Madrid, 25 y 26 de mayo de 2015

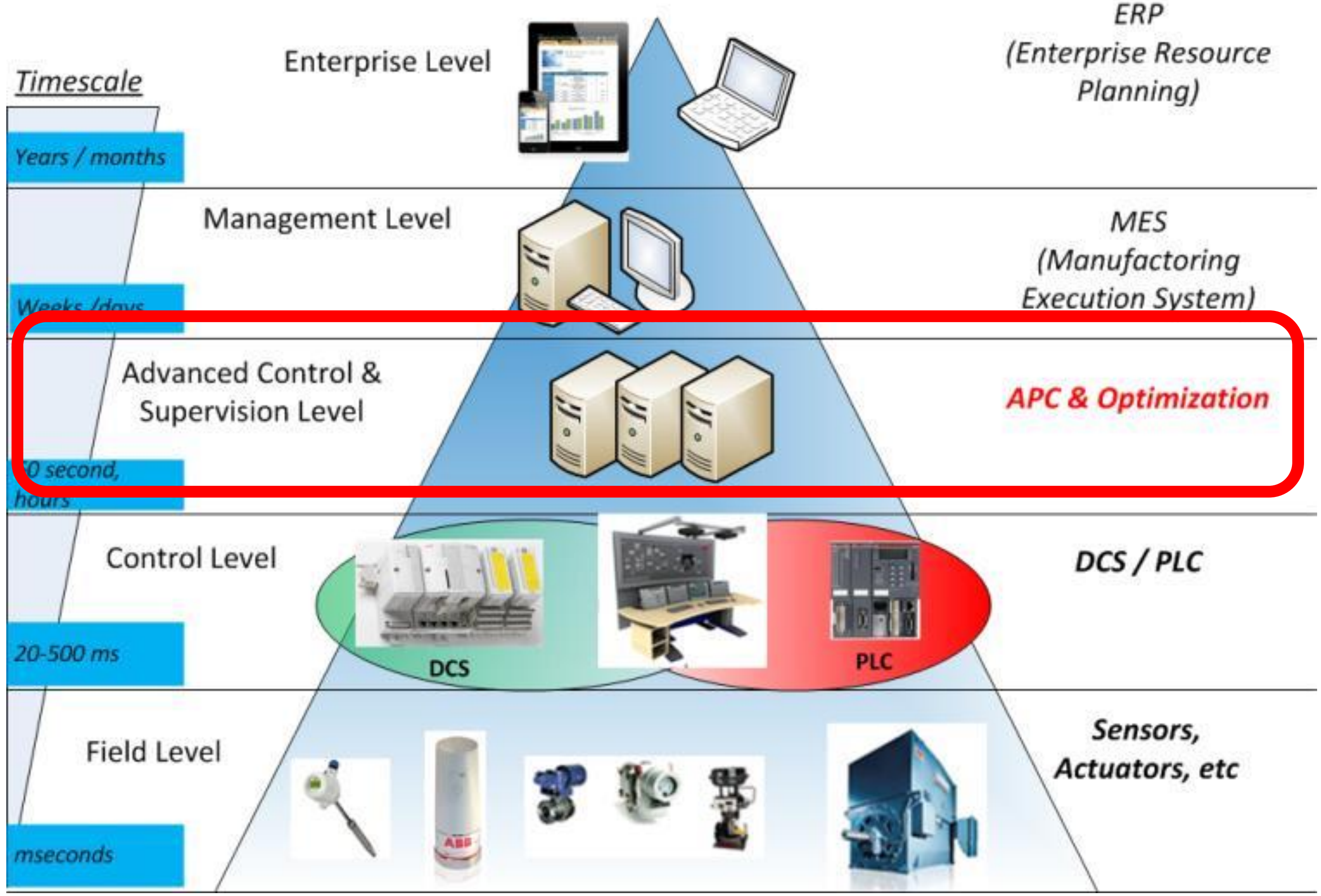
# ABB Automation Days
# Industrias de proceso y generación de energía

Power and productivity for a better world™

# Proposed agenda

- Introduction
  - APC Technology
  - ServicePort- Loop Performance
  - Predict & Control software
- APC Applications in Industrial Power Generation & Steam Networks
- Open Discussion

