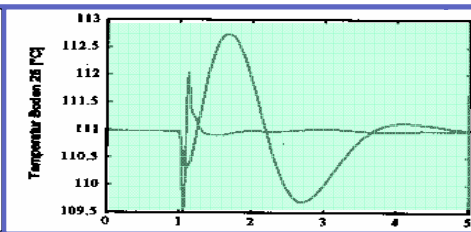
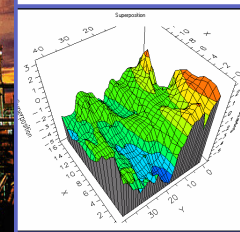


Raffaele Rea
GE-Bayer Specialties Srl -
Termoli
Paolo Belli, Nunzio Bonavita
ABB PS&S SpA - Genova

An Integrated Environment for Industrial Control Performances Assessment, Diagnosis and Improvement



Methodologies for Emerging
Technologies in
Automation

Rome 15 November 2006

Agenda



An Innovative Approach to Control Loop Performance Assessment

- Why Control Loop Condition Monitoring?
- Introducing Loop Performance Manager

A Case Study on a Chemical Plant

- The GE – Bayer Termoli Plant
- LPM Application
- Example and Overall results

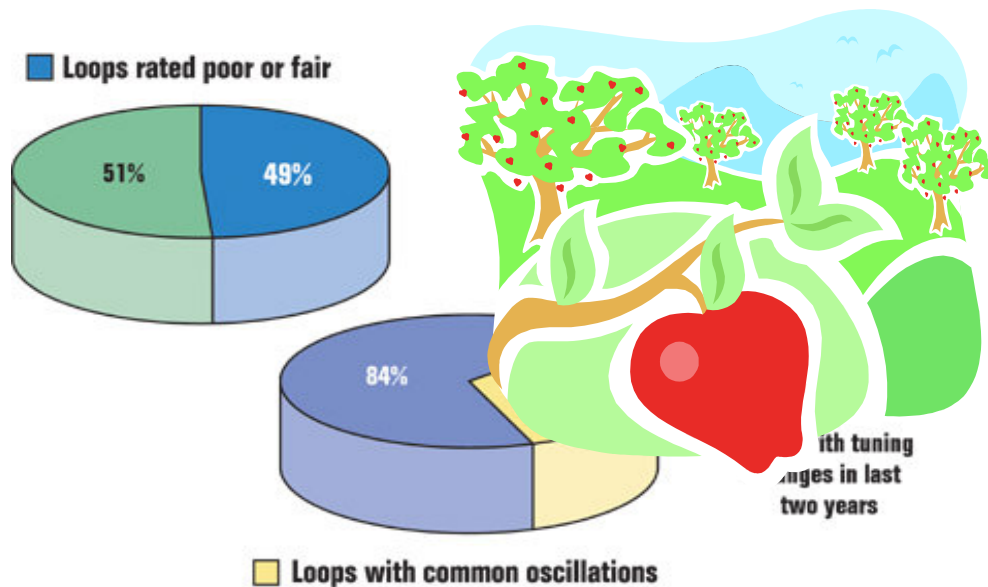
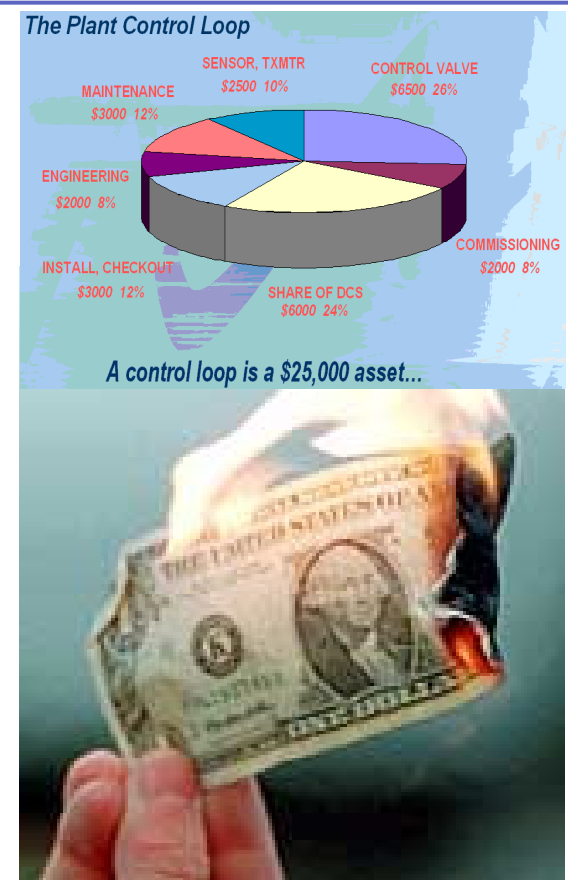


