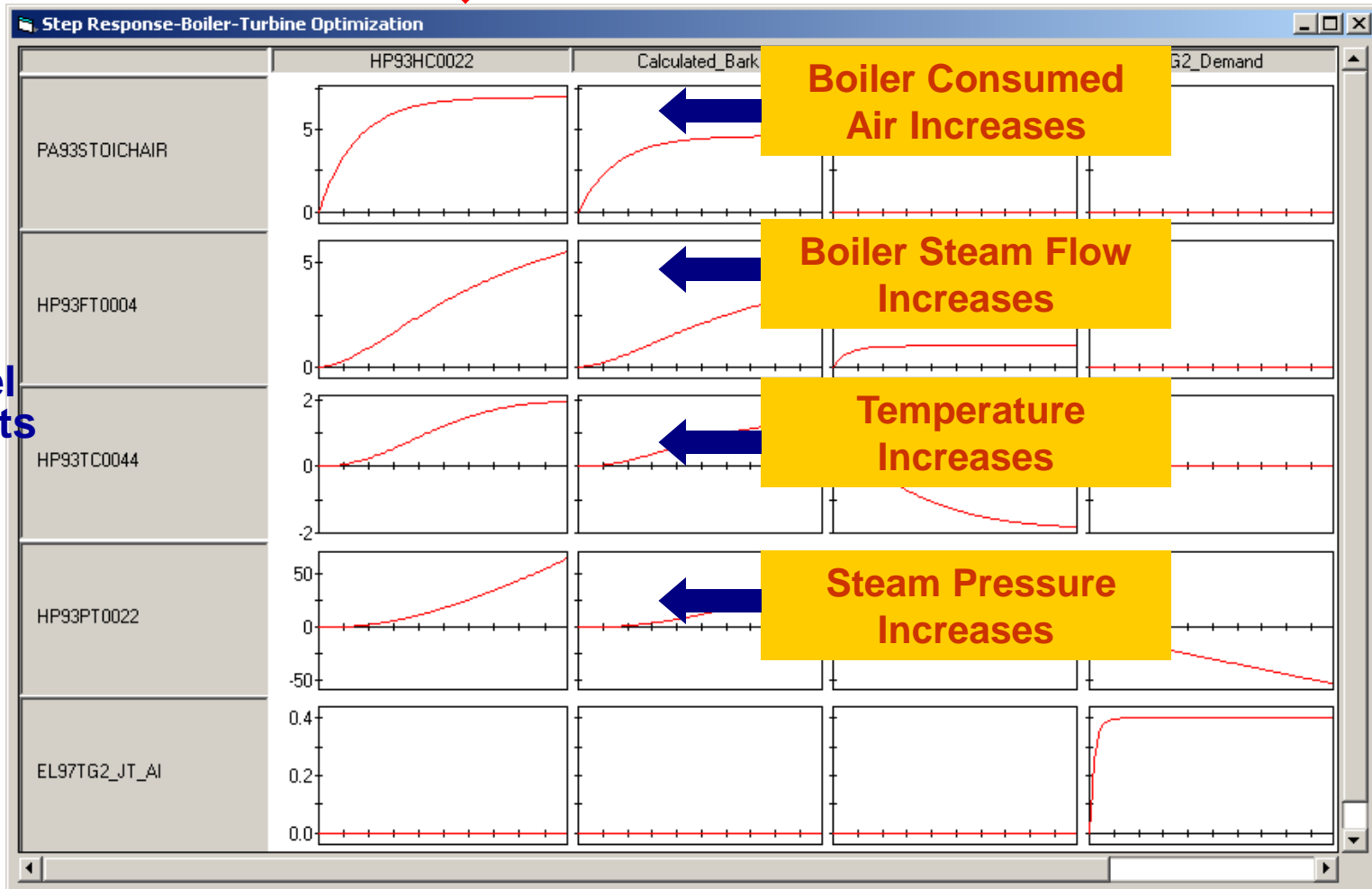
# Advanced Control of Boiler

Step Increase in  
Boiler Coal Input

Model Inputs

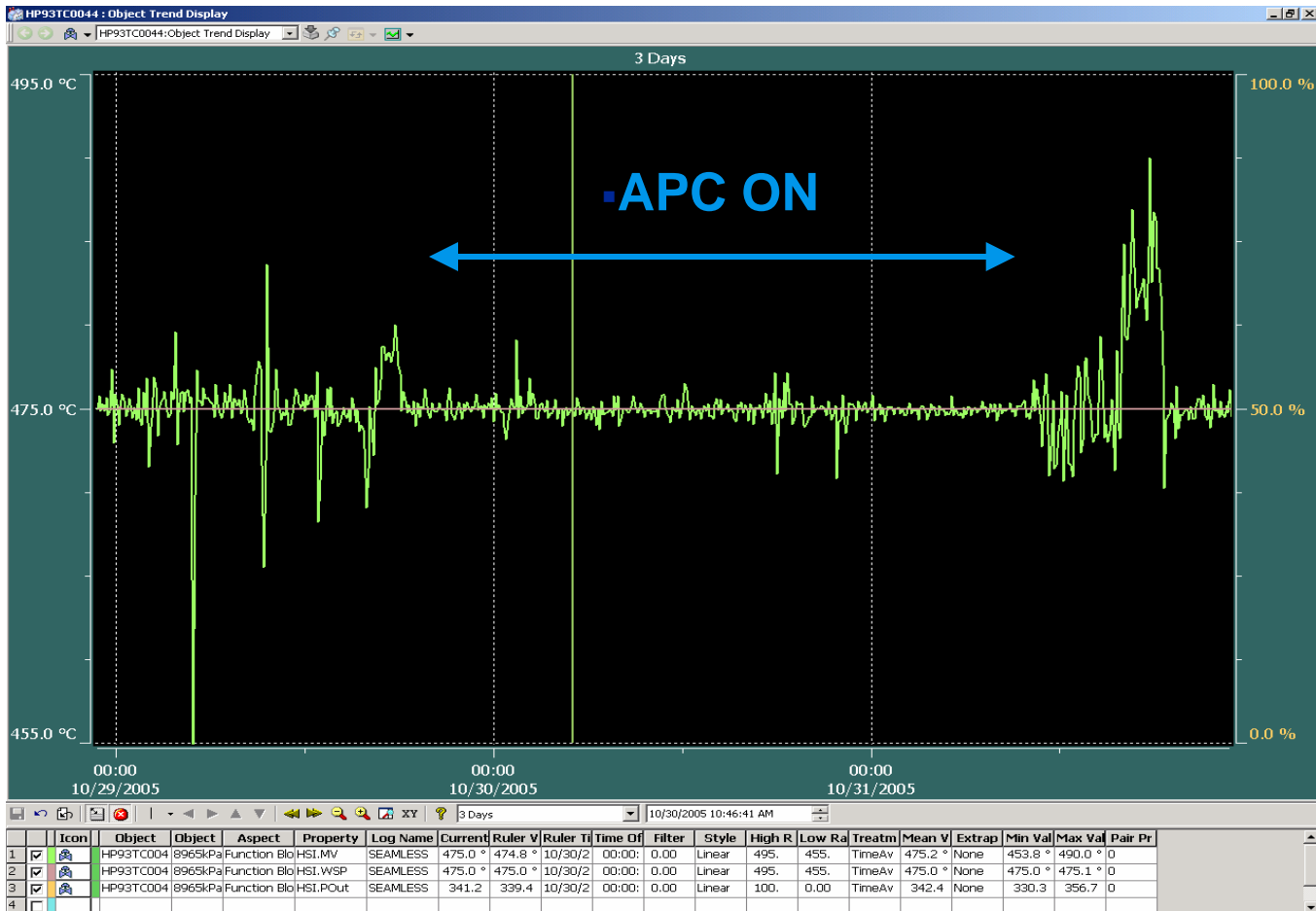


Model  
Outputs