# APC & Process Optimization - Positioning

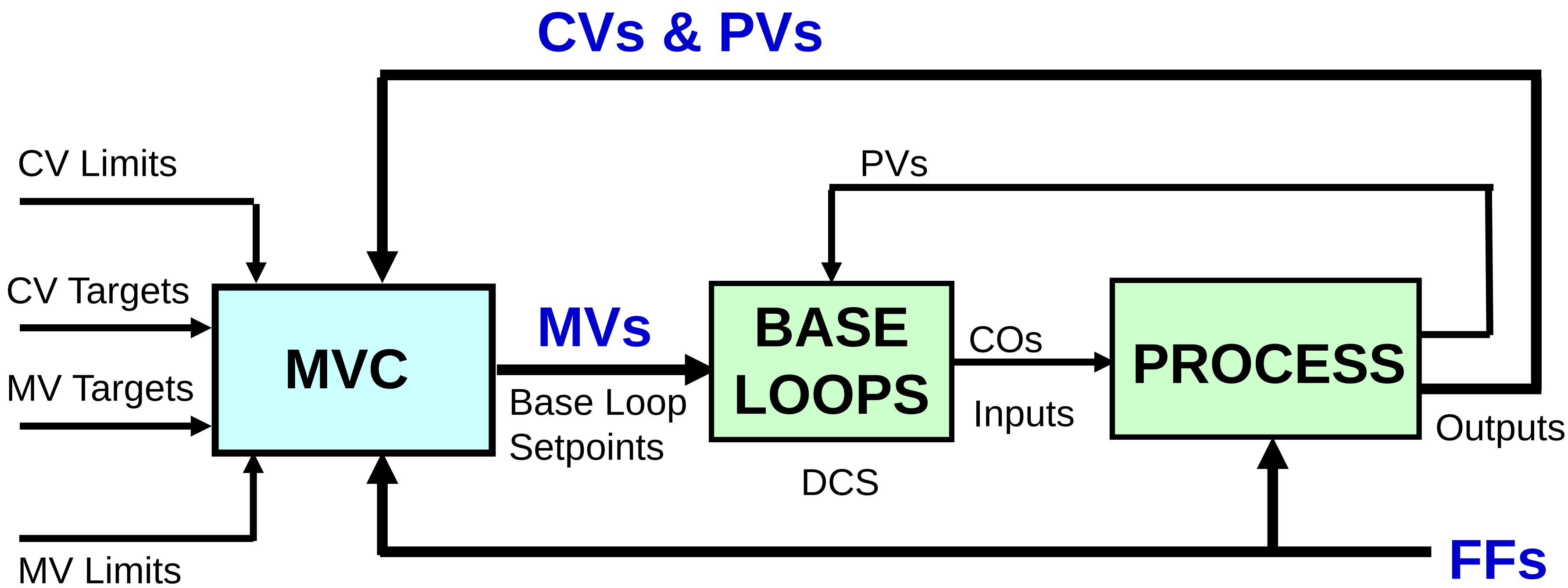






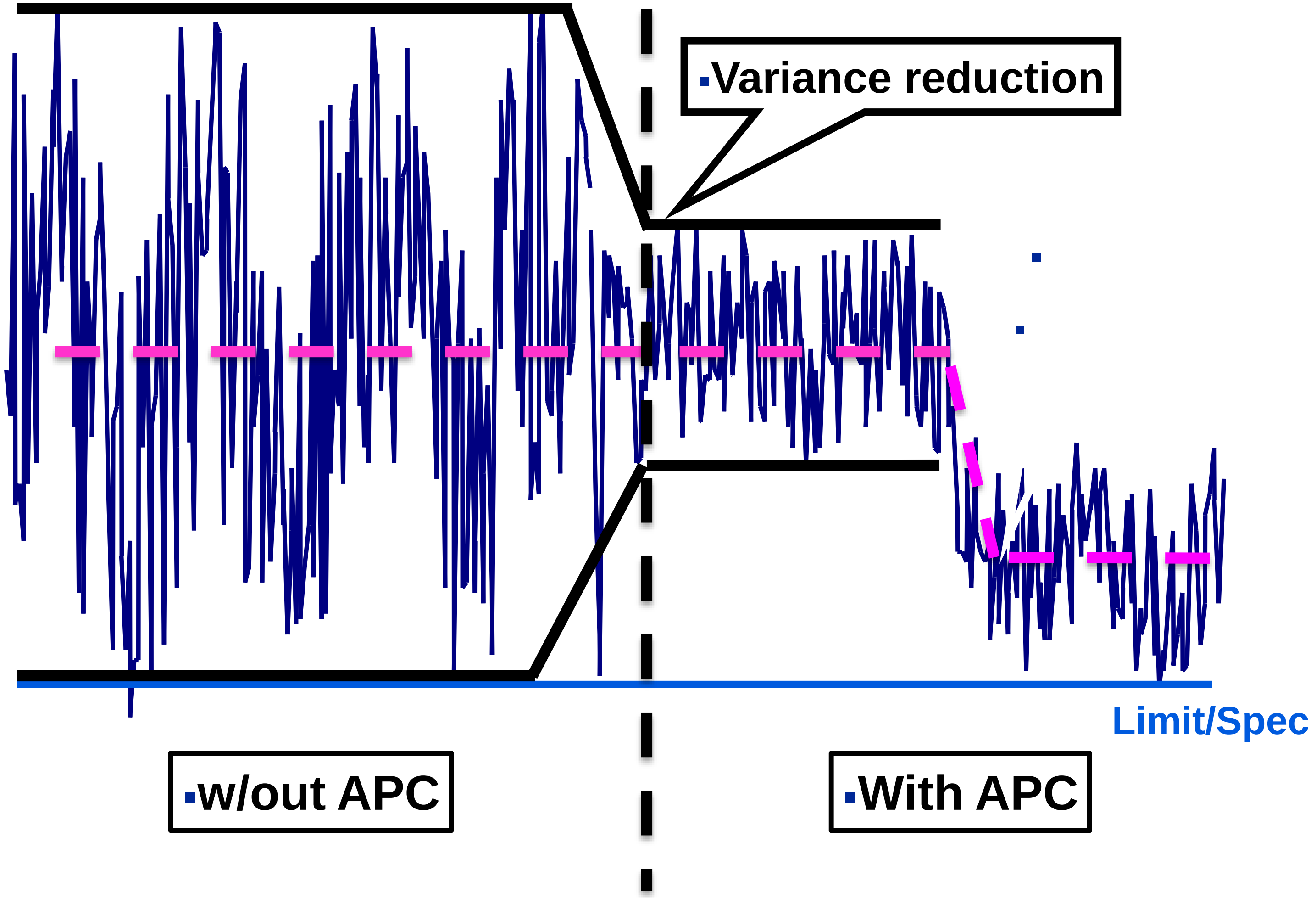
ABB

# Introduction to APC - The Nomenclature



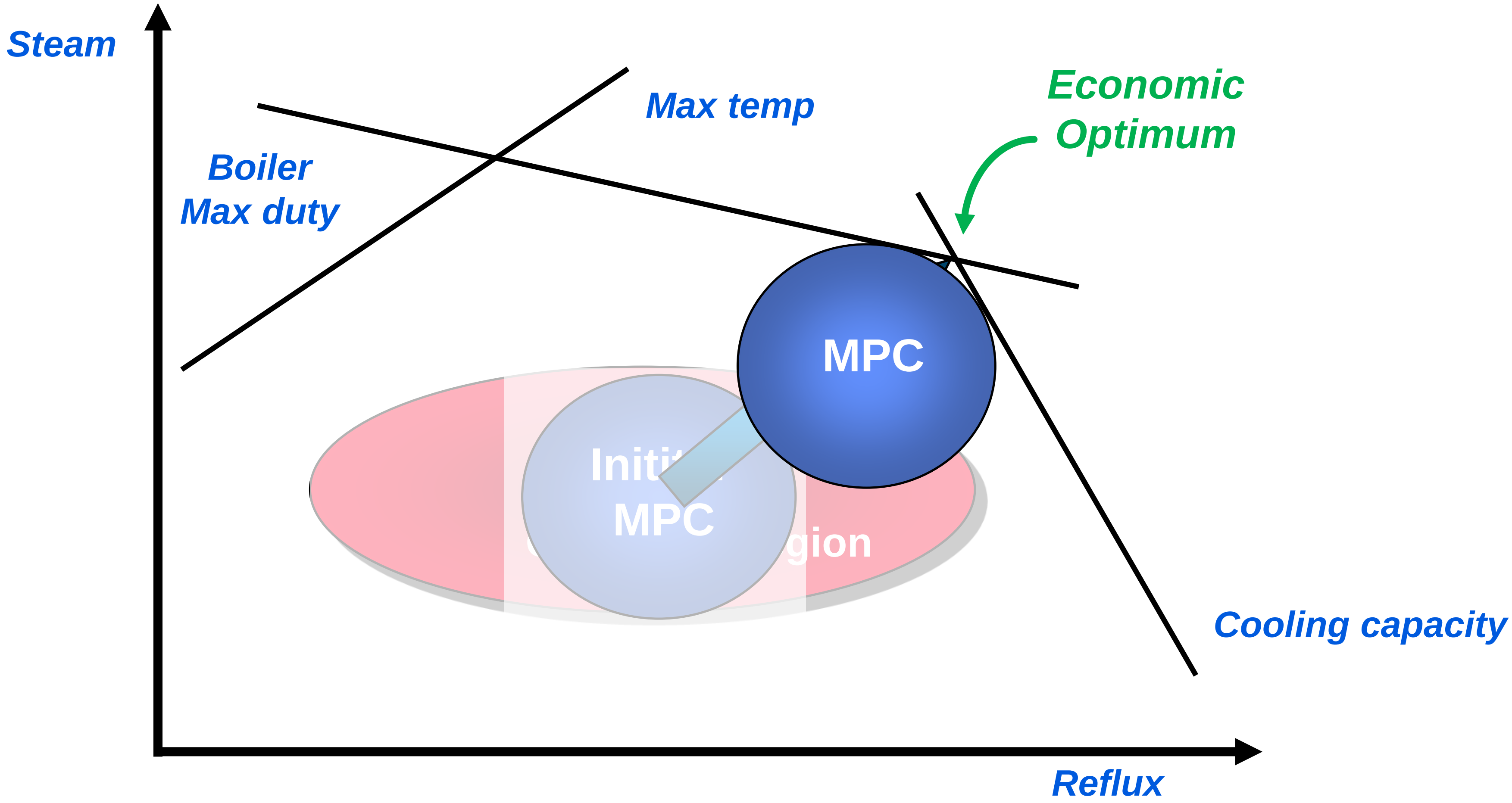

**MVs = Independent, Manipulated Process Inputs (Base Controller SPs)**
**FFs = Feedforward, Measured Disturbance Process Inputs**
**CVs = Dependent, Controlled (Constraint) Process Outputs,**
**PVs = Estimator Feedback Variables, improve prediction**

# How APC improves Performance (1/2)



# How APC Improves Performance (2/2)

- Handling simultaneous constraints and variables

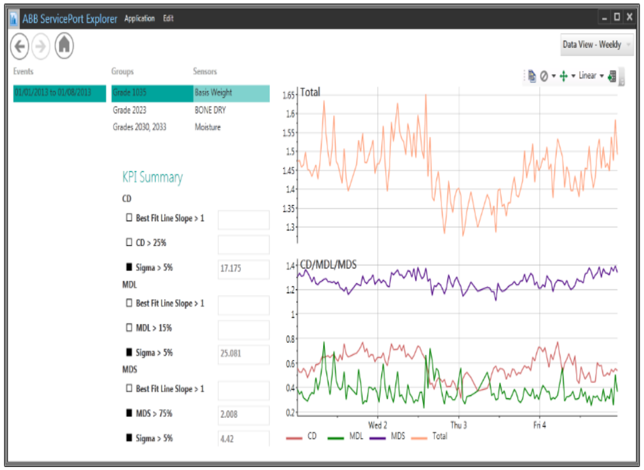


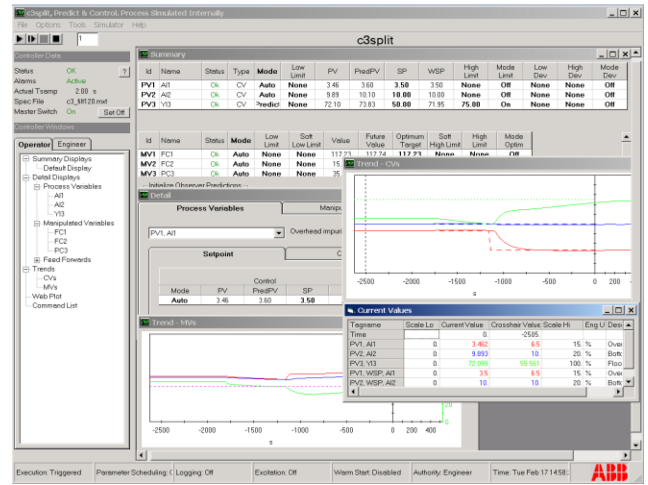
# Introduction to MPC- ABB Products Suite

- Deliver state of the art technology
- Create a suite of products that have consistent look and feel that work together seamlessly
- Reduce service and maintenance efforts

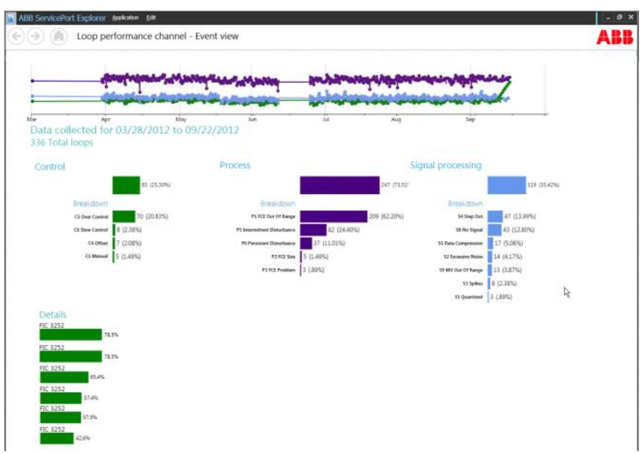
# Introduction to MPC- ABB Products Suite

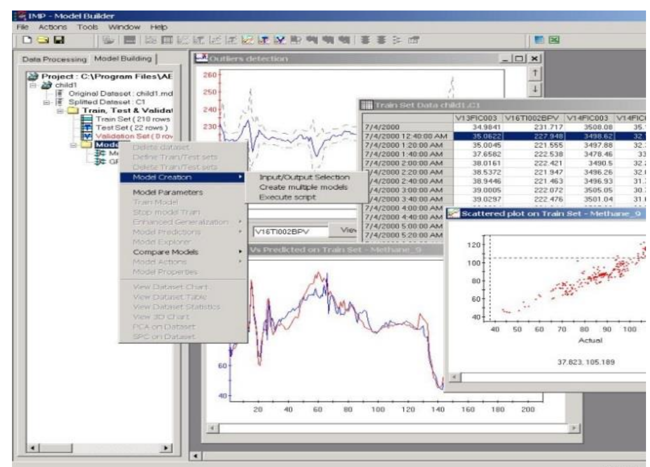
Service Port




Predict & Control




Inferential Modeling Platform

# Introduction to MPC – P&C Technology

- Predict & Control is an *Observer Based Model Predictive Controller*
- It uses *State-Space* technology to describe models and control process
- Any model is defined by a discrete time state-space process model description:

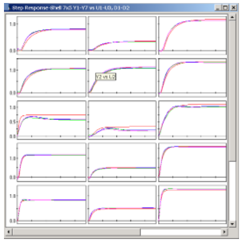
$$x(k)=Ax(k-1)+B_u u(k-1)+B_d d(k-1)+w(k-1)$$

$$y(k)=Cx(k) + h(k)$$

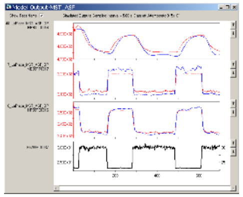
**A, B, C=dynamics, x=state vector, u=controller output, d=feedforward, w=process noise, y=measured process variable, h=measurement noise**

- P&C is made up of 2 main modules:
  - Offline Engineering Tool
  - Online Controller Server

# Introduction to MPC – P&C Models& Approach

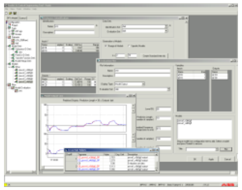


- Unit/section overall management (instead of single loop)
- Multiple objectives with relevant priorities
- Predict & Control models are usually “discovered” by collecting process data and by conducting step tests.
- Predict & Control model building software is used to analyze the data and develop the model equations. The form of the equations is known, the coefficients are calculated.



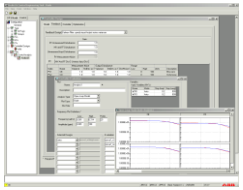
- The model is then used in the controller to compute how “Process Variables” change when “Manipulated Variables” (or “Feedforward” variables) are moved.
- Graphical representation from the model identification tool of Predict and Control, how each MV (column) affects each PV (row)
- Multiple alternative models are presented to compare dynamics and steady state gain

# P&C Engineering Tool - Model development



**Model Development**

- Basic configuration
- Tags definitions
- Data import & data processing
- Model identification and order selection
- Model evaluation

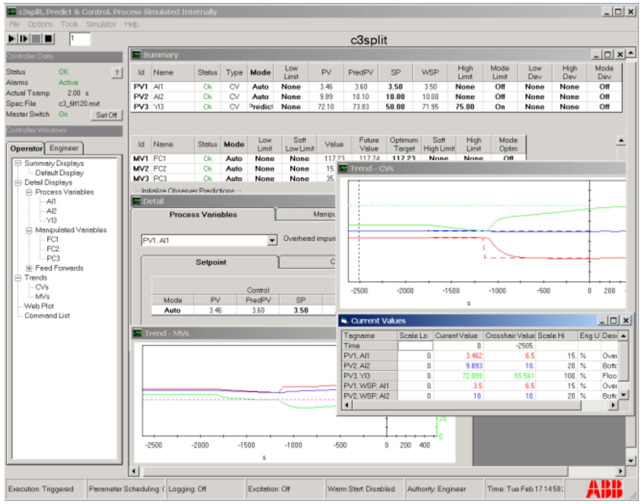


**Controller Tuning**

- OPC general configuration & DCS tags connection
- Controller tuning
- Controller design evaluation
- Simulations

# P&C Online Controller Server and User Interface

- Controller status summary
- Controller insertion
- On-line configuration (limits and constraints manipulation)
- Trend display
- Simulation
- Prediction Horizon visualization
- Optimization Function  Activation-DeActivation



# Introduction to MPC –ServicePort™for PID Loop Opt

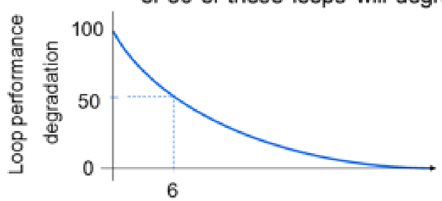
PID Optimal Performances are at basis for good APC Project Execution