GE Bayer Silicones

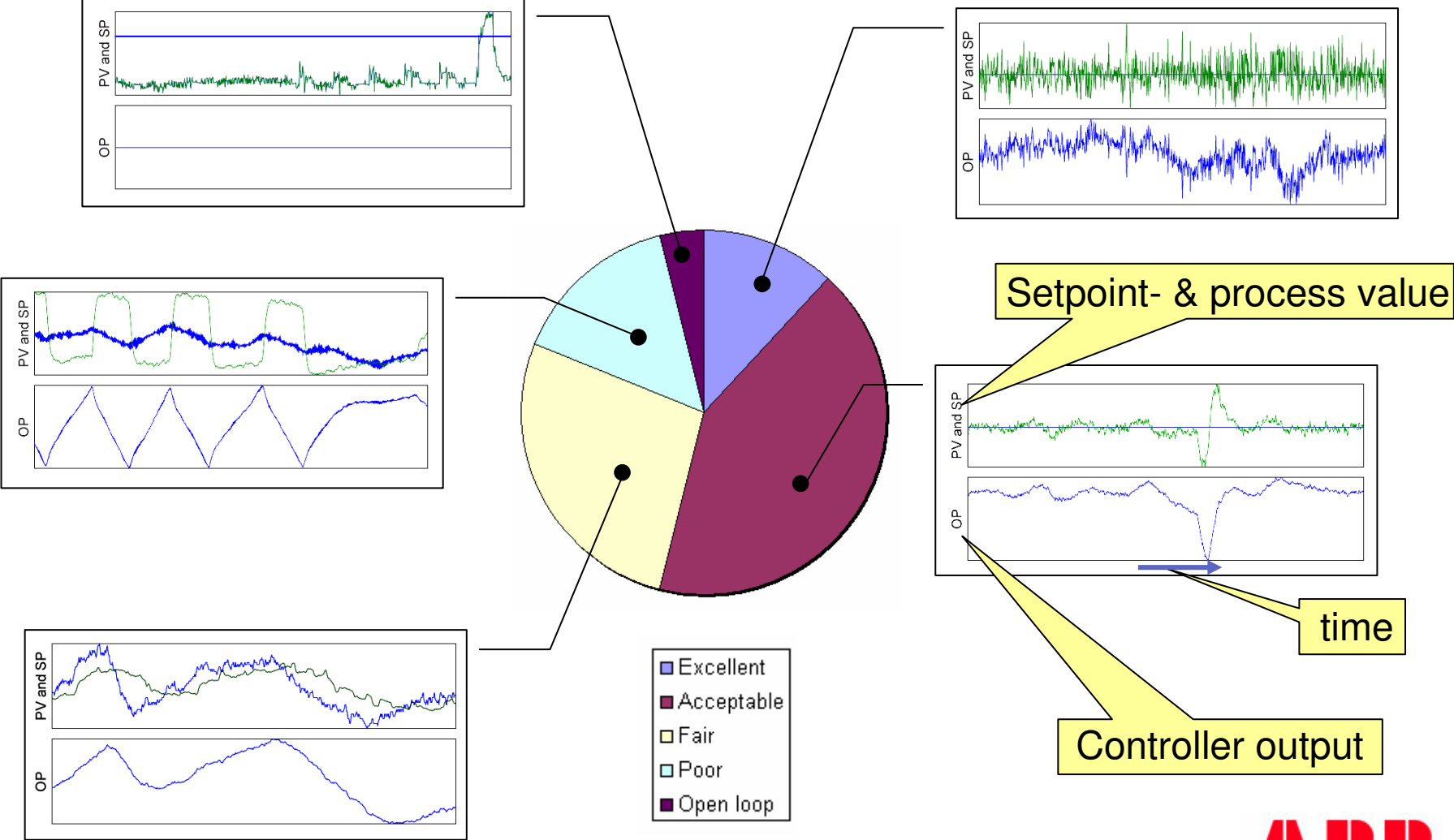


Why Control Loop Condition Monitoring?