# Advanced Control of Boiler - results

## Steam Temperature Control



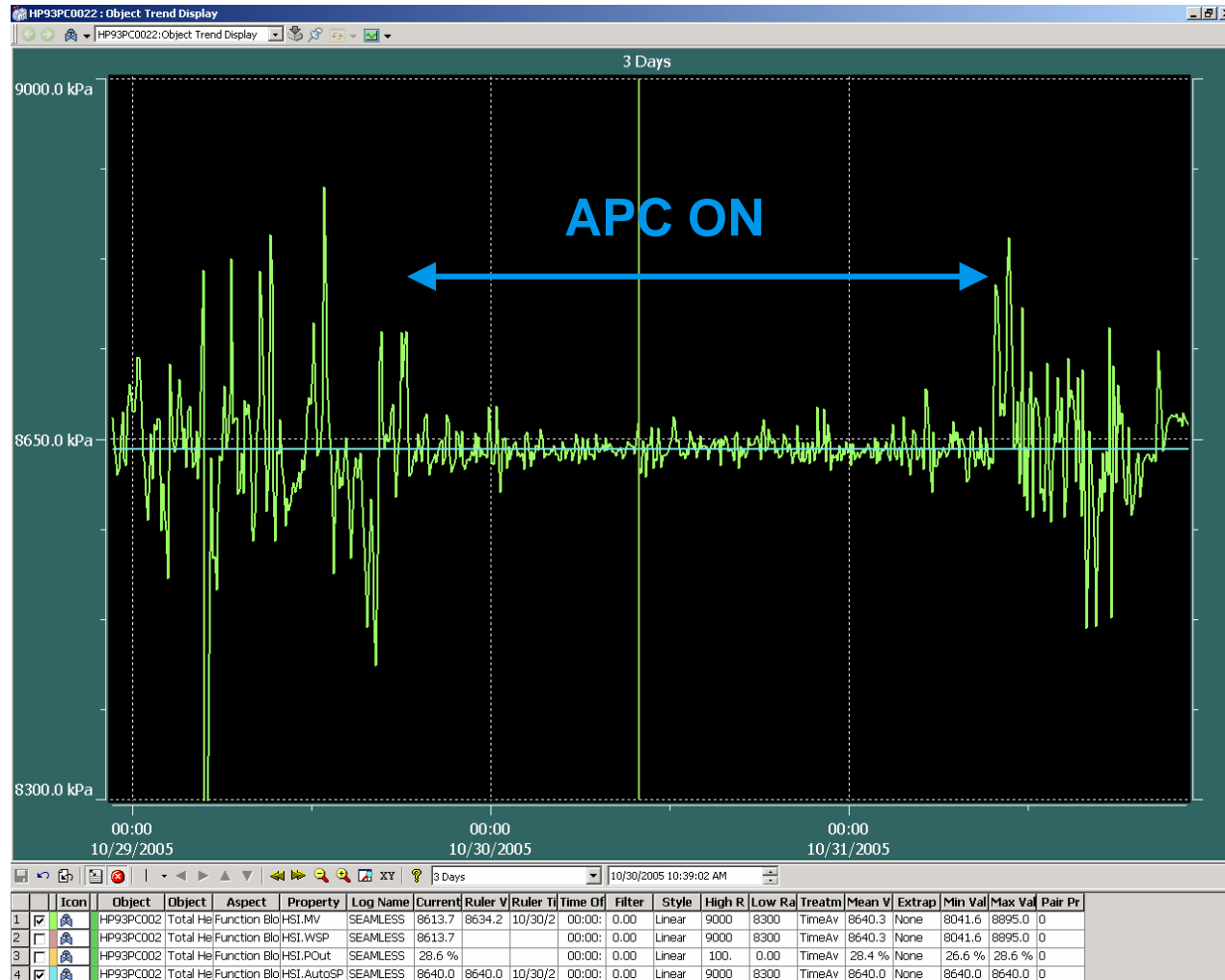
# Advanced Control of Boiler - results

## Steam Temperature Control

- Steam temperature standard deviation with **base** controls: 3.8 °C
- Steam temperature standard deviation with **APC**: 0.8 °C
- Average increase in steam temperature 7 °C
- 7 °C increase => 1.2 MWh of power