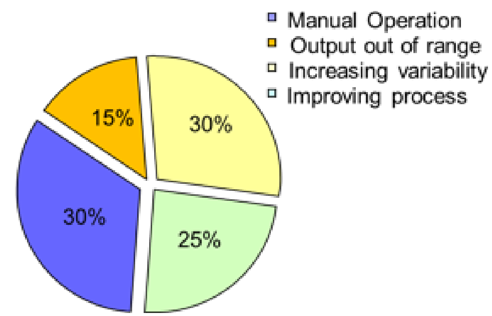
But…

Half life of process controllers

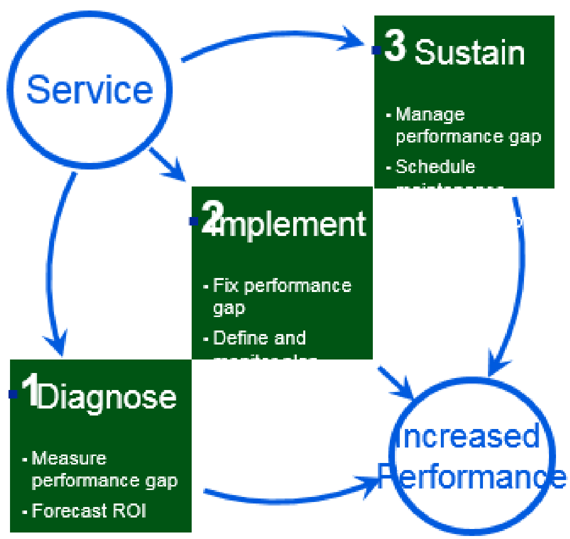
Given: 100 PID loops tuned at once

Then: Within 6 months, performance of 50 of these loops will degrade

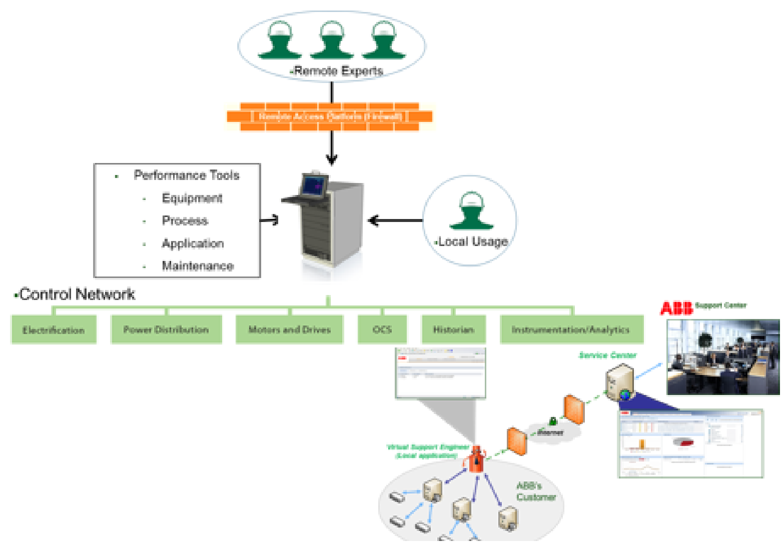



## ABB Adv. Service




## ABB ServicePort™

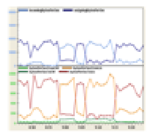


# Loop Advanced Services by ServicePort™

Platform Features&Capabilities. Service Content & Methodology

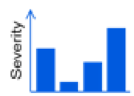
## Service Port Features

**View** Raw Data



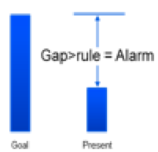

raw data associated with each channel

**Scan** Math



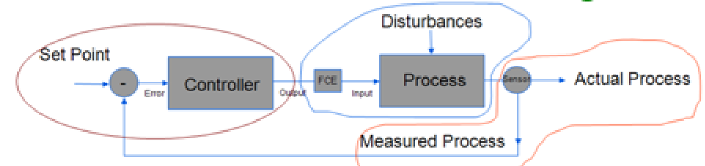

presents KPIs generated from raw data through periodic diagnostic monitoring

**Track** Rules

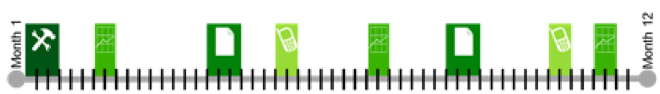



generates notifications based on predefined KPIs

## Service Port KPI Monitoring




| CONTROL | PROCESS | SIGNAL CONDITION |
|---|---|---|
| C1: Manual | P1: FCE Out of Range | S1: Quantized |
| C2: Oscillating Setpoint | P2: FCE Size | S2: Excessive Noise |
| C3: Deadband | P3: FCE Problem | S3: Spikes |
| C4: Offset | P4: FCE Leakage | S4: Step Out |
| C5: Over Control | P5: Intermittent Disturbance | S5: Compression |
| C6: Slow Control | P6: Persistent Disturbance | S6: Over Filtered |
| C7: FCE Travel | P7: Questionable | S7: Sampling Rate |
| C8: Slow Update Rate | | S8: No Signal |
| C9: Questionable | | S9: MV Out of Range |
| | | S10: Questionable |




**Initialization, Baseline Setting, Training**

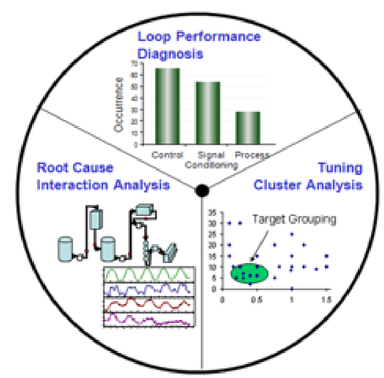
**View (performance)** Calculations / evaluations / daily usage

**Scan (scheduled)**: Scan analysis / report / implementation planning / notification validation

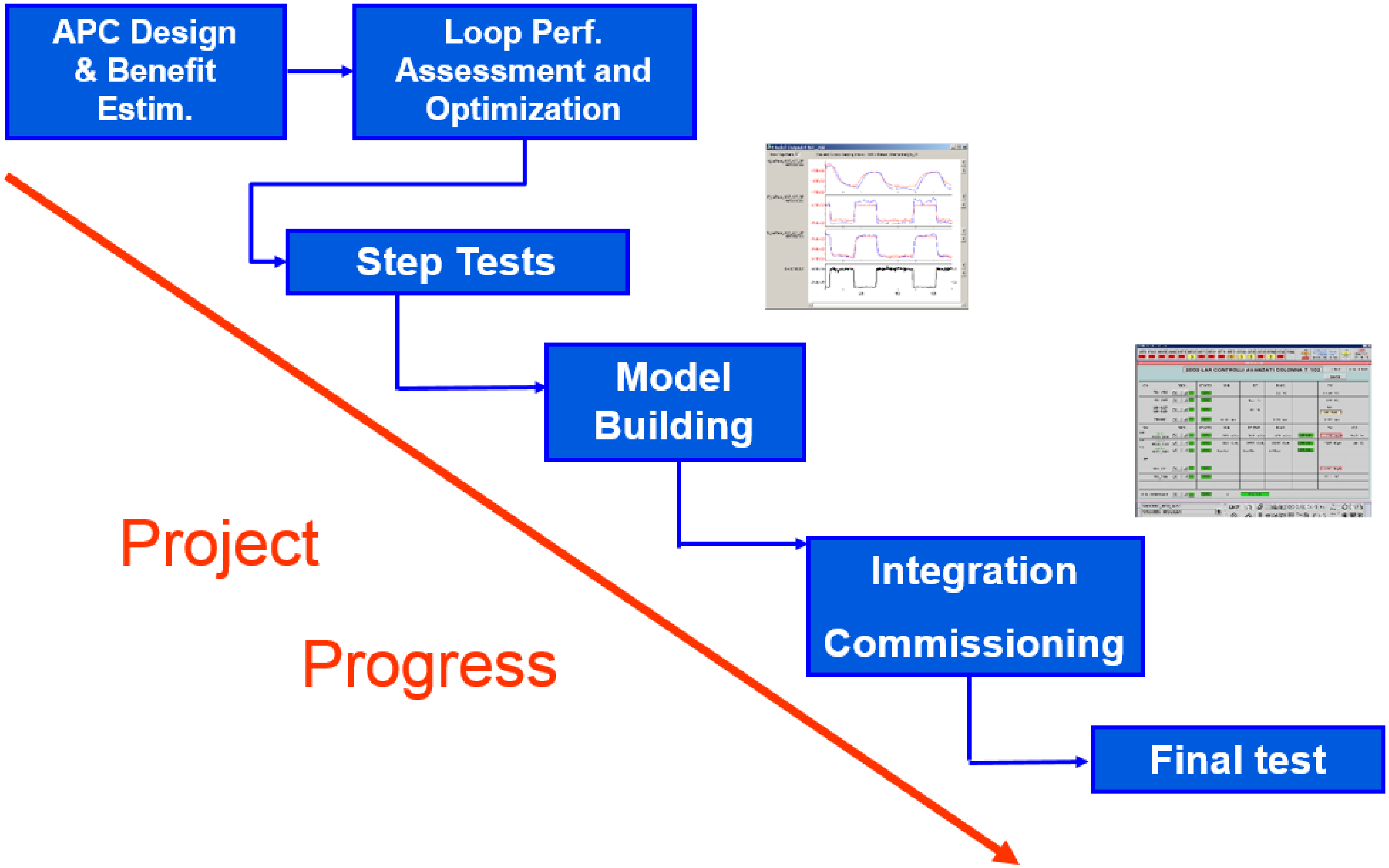
**Track (event-triggered)**: remote troubleshooting assistance

**Customer (on demand)**

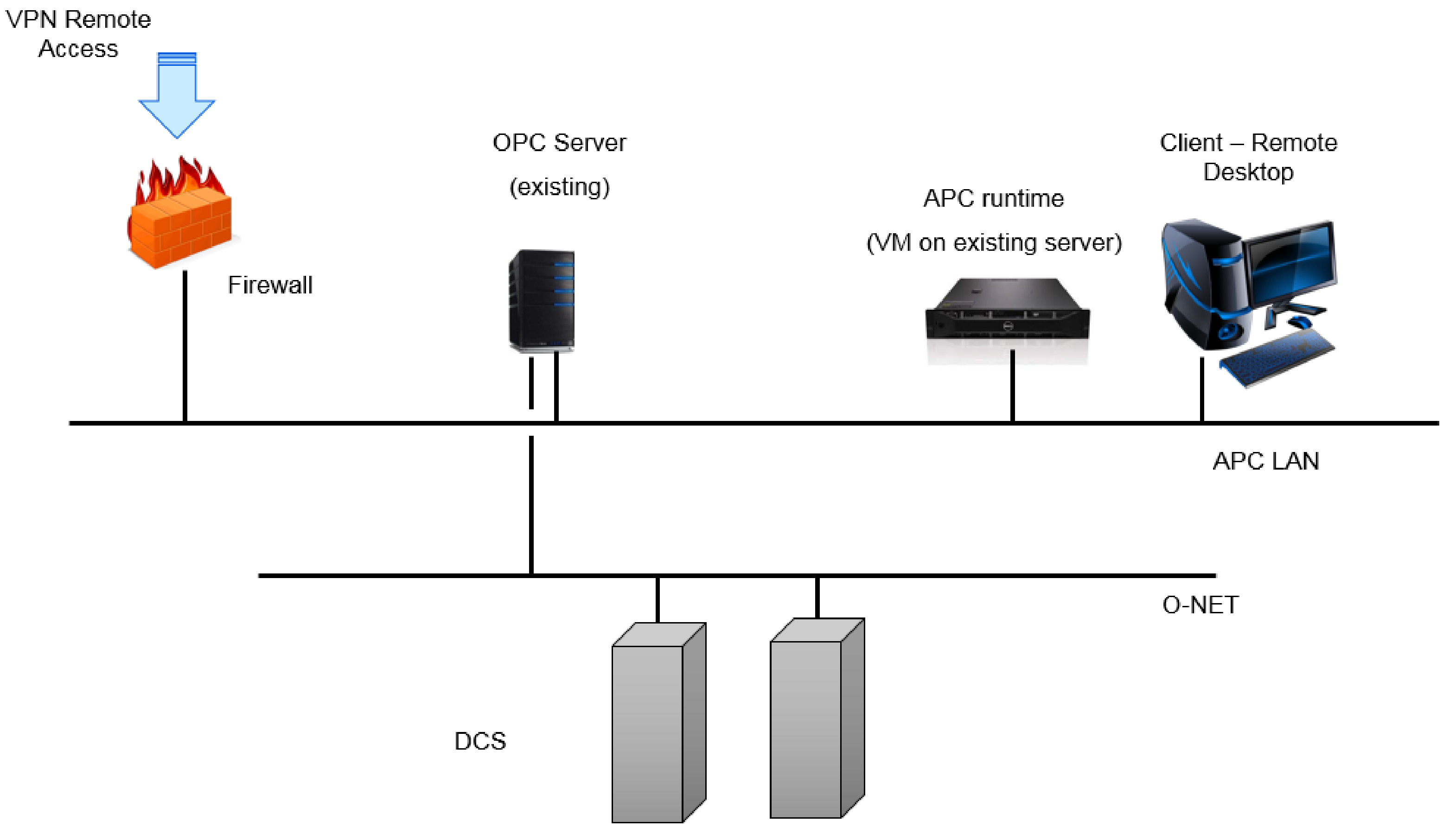
## ServicePort Loop Performance Service Content & Methodology