- ... because they are a not negligible part of the process investment
- ... because they are a crucial element in the value-creation chain
- ... because their performances are statistically prone to WIDE improvement
- ... because they are the typical “low-hanging fruit”

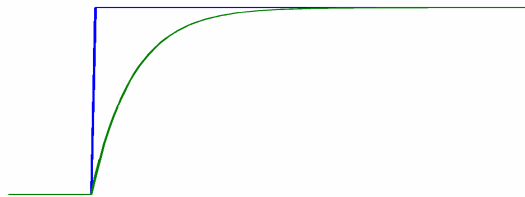


Control Loop Condition Monitoring (CLCM)

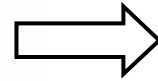


Performance Assessment: Tuning vs. Auditing

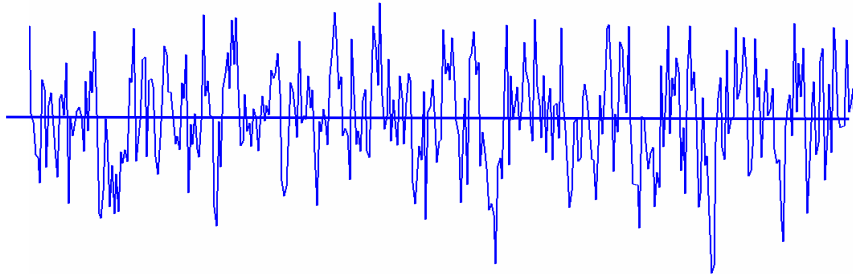
■ Tuning - Design stage



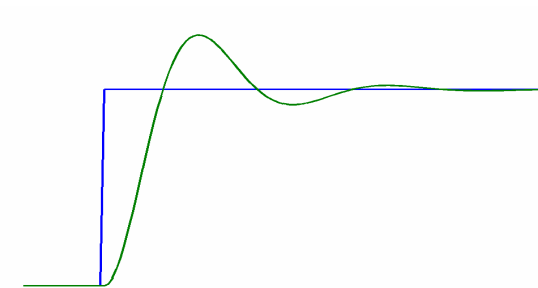
Reasonable design



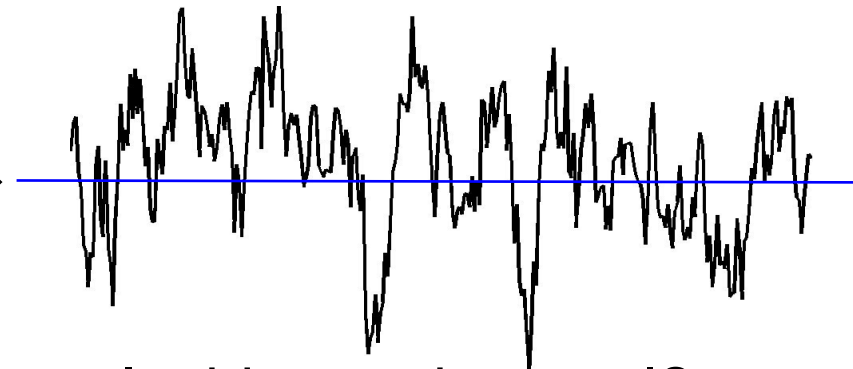
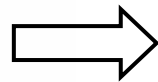
■ Assessment stage



If not: why?