# Advanced Control of Boiler - results

## Main Steam Pressure Control



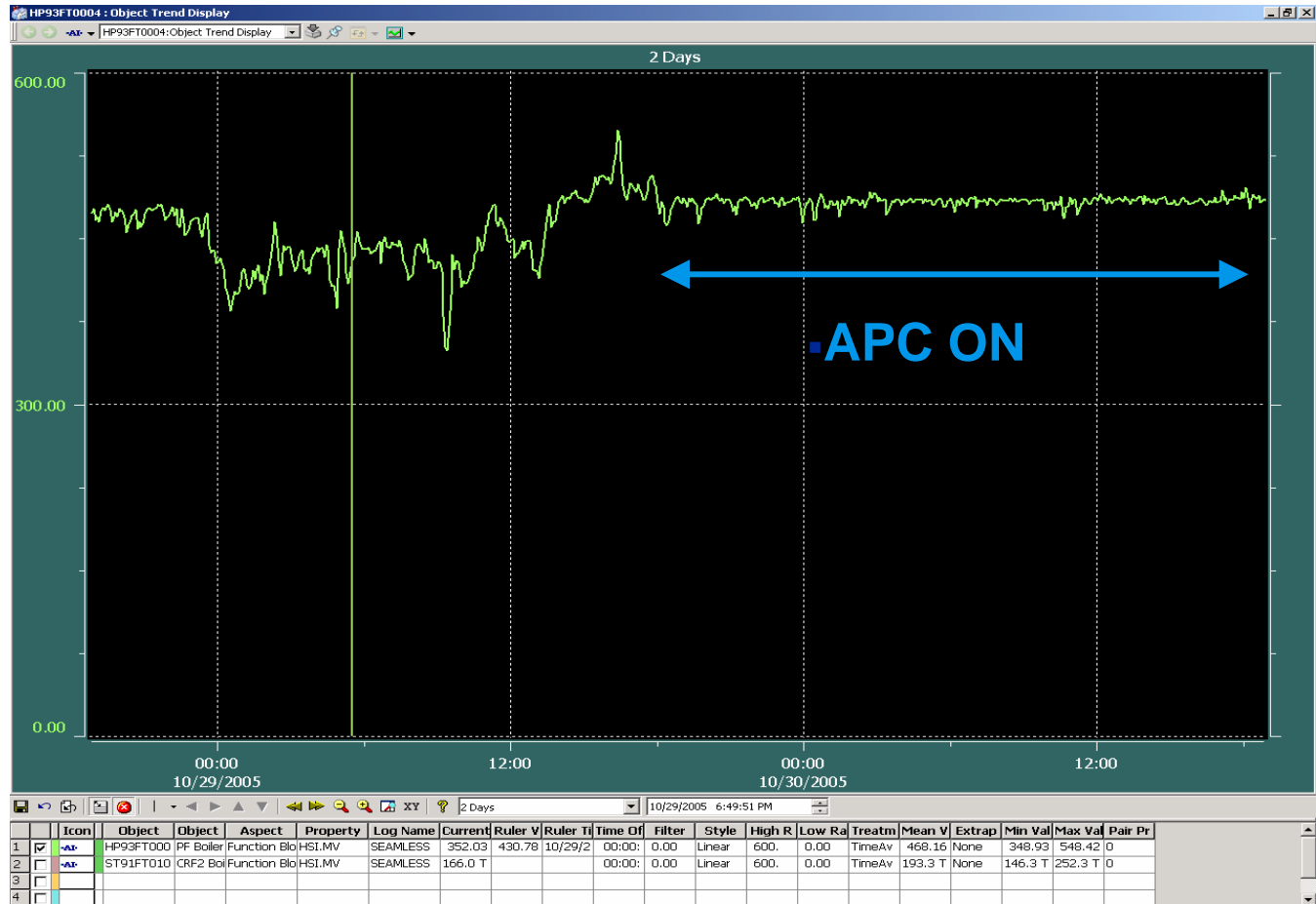
# Advanced Control of Boiler - results

## Main Steam Pressure Control

- Steam pressure standard deviation with **base** controls: **12.8** psi
- Steam pressure standard deviation with **APC**: **2.6** psi
- Benefits are indirect:
  - less thermal cycle stress on the high pressure parts
  - more stable operation and less operator intervention required

# Advanced Control of Boiler – results

## Steam Flow Control



# Advanced Control of Boiler – results

## Steam Flow Control

- Steam flow average control margin with **base** controls: **51** T/Hr
- Steam flow standard deviation with **APC**: **22** T/Hr
- Boiler steam flow increase potential: **29** T/Hr
- 29 T/Hr increase => **6.9** MW of power

# **Advanced Performance Monitoring of Recovery Boiler**

# Recovery Boiler in Pulp Mill

## Objective:

- Recover cooking chemicals
- Burn lignin and combustible gases to generate steam)

## Performance depends on

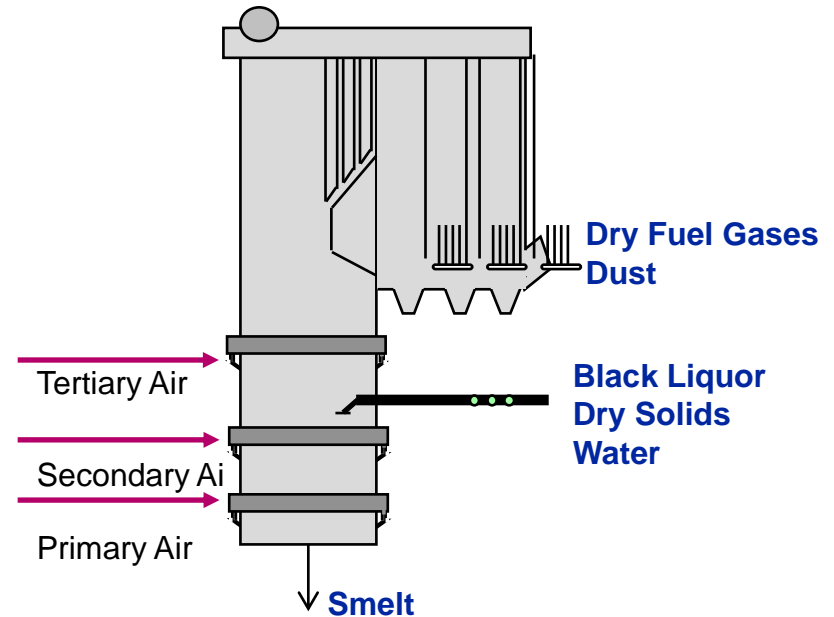
- Black liquor flow & Temperature
- Combustion airflow
- NCG flows
- Recycled flue gas dust

Combustion takes place in upper region

Reduction takes place in the smelt

Online monitoring of the performance ( combustion, reduction, bed height) is very much useful in efficient operation of the recovery boiler

A nonlinear model based approach for advanced performance monitoring of recovery boiler



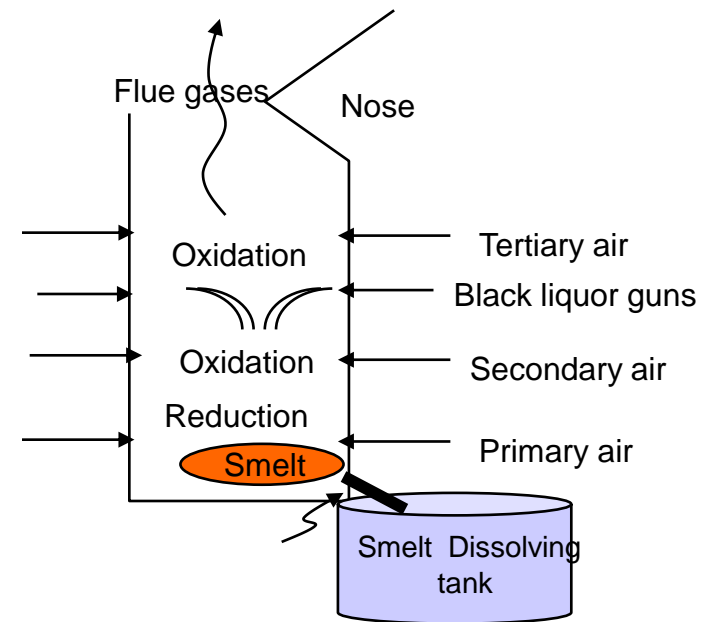
# Recovery Boiler Model

Features of the developed model:

- Object Oriented approach to modeling
- Developed in Modelica language
- Model based on heat and mass balances

Nonlinear rigorous Models for

- Furnace
  - Gasification, oxidation & reduction reactions
  - Heat transfer due to radiation
- Steam drum,
- Superheater,
- Economizer,
- Smelt dissolving tank, etc

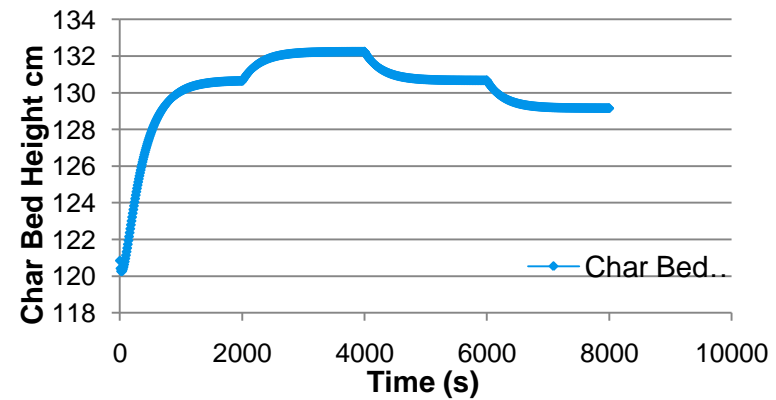
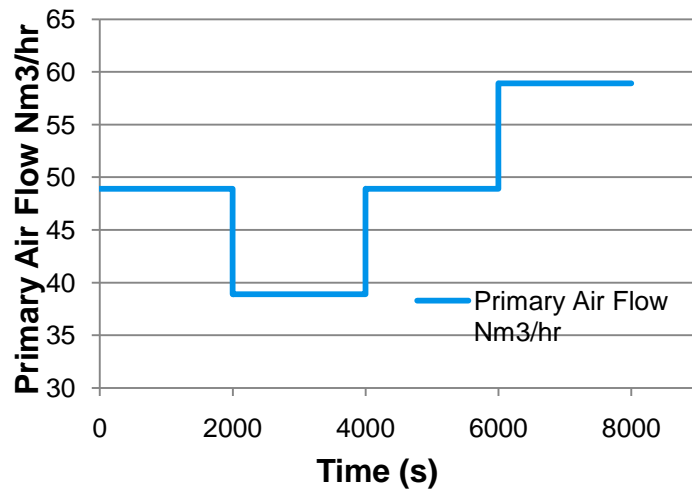
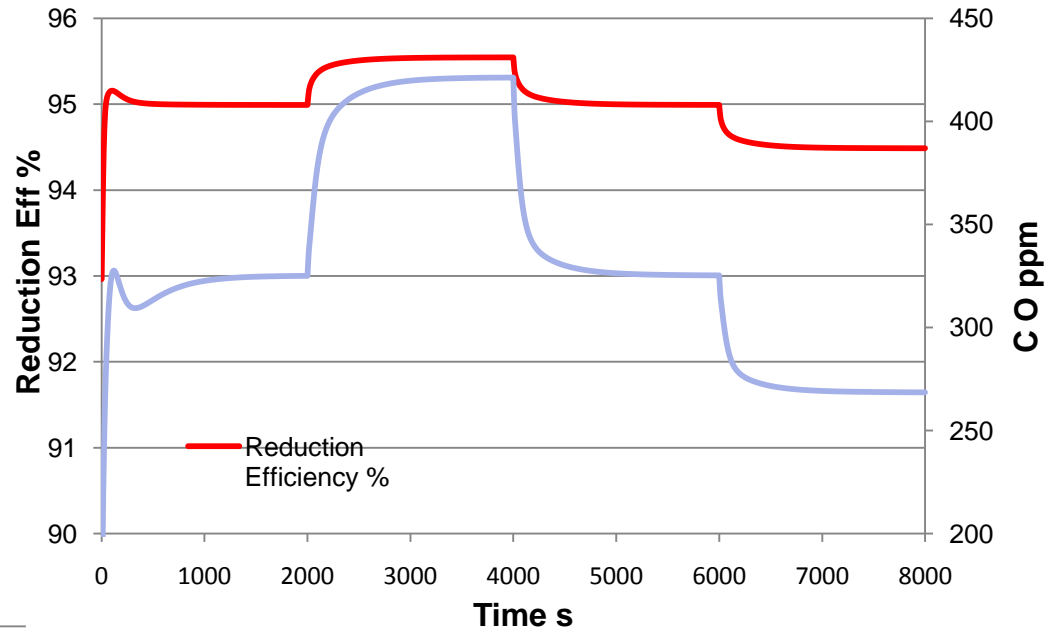