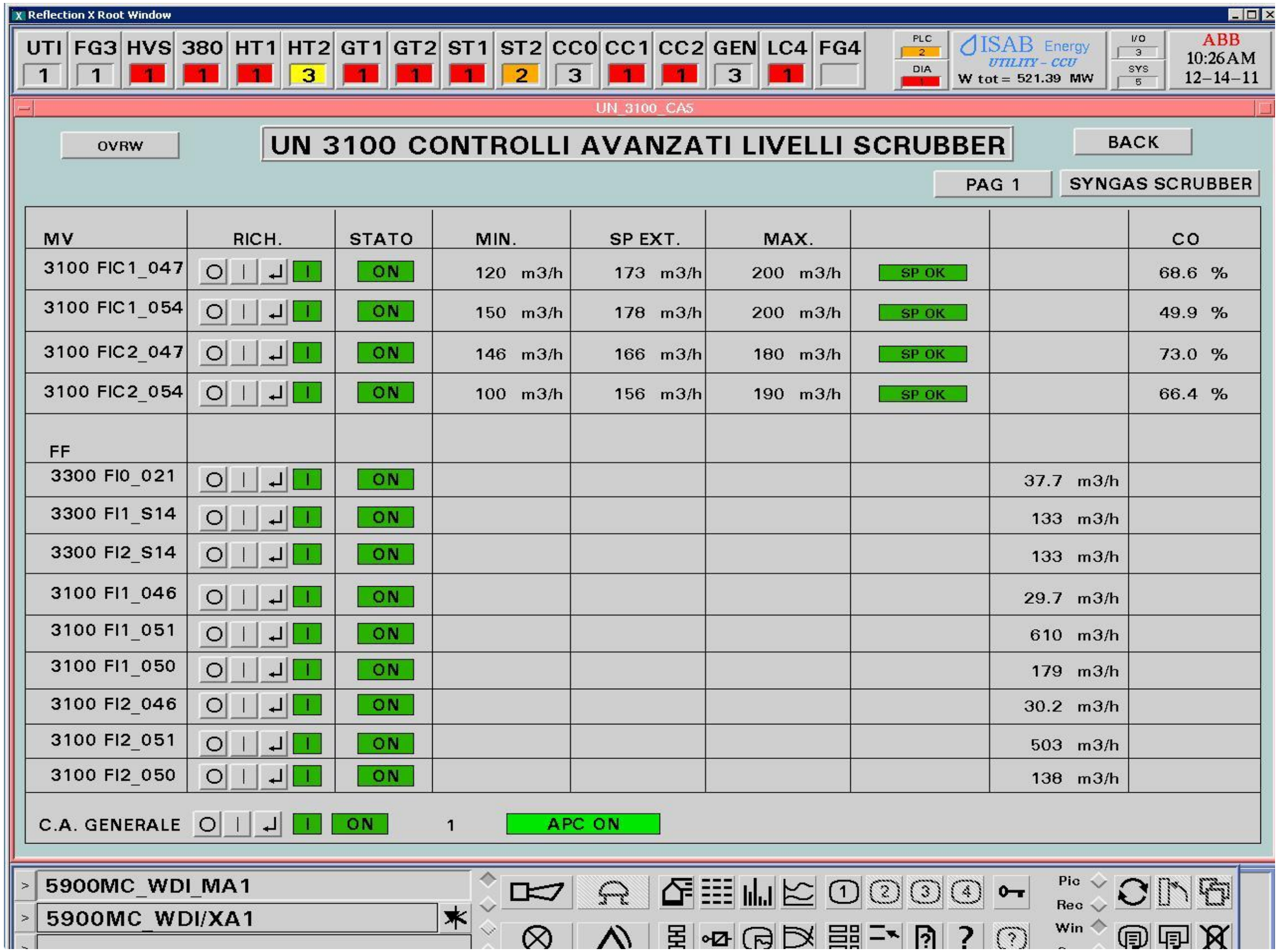
# APC - Project development tasks



# APC – System integration



# Sample DCS Play



# Some recent APC references – Power plants

- Alcoa Point Confort, TX, USA
- Colstrip, USA
- Windalco , Jamaica
- Sappi Ngodwana, SA
- Sappi Saiccor, SA
- Celgar Zelsfoff, Ca
- Twin Rivers, USA
- Confide. Client, Fl, USA

- Powerhouse & Steam Network
- Powerplant optimization
- Powerhouse & Steam Network
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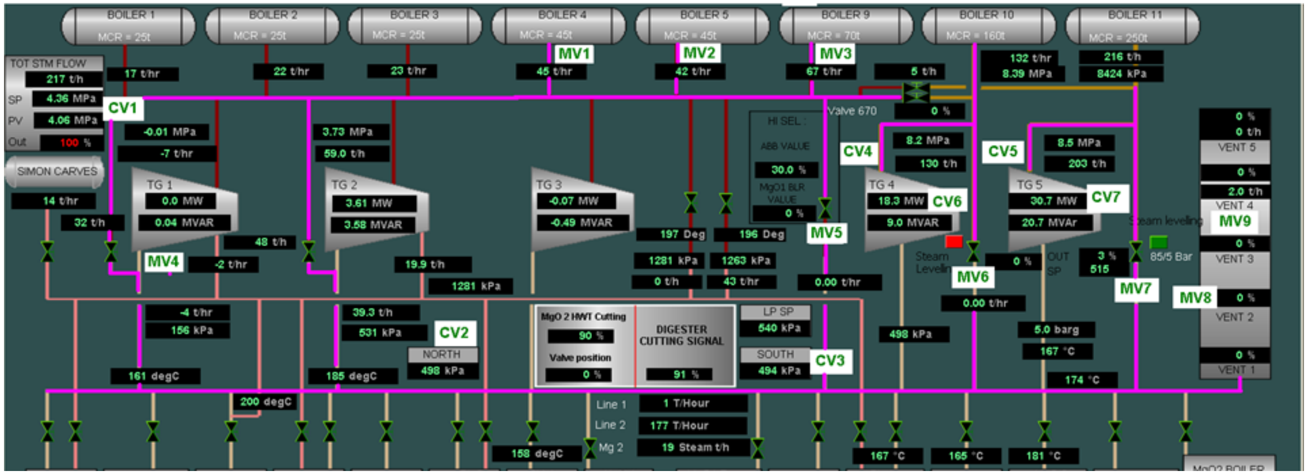
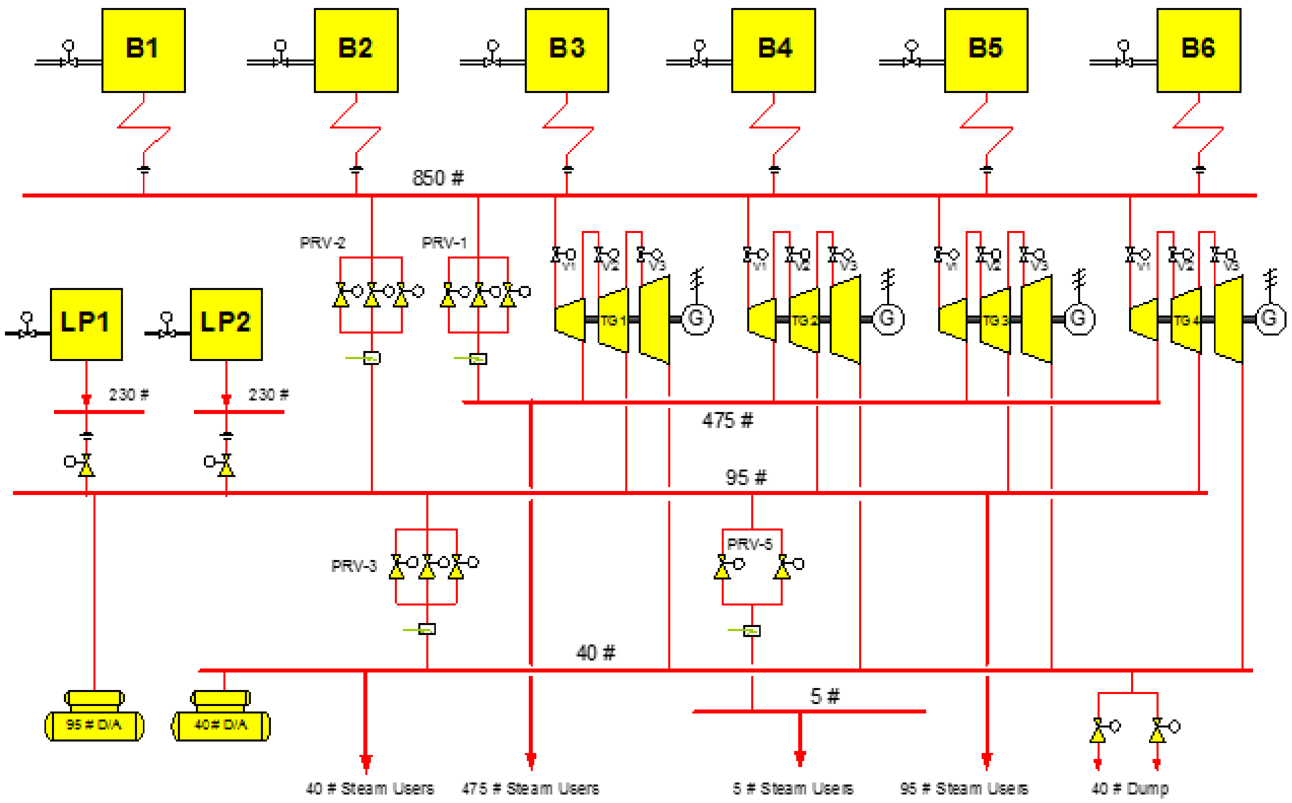


# Some recent APC references
## ABB CoE Italy

| Client | Scope | Industry | Year | Size |
|---|---|---|---|---|
| Ilva | Gas Network & Powerplant | Prim. Steel | 2014-15 | 960 MW |
| ERG Power | Steam Network & Powerplant | Refining | 2015 | 520 MW |
| Isab Energy | Gas Network & Powerplant & Steam network | Process+Power | 2014 | 535 MW |
| EDF (3 sites) | Combustion Optimization | Power | 2014 | 1800 MW |
| CoProB | Powerhouse | Sugar | 2013 | 25 MW |
| Uipsa | Paper Mill Cogeneration | Paper | 2015 | 32 MW |
| **Total** | | | | **3872 MW** |

# Case study – Multiple Boilers optimization
## Highly complex and interacting configuration

6 HP boilers
2 LP boilers
5 steam headers
PRV's for each header
Steam vent valves



# Case study – ACP Design
## Inputs

### Manipulated Variables

| | |
|---|---|
| HP Boiler 1 Gas Flow | HP Extraction Demand |
| HP Boiler 2 Gas Flow | LP Extraction Demand |
| HP Boiler 3 Gas Flow | Turbine Exhaust Demand |
| HP Boiler 4 Gas Flow | PRV 850/475 –psig |
| HP Boiler 5 Gas Flow | PRV 850/95 -psig |
| HP Boiler 6 Gas Flow | PRV 95/40 -psig |
| LP Boiler 1 Gas Flow | 475 # Dump Valve |
| LP Boiler 2 Gas Flow | 95 # Dump Valve |
| LP Boiler 1 Steam Flow | 40 # Dump Valve |
| LP Boiler 2 Steam Flow | |

# Case study – ACP Design
## Outputs

### Controlled Variables

| | |
|---|---|
| 850# header pressure | 40# Header Pressure |
| 475# Header Pressure | LP Boiler 1 Pressure |
| 95# Header Pressure | LP Boiler 2 Pressure |

### Feed-Forward Variables

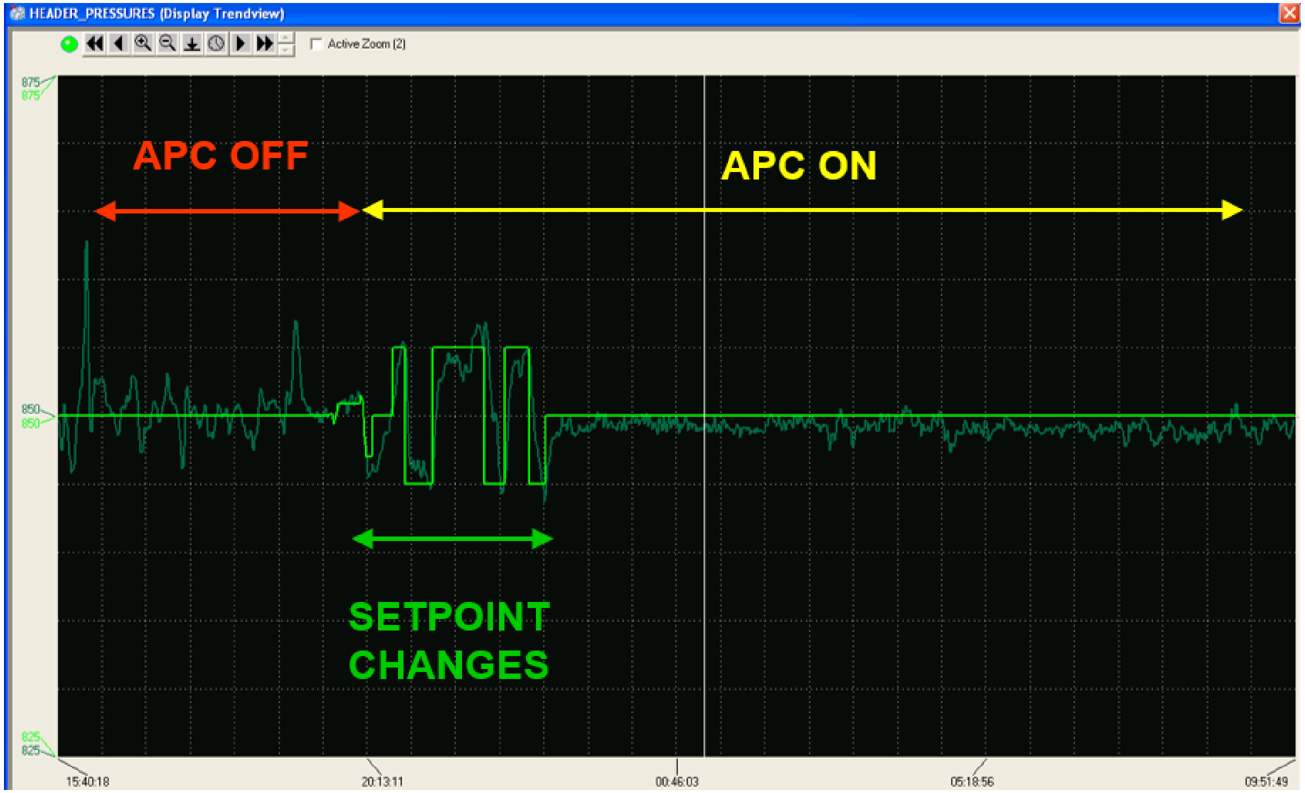
| | |
|---|---|
| 475 # Steam Demand | 40 # Steam Demand |
| 95 # Steam Demand | 5 # Steam Demand |