Slightly tight design

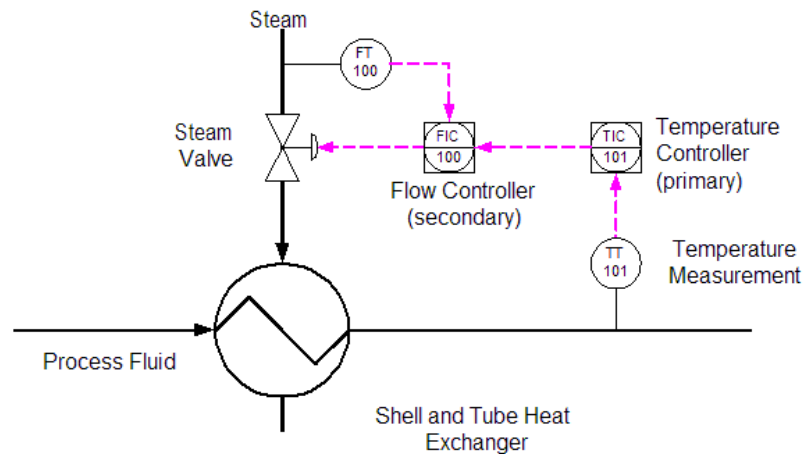
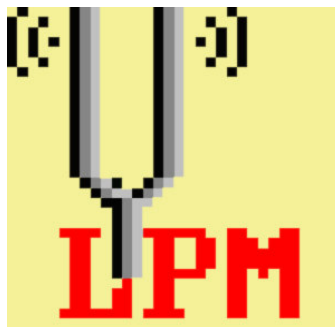


Is this good control?



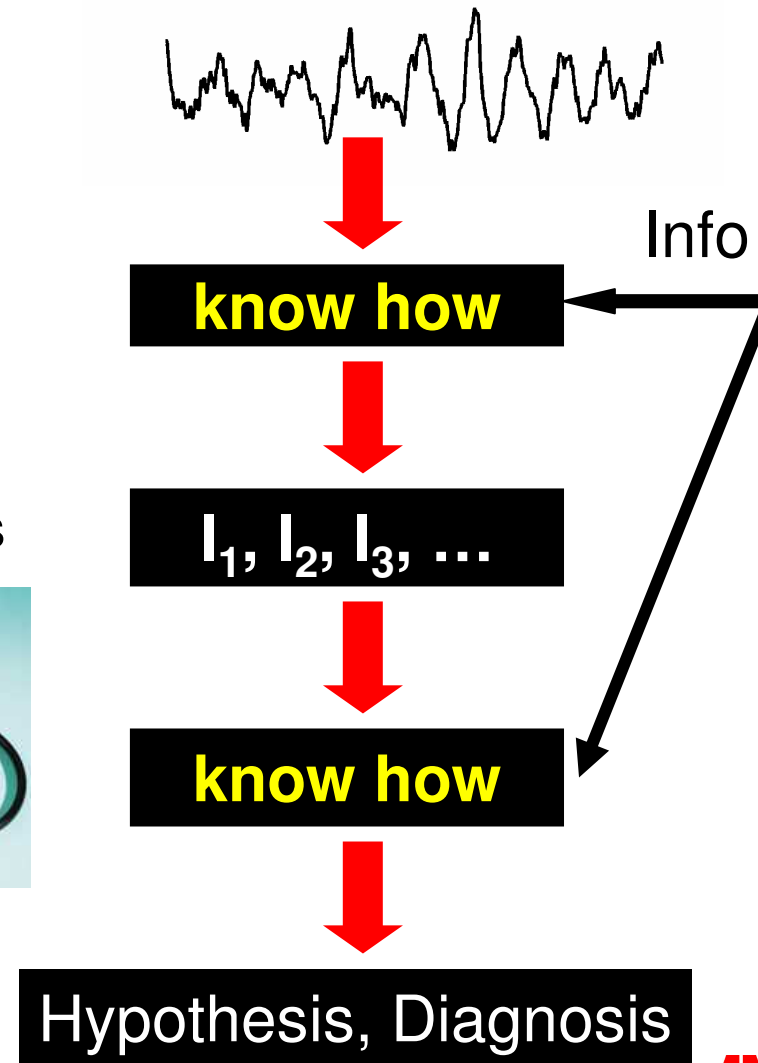
An Innovative Solution

- **Optimize^{IT} Loