ABB Automation Days
Industrias de proceso y generación de energía
Madrid, 25 y 26 de mayo de 2015
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

![Diagram showing various levels of enterprise systems and their timescales.](image)
**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)

- w/out APC
- With APC
- Variance reduction

Limit/Spec
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
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:

\[
x(k) = Ax(k-1) + B_u u(k-1) + B_d d(k-1) + w(k-1)
\]

\[
y(k) = C x(k) + h(k)
\]

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

1. Diagnose
   - Measure performance gap
   - Forecast KPI

2. Implement
   - Fix performance gap
   - Define and prioritize

3. Sustain
   - Manage performance gap
   - Schedule

ABB ServicePort™

- Manual Operation
- Output out of range
- Increasing variability
- Improving process

Increased Performance

Control Network
- Equipment
- Process
- Application
- Maintenance

Remote Experts

Local Usage

ABB Support Center

ABB’s Customer

[Image of process flowchart with ABB logos]
Loop Advanced Services by ServicePort™

Platform Features & Capabilities
s. Service Content & Methodology

Service Port Features

View
- Raw Data: raw data associated with each channel
- Trends for Experts

Scan
- Security
- KP(s): presents KPIs generated from raw data through periodic diagnostic monitoring

Track
- Rules
- Gap rule = Alarm
- Generates notifications based on predefined KPIs

Service Port KPI Monitoring

<table>
<thead>
<tr>
<th>CONTROL</th>
<th>PROCESS</th>
<th>SIGNAL CONDITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1: Manual</td>
<td>P1: FCE Out of Range</td>
<td>S1: Quantized</td>
</tr>
<tr>
<td>C2: Oscillating Setpoint</td>
<td>P2: FCE Size</td>
<td>S2: Excessive Noise</td>
</tr>
<tr>
<td>C3: Deadband</td>
<td>P3: FCE Problem</td>
<td>S3: Spikes</td>
</tr>
<tr>
<td>C4: Offset</td>
<td>P4: FCE Leakage</td>
<td>S4: Step Out</td>
</tr>
<tr>
<td>C5: Over Control</td>
<td>P5: Intermittent Disturbance</td>
<td>S5: Compression</td>
</tr>
<tr>
<td>C6: Slow Control</td>
<td>P6: Persistent Disturbance</td>
<td>S6: Over Filtered</td>
</tr>
<tr>
<td>C7: FCE Travel</td>
<td>P7: Questionable</td>
<td>S7: Sampling Rate</td>
</tr>
<tr>
<td>C8: Slow Update Rate</td>
<td></td>
<td>S8: No Signal</td>
</tr>
<tr>
<td>C9: Questionable</td>
<td></td>
<td>S9: MV Out of Range</td>
</tr>
<tr>
<td>C10: Questionable</td>
<td></td>
<td>S10: Questionable</td>
</tr>
</tbody>
</table>

ServicePort Loop Performance
Service Content & Methodology
APC - Project development tasks

APC Design & Benefit Estim.

Loop Perf. Assessment and Optimization

Step Tests

Model Building

Integration Commissioning

Final test
APC – System integration

- VPN Remote Access
- Firewall
- OPC Server (existing)
- APC runtime (VM on existing server)
- Client – Remote Desktop
- APC LAN
- O-Net
- DCS
Sample DCS Play

![DCS Process Control Interface](image)

### UN 3100 CONTROLLI AVANZATI LIVELLI SCRUBBER

<table>
<thead>
<tr>
<th>MY</th>
<th>RICH</th>
<th>STATO</th>
<th>MIN.</th>
<th>SP EXT.</th>
<th>MAX.</th>
<th>CO</th>
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</thead>
<tbody>
<tr>
<td>3100 FIC1_047</td>
<td></td>
<td>ON</td>
<td>120 m³/h</td>
<td>173 m³/h</td>
<td>200 m³/h</td>
<td>68.6 %</td>
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<tr>
<td>3100 FIC1_054</td>
<td></td>
<td>ON</td>
<td>150 m³/h</td>
<td>178 m³/h</td>
<td>200 m³/h</td>
<td>49.9 %</td>
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<tr>
<td>3100 FIC2_047</td>
<td></td>
<td>ON</td>
<td>146 m³/h</td>
<td>166 m³/h</td>
<td>180 m³/h</td>
<td>73.0 %</td>
</tr>
<tr>
<td>3100 FIC2_054</td>
<td></td>
<td>ON</td>
<td>100 m³/h</td>
<td>156 m³/h</td>
<td>190 m³/h</td>
<td>66.4 %</td>
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</table>