### Constraint Variables

| |
|---|
| HP Section Valve Positions |
| IP Section Valve Positions |
| LP Section Valve Positions |
| Turbine Megawatts |

# Case Study - Steam header stabilization

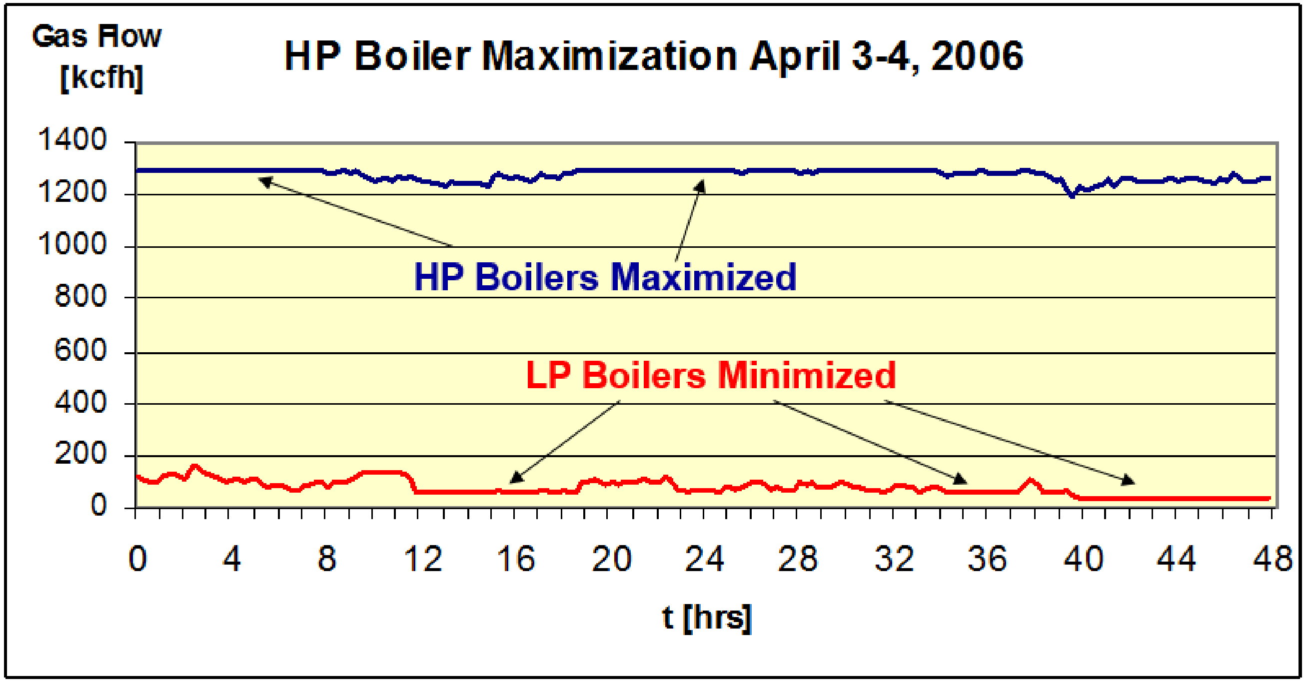
Steam Pressure
Control



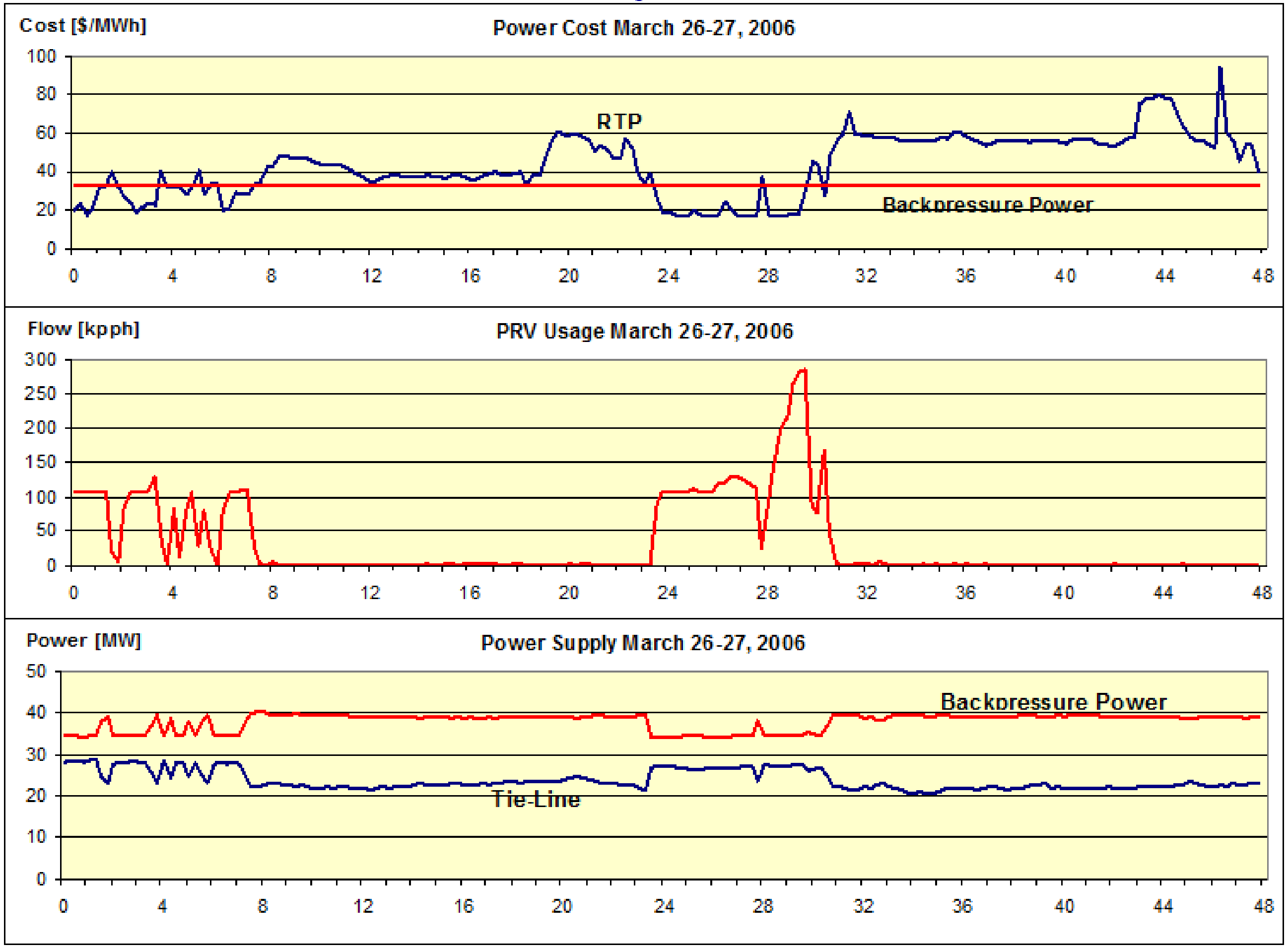
# Case Study - HP/LP boilers…when to use
## Backpressure Power Maximization

LP boilers above minimum load only when HP boilers maximized

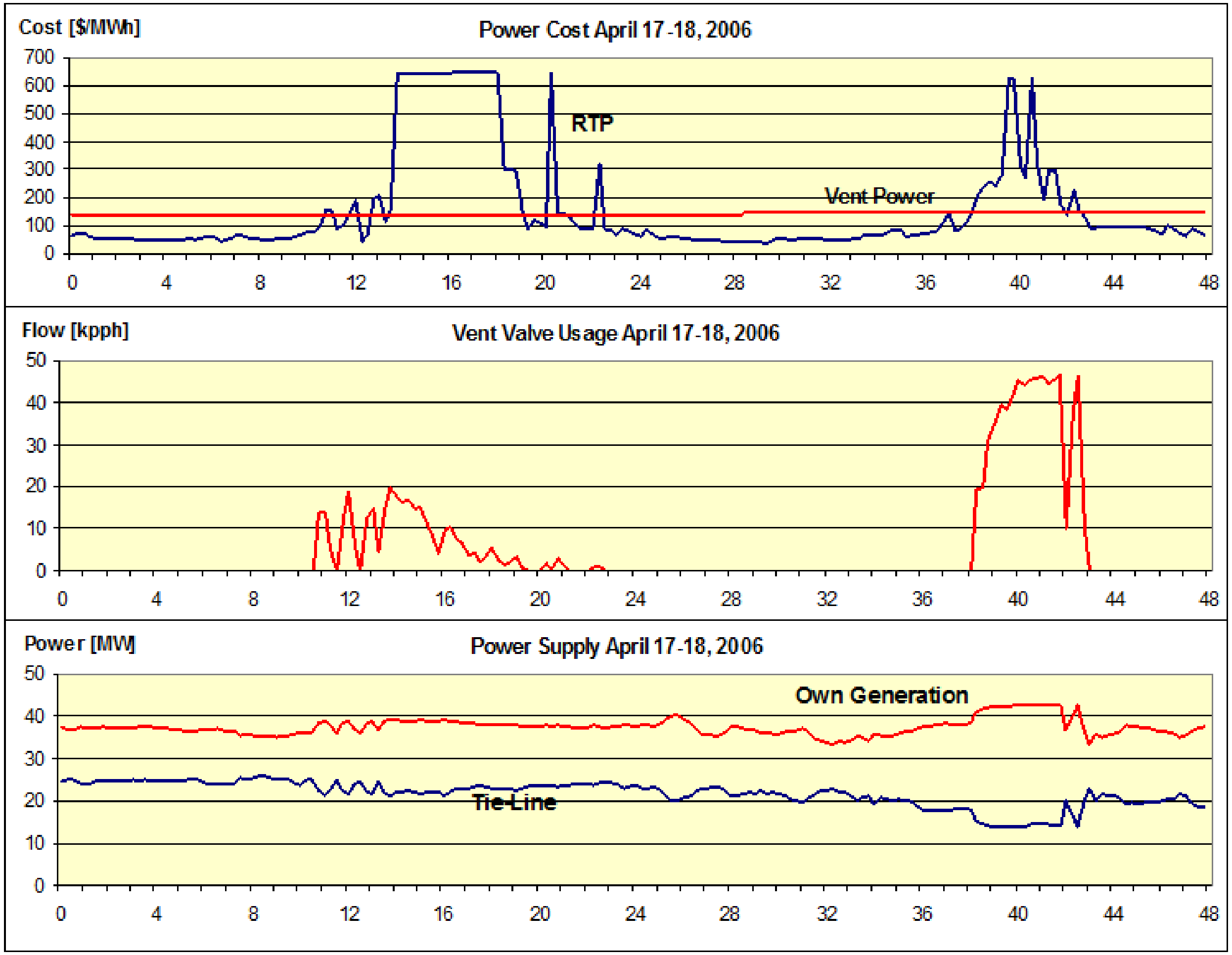
HP boilers below maximum load only when LP boilers minimized



# Case Study - PRVs ….coordinated control
## PRV Optimization



# Case Study – Steam vent optimization



# Electrical grid basics

- Power Production must match Power usage at all times to preserve frequency stability
- Grid management trim Power Production continuously to achieve balance, 24x7
- Changes are due not only to changes in demand but also to production changes from high priority supplies e.g. wind, solar
- Power producers able to implement real-time control of energy following Grid dispatch requests have a price premium e.g. MSD market
- Power producers that cannot implement real-time control sell at ordinary, lower price e.g. MGP market

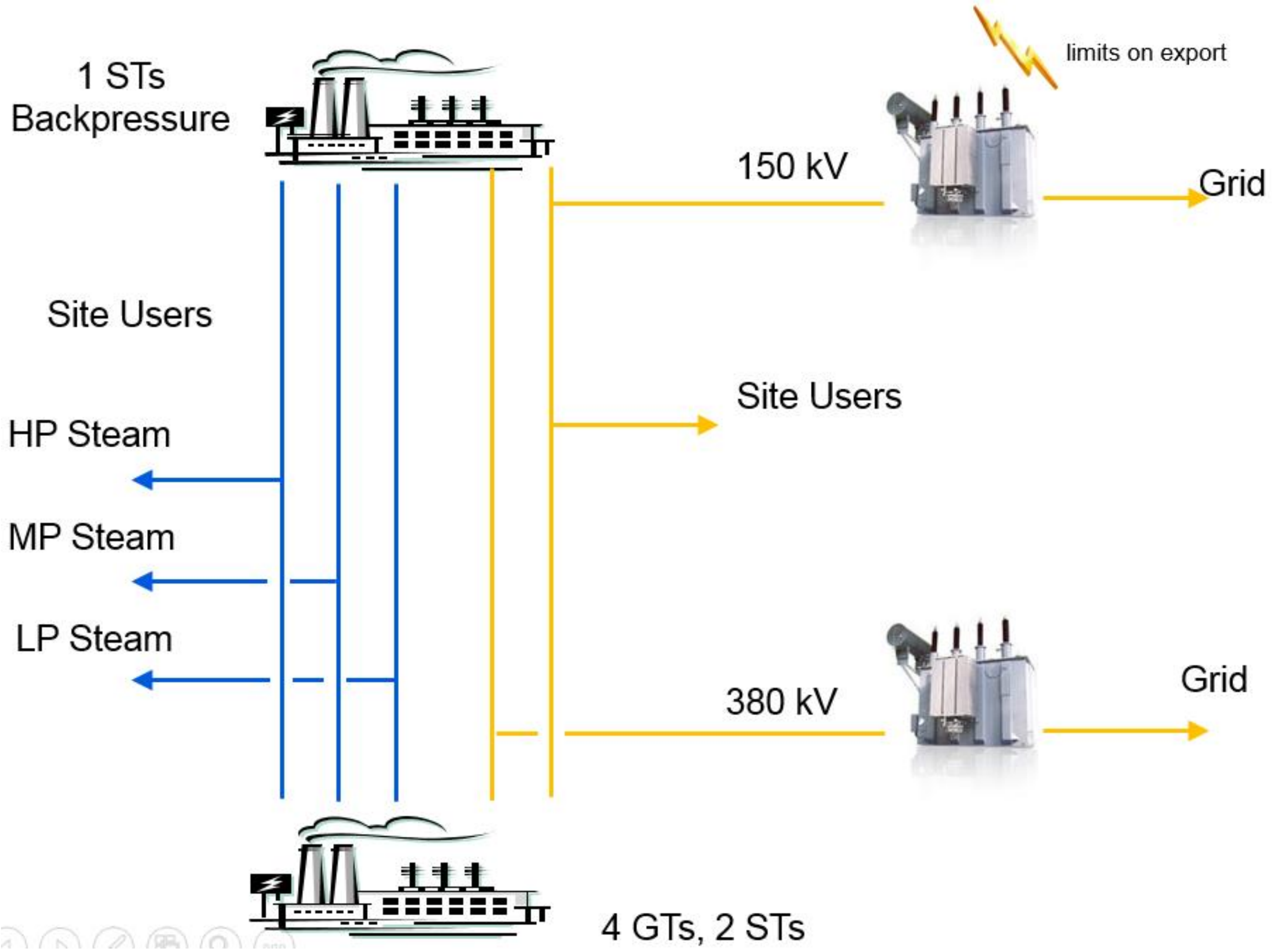
# Italian Energy Market - 'MSD' brief concepts

- Grid requirements: provide various energy contributions:
- Primary contribution: direct GT response to frequency changes, timeframe tens of seconds
- Secondary contribution: quick changes in energy production following direct request from grid control via RTU connected to DCS; request comes as a real-time trim signal applied to a contractually agreed plant max contribution
- Tertiary contribution: periodic changes (every 15 minutes) in energy production following a schedule approved by grid and available to open market bid/sale.

# Site status

- Two twin combined cycles, 4 GTs, 2 ST with steam export to site users (refinery, petrochem site), 480 MW
- Backpressure FG/FO fired plant, production of max 48 MW.
- Complex site, with strong usage of steam and power (~70 MW, 200 t/h of steam)
- Three levels of steam (HP, MP and BP), combined cycles and backpressure units connected to all steam headers
- Need to access to MSD market while preserving steam/energy supply - quality and reliability

# Site utilities configuration



# Site overall objectives

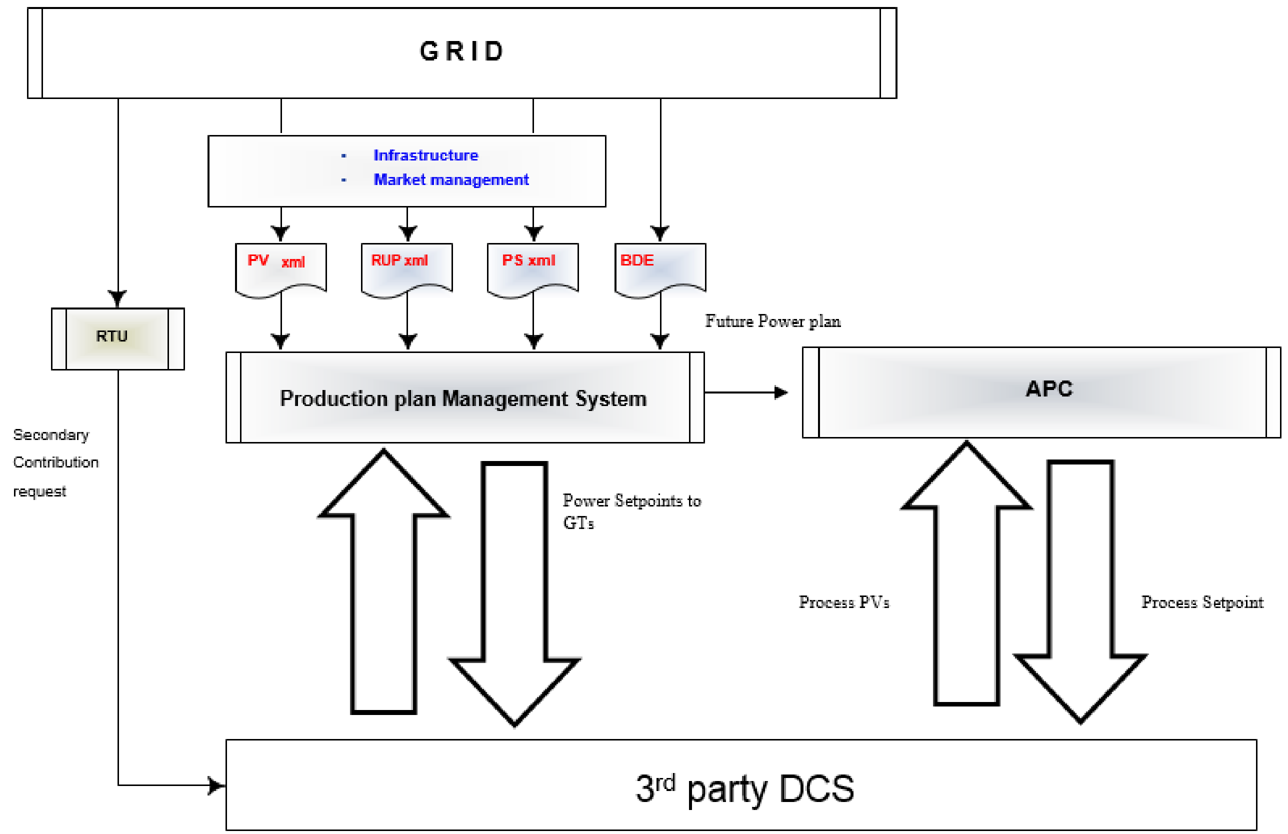
- Satisfy site requests for steam and energy, maintain steam headers quality
- When energy price is high, take advantage of available power - maximize production of backpressure plant so to maximize export and profits
- When energy price is low, minimize production of backpressure plant so to minimize production costs
- In all cases, trim backpressure plant so to satisfy production with minimum production cost

# Multiple time-horizons

- Primary contribution implementation – GT level
- Secondary contribution implementation – DCS level & Production Plan Management software
- Tertiary contribution implementation – need to coordinate multiple plant loads
- Optimization

- Need to have multiple automation layers running with objectives set on very different time horizons – from seconds to an hour

# Control architecture



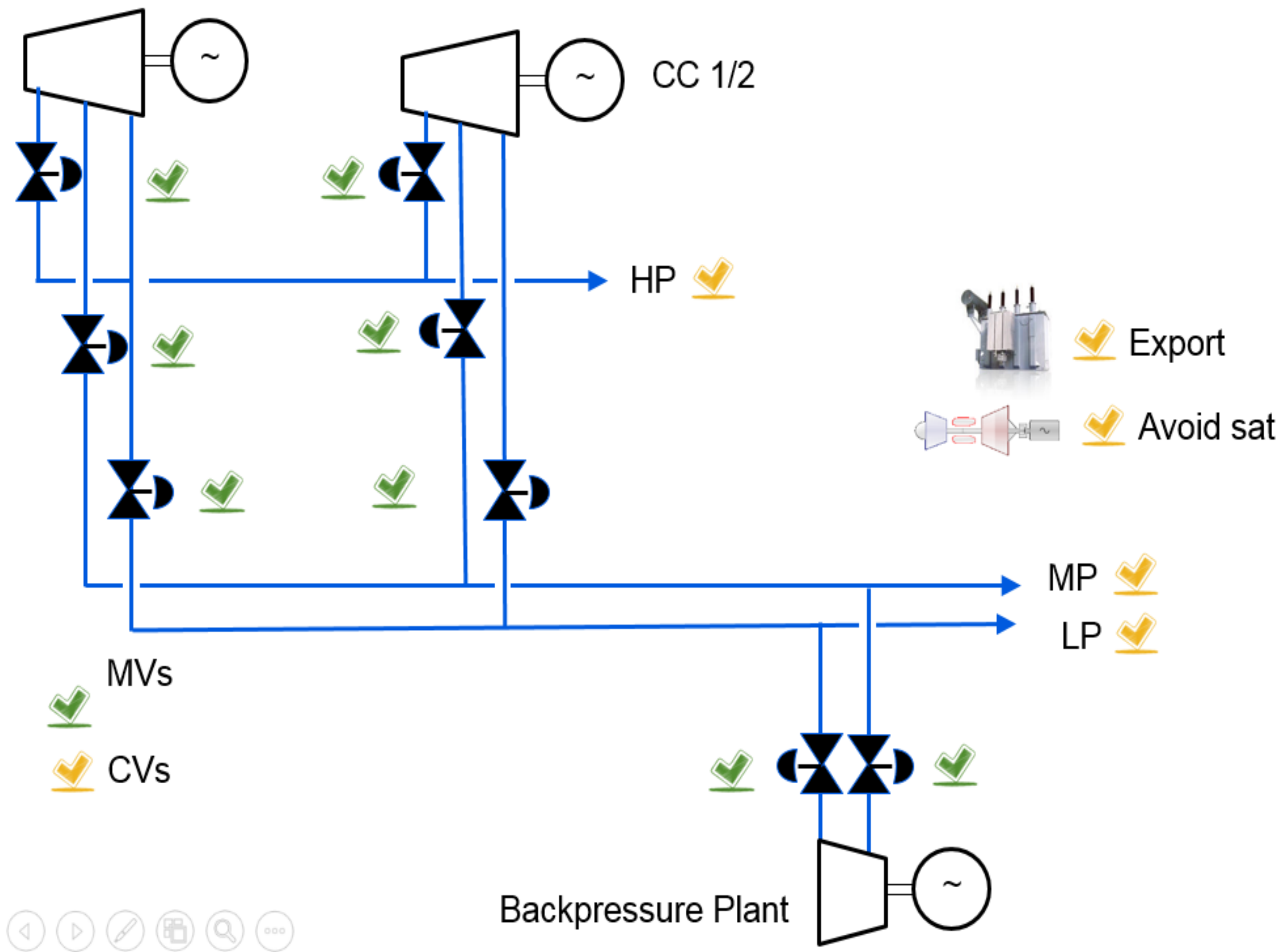
# Control architecture – layered approach (1/2)