The developed model can be deployed for on-line monitoring of the performance

# Recovery Boiler Performance Monitoring

Use the model for

- on-line monitoring of key performance parameters
- Training the operators
- Development of better operation strategies



# Advanced Monitoring & Control of Boilers – Implementation

## Three-Phase Implementation Process



**Objective:**

- Identify opportunities and solutions
- Estimate benefits
- Proposal & Justification
- Establish Baseline

**Objective:**

- Engineering of the solution
- Commissioning
- Training

**Objective:**

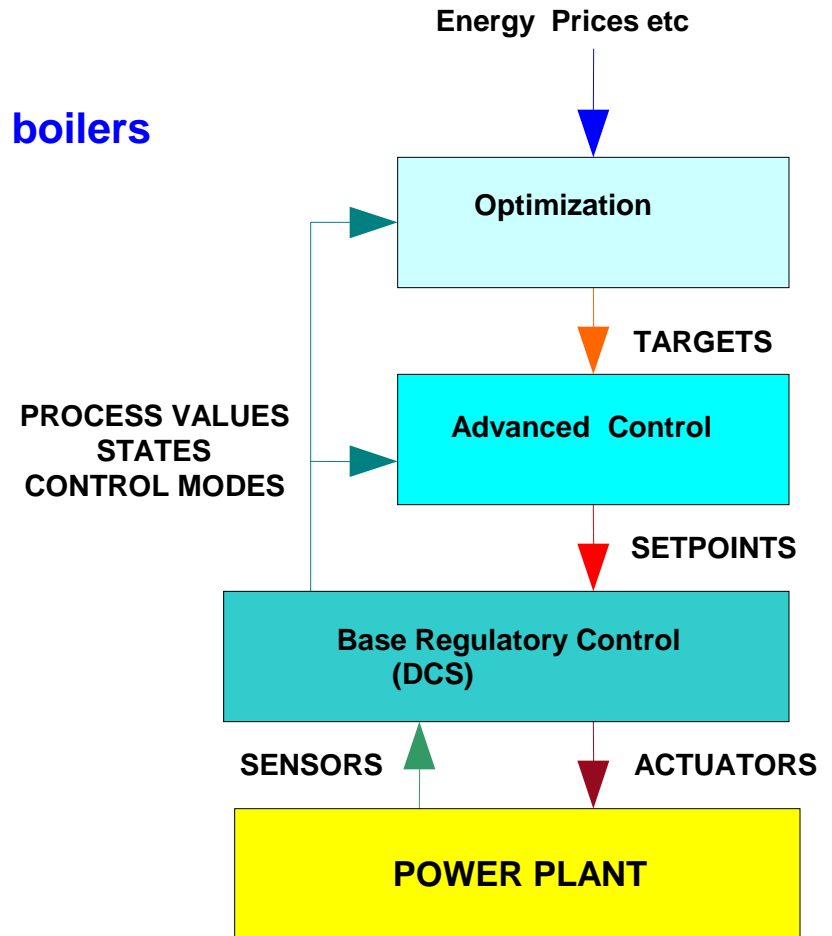
- Verification of savings
- Sustaining the results

# Conclusions

**Advanced Model based monitoring and control solutions help in improving the performance of boilers in pulp mills.**

## ABB's Layered Solution for Powerhouse

- Optimizer generates the target to the boilers based on energy prices etc.
- Advanced controls utilizes MVPC to coordinate all equipments and reduce the variation in process variables.
- MVPC connects to existing distributed control system (DCS) and downloads the setpoints to regulatory control loops



Power and productivity  
for a better world™