<table>
<thead>
<tr>
<th>FF</th>
<th></th>
<th></th>
<th></th>
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<th></th>
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<tbody>
<tr>
<td>3300 FI0_021</td>
<td></td>
<td>ON</td>
<td></td>
<td></td>
<td></td>
<td>37.7 m³/h</td>
</tr>
<tr>
<td>3300 FI1_S14</td>
<td></td>
<td>ON</td>
<td></td>
<td></td>
<td></td>
<td>133 m³/h</td>
</tr>
<tr>
<td>3300 FI2_S14</td>
<td></td>
<td>ON</td>
<td></td>
<td></td>
<td></td>
<td>133 m³/h</td>
</tr>
<tr>
<td>3100 FI1_046</td>
<td></td>
<td>ON</td>
<td></td>
<td></td>
<td></td>
<td>29.7 m³/h</td>
</tr>
<tr>
<td>3100 FI1_051</td>
<td></td>
<td>ON</td>
<td></td>
<td></td>
<td></td>
<td>610 m³/h</td>
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<tr>
<td>3100 FI1_050</td>
<td></td>
<td>ON</td>
<td></td>
<td></td>
<td></td>
<td>179 m³/h</td>
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<tr>
<td>3100 FI2_046</td>
<td></td>
<td>ON</td>
<td></td>
<td></td>
<td></td>
<td>30.2 m³/h</td>
</tr>
<tr>
<td>3100 FI2_051</td>
<td></td>
<td>ON</td>
<td></td>
<td></td>
<td></td>
<td>503 m³/h</td>
</tr>
<tr>
<td>3100 FI2_050</td>
<td></td>
<td>ON</td>
<td></td>
<td></td>
<td></td>
<td>138 m³/h</td>
</tr>
</tbody>
</table>

| C.A. GENERALE |  | ON | 1 | | APC ON |

### Additional Information

- **Slide 17**
- **ABB Automation Days 2015**
- **Mayo de 2015**
- **ABB**
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
- Powerhouse & Steam Network
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- Powerhouse & Steam Network
- Powerhouse & Steam Network
- Powerhouse & Steam Network
### Some recent APC references

**ABB CoE Italy**

<table>
<thead>
<tr>
<th>Client</th>
<th>Scope</th>
<th>Industry</th>
<th>Year</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ilva</td>
<td>Gas Network &amp; Powerplant</td>
<td>Prim. Steel</td>
<td>2014-15</td>
<td>960 MW</td>
</tr>
<tr>
<td>ERG Power</td>
<td>Steam Network &amp; Powerplant</td>
<td>Refining</td>
<td>2015</td>
<td>520 MW</td>
</tr>
<tr>
<td>Isab Energy</td>
<td>Gas Network &amp; Powerplant &amp; Steam network</td>
<td>Process+Power</td>
<td>2014</td>
<td>535 MW</td>
</tr>
<tr>
<td>EDF (3 sites)</td>
<td>Combustion Optimization</td>
<td>Power</td>
<td>2014</td>
<td>1800 MW</td>
</tr>
<tr>
<td>CoProB</td>
<td>Powerhouse</td>
<td>Sugar</td>
<td>2013</td>
<td>25 MW</td>
</tr>
<tr>
<td>Uipsa</td>
<td>Paper Mill Cogeneration</td>
<td>Paper</td>
<td>2015</td>
<td>32 MW</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td>3872 MW</td>
</tr>
</tbody>
</table>
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
## Manipulated Variables