- DCS control layer to
  - Control total current production by moving all GTs, considering Hi/Lo limits and saturation
  - Provide response to secondary contribution changes via RTU
  - Production Plan Management System able to:
  - Compute energy production over 15 m interval
  - Control/compensate energy imbalances
  - Process Grid plan messages
  - Present detailed HMI related to production plans
  - Store plans production data for monitoring and accounting purposes

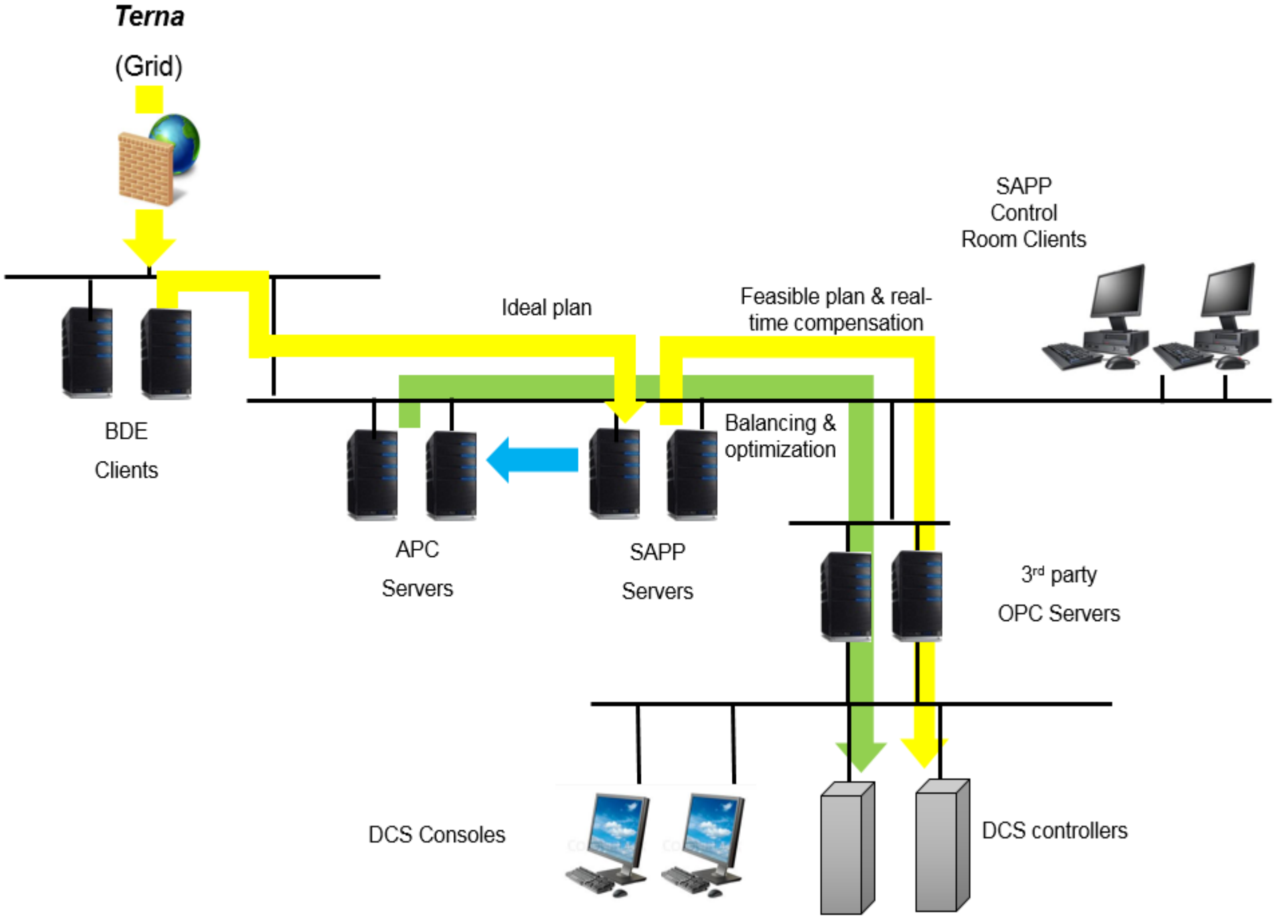
# Control architecture – layered approach (1/2)

- APC Layer to:
  - Maintain limits on power export (limits on two separate export lines, 150 and 400 kV)
  - Maintain pressure and pressure control ability
  - Maintain GTs margins, both current and future
  - Optimize cogen/backpressure balance to minimize costs
  - Keep process values within constraints

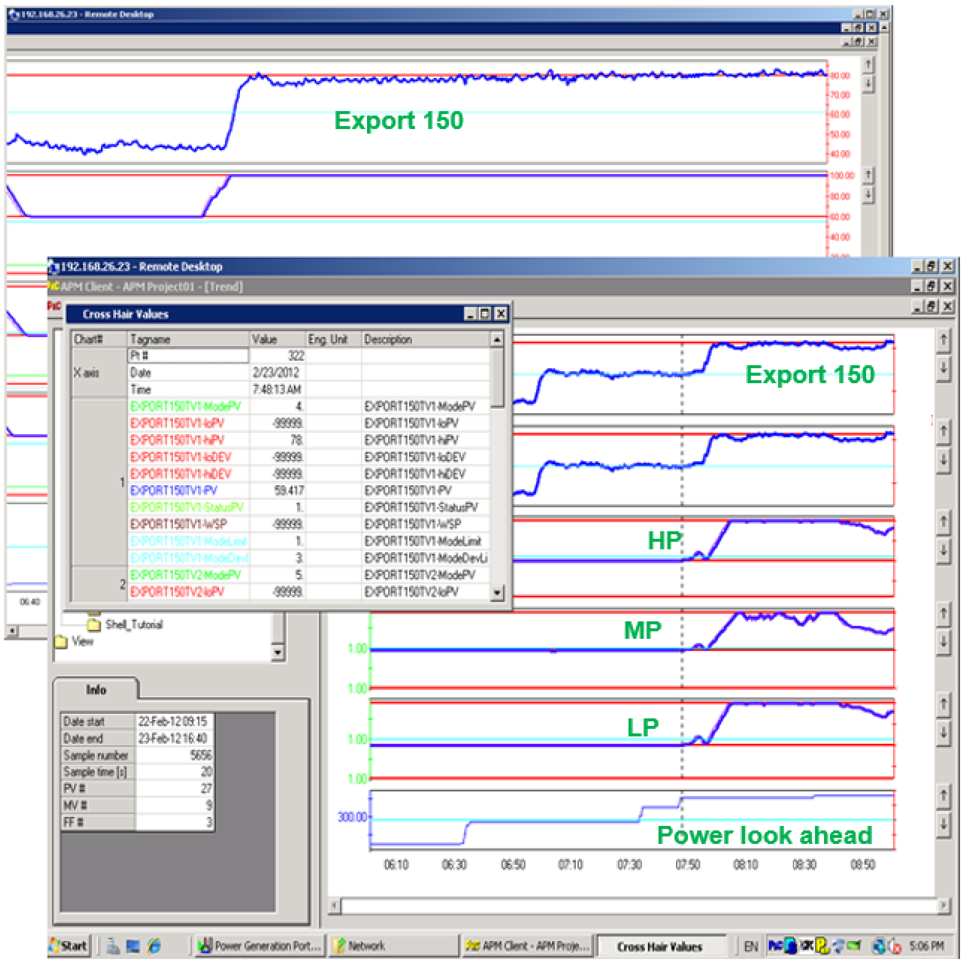
# APC main variables



# System Architecture – Information flow



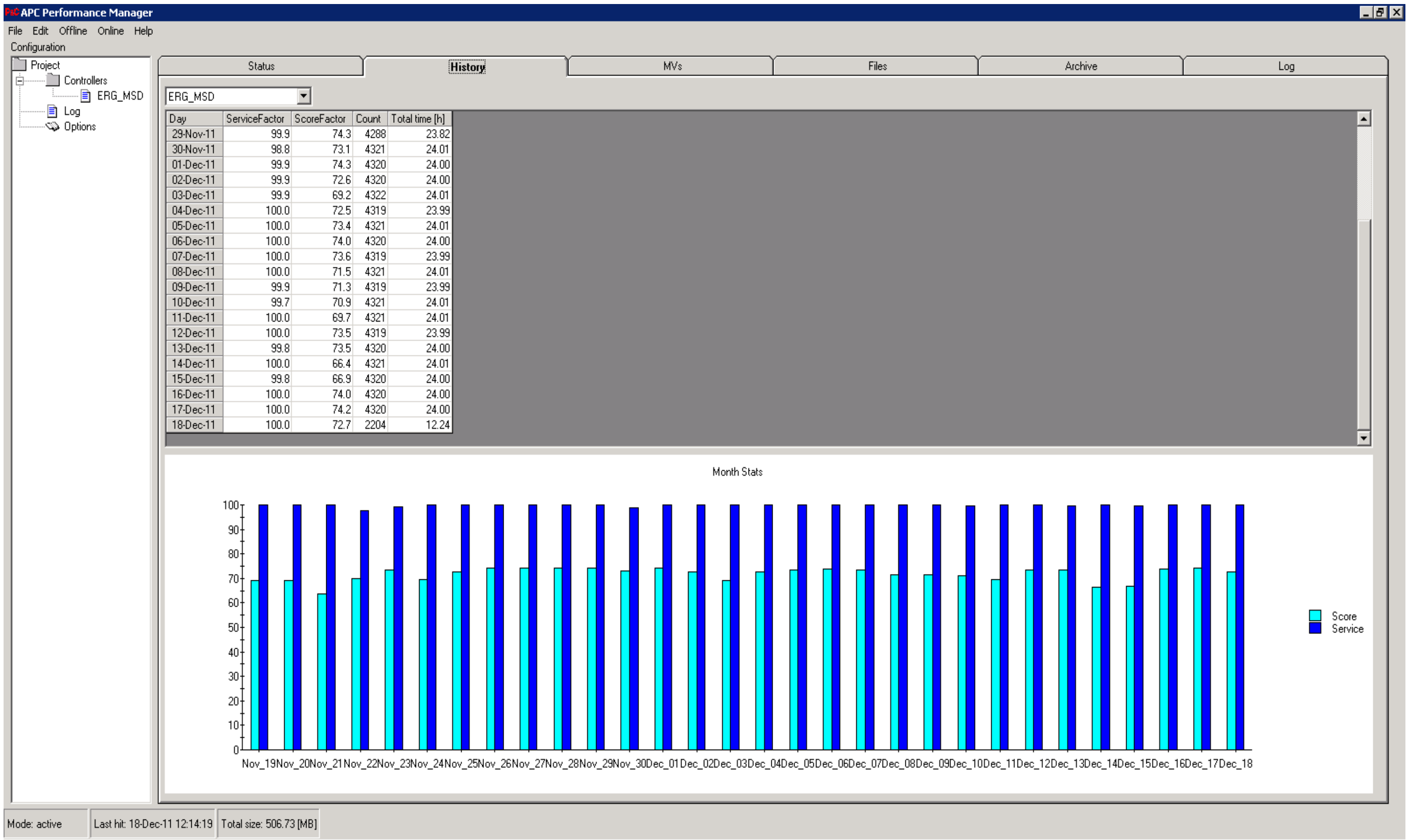
# Load increase, use of HICs



# Load increase, use of HICs

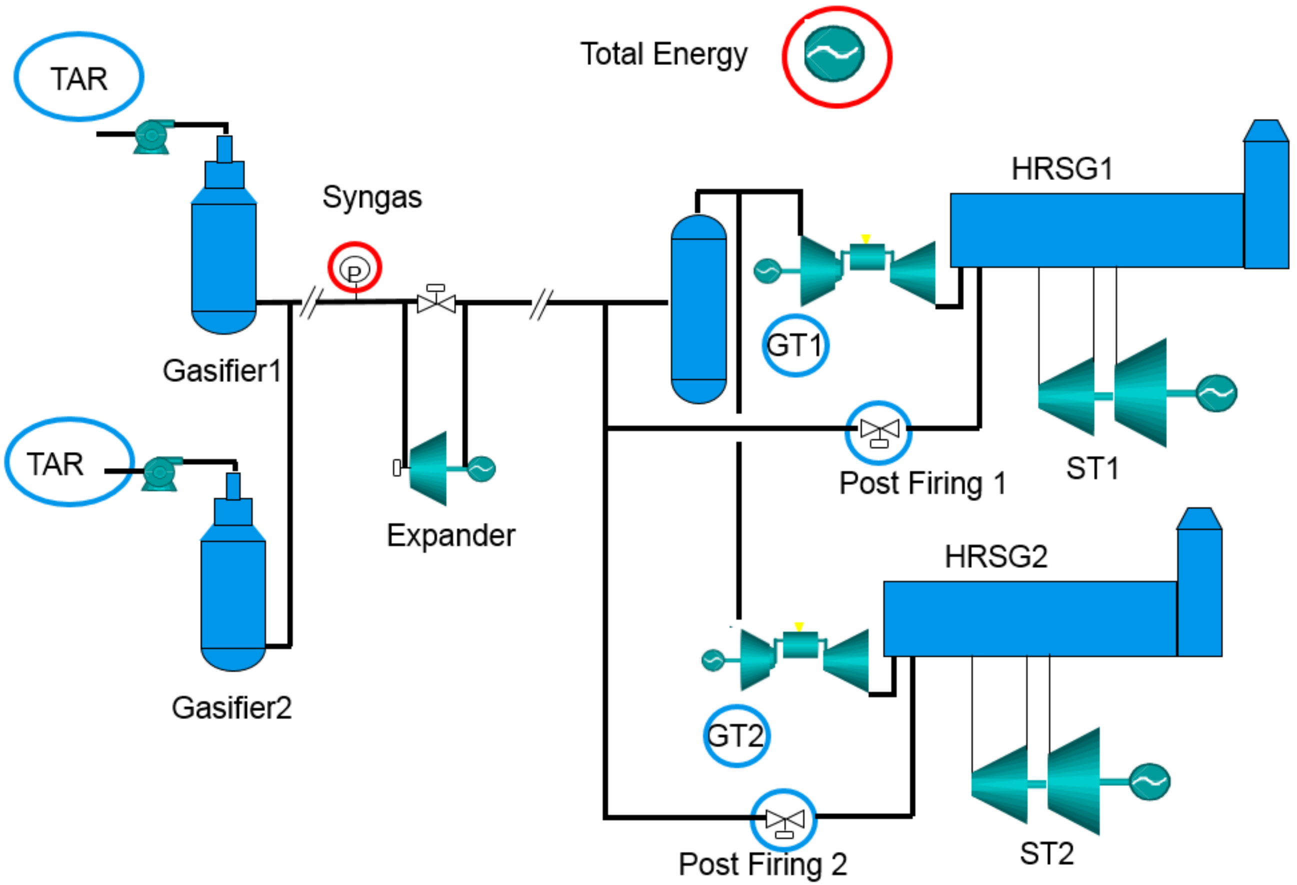
- Production increase early morning
- Schedule information anticipate actual load  request increase (~20 min ahead)
- APC reduces steam export from CC so to increase Power Production from BP unit
- APC moves MVs ahead to reduce ratio 150 kV/380 kV export i.e. increasing steam export from 150 kV linked gen vs. 380
- As MW export is close to maximum limit, the APC system trims backpressure power plant by modulating CC steam export

# Service factor sample



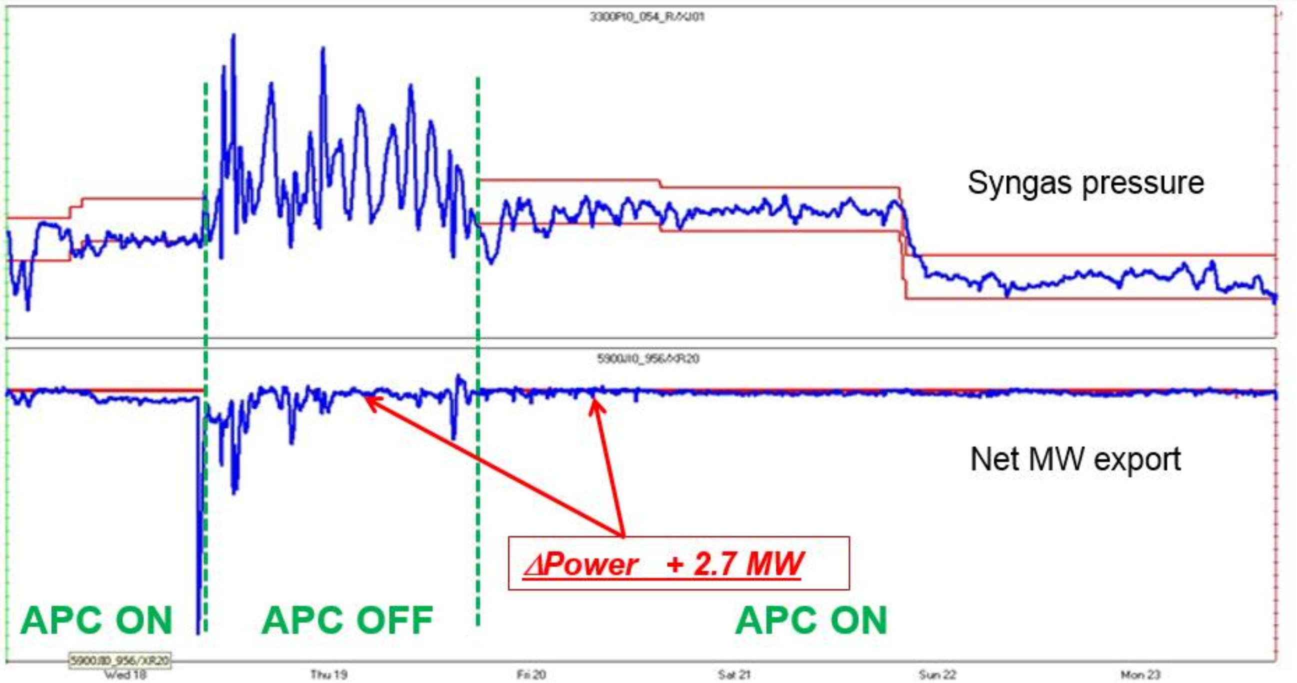

| Day | ServiceFactor | ScoreFactor | Count | Total time [h] |
|---|---|---|---|---|
| 29-Nov-11 | 99.9 | 74.3 | 4288 | 23.82 |
| 30-Nov-11 | 98.8 | 73.1 | 4321 | 24.01 |
| 01-Dec-11 | 99.9 | 74.3 | 4320 | 24.00 |
| 02-Dec-11 | 99.9 | 72.6 | 4320 | 24.00 |
| 03-Dec-11 | 99.9 | 69.2 | 4322 | 24.01 |
| 04-Dec-11 | 100.0 | 72.5 | 4319 | 23.99 |
| 05-Dec-11 | 100.0 | 73.4 | 4321 | 24.01 |
| 06-Dec-11 | 100.0 | 74.0 | 4320 | 24.00 |
| 07-Dec-11 | 100.0 | 73.6 | 4319 | 23.99 |
| 08-Dec-11 | 100.0 | 71.5 | 4321 | 24.01 |
| 09-Dec-11 | 99.9 | 71.3 | 4319 | 23.99 |
| 10-Dec-11 | 99.7 | 70.9 | 4321 | 24.01 |
| 11-Dec-11 | 100.0 | 69.7 | 4321 | 24.01 |
| 12-Dec-11 | 100.0 | 73.5 | 4319 | 23.99 |
| 13-Dec-11 | 99.8 | 73.5 | 4320 | 24.00 |
| 14-Dec-11 | 100.0 | 66.4 | 4321 | 24.01 |
| 15-Dec-11 | 99.8 | 66.9 | 4320 | 24.00 |
| 16-Dec-11 | 100.0 | 74.0 | 4320 | 24.00 |
| 17-Dec-11 | 100.0 | 74.2 | 4320 | 24.00 |
| 18-Dec-11 | 100.0 | 72.7 | 2204 | 12.24 |

# Master controller structure

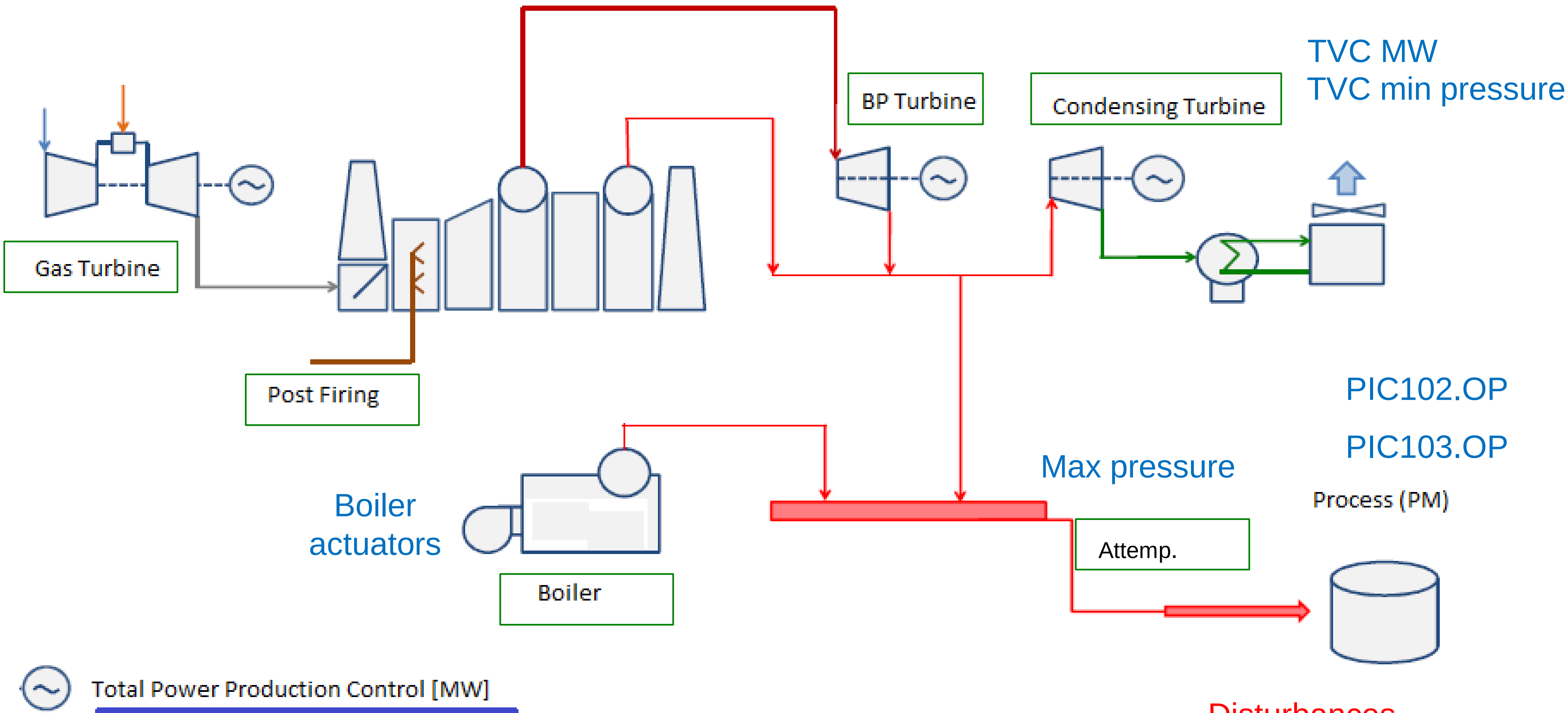


# Master controller results

PV – Blue
Limits - Red



# APC applied to a Paper Mill Cogeneration




Disturbances

- Paper breaks
- Product changes

# APC Proposed Solution

- Main targets/constraints
- Net MW export (considers integral over time)
- PM valve positions to maximize pressure drop on backpressure turbine
- Other Paper Mill constraints
- Condensing Turbine  minimum inlet pressure
- Condensing Turbine production (minimize)
- Boiler (minimize)

- Main handles
- GT MW setpoint
- Backpresssure Turbine Pressure
- Consensing Turbine Pressure or MW
- Boiler steam flow
- Postfiring flow
- LP Attemperator

# APC Integrated Solution

Weather Forecast | Market | Product Scheduler | Sales/Broker

Medium term Optimization

30 minutes

(24 hours horizon)

**Energy Export Scheduler** ▪Phase 2

Real time control

15- 60 seconds

(30 minutes)

**APC** ▪Phase 1

Real time control

100 milliseconds

(minutes)

**DCS**

Power and productivity
for a better world™

ABB