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>HP Boiler 1 Gas Flow</td>
<td>HP Extraction Demand</td>
</tr>
<tr>
<td>HP Boiler 2 Gas Flow</td>
<td>LP Extraction Demand</td>
</tr>
<tr>
<td>HP Boiler 3 Gas Flow</td>
<td>Turbine Exhaust Demand</td>
</tr>
<tr>
<td>HP Boiler 4 Gas Flow</td>
<td>PRV 850/475 -psig</td>
</tr>
<tr>
<td>HP Boiler 5 Gas Flow</td>
<td>PRV 850/95 -psig</td>
</tr>
<tr>
<td>HP Boiler 6 Gas Flow</td>
<td>PRV 95/40 -psig</td>
</tr>
<tr>
<td>LP Boiler 1 Gas Flow</td>
<td>475 # Dump Valve</td>
</tr>
<tr>
<td>LP Boiler 2 Gas Flow</td>
<td>95 # Dump Valve</td>
</tr>
<tr>
<td>LP Boiler 1 Steam Flow</td>
<td>40 # Dump Valve</td>
</tr>
<tr>
<td>LP Boiler 2 Steam Flow</td>
<td></td>
</tr>
</tbody>
</table>
## Case study – ACP Design Outputs

### Controlled Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>850# header pressure</td>
<td>40# Header Pressure</td>
</tr>
<tr>
<td>475# Header Pressure</td>
<td>LP Boiler 1 Pressure</td>
</tr>
<tr>
<td>95# Header Pressure</td>
<td>LP Boiler 2 Pressure</td>
</tr>
</tbody>
</table>

### Feed-Forward Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>475 # Steam Demand</td>
<td>40 # Steam Demand</td>
</tr>
<tr>
<td>95 # Steam Demand</td>
<td>5 # Steam Demand</td>
</tr>
</tbody>
</table>

### Constraint Variables

- HP Section Valve Positions
- IP Section Valve Positions
- LP Section Valve Positions
- Turbine Megawatts
Case Study - Steam header stabilization

Steam Pressure Control

APC OFF

APC ON

SETPOINT CHANGES
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

Graph showing gas flow over time with HP Boilers Maximized and 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

1 STs
Backpressure

Site Users
HP Steam
MP Steam
LP Steam

4 GTs, 2 STs

150 kV

Grid

380 kV

Site Users

limits on export

Grid
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 – 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

- **Terna** (Grid)
- BDE Clients
- APC Servers
- SAPP Servers
- Balancing & optimization
- Feasible plan & real-time compensation
- Ideal plan

Connections:
- BDE Clients to Terna
- SAPP Control Room Clients
- 3rd party OPC Servers
- DCS Consoles
- DCS controllers
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
Master controller structure

Diagram showing the flow of materials and energy from Gasifier1, Gasifier2, Expander, Syngas, TAR, Total Energy, HRSG1, HRSG2, GT1, GT2, Post Firing 1, Post Firing 2, ST1, ST2.
Master controller results

PV – Blue
Limits - Red

Syngas pressure

Net MW export

$\Delta$Power + 2.7 MW
APC applied to a Paper Mill Cogeneration

- Disturbances:
  - Paper breaks
  - Product changes
APC Proposed Solution

- Main targets/constraints
  - Net MW export \text{ (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 \text{ (minimize)}
  - Boiler \text{ (minimize)}

- Main handles
  - GT MW setpoint
  - Backpressure Turbine Pressure
  - Consensing Turbine Pressure or MW
  - Boiler steam flow
  - Postfiring flow
  - LP Attemperator
APC Integrated Solution

- Phase 1
  - Real time control
    - 100 milliseconds
      - 100 milliseconds (minutes)
  - APC

- Phase 2
  - Energy Export Scheduler
    - Medium term Optimization
      - 30 minutes
        - 30 minutes (24 hours horizon)
    - Real time control
      - 15-60 seconds
        - 15-60 seconds (30 minutes)

Boxes:
- Weather Forecast
- Market
- Product Scheduler
- Sales/Broker

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Mayo de 2015 | Slide 45
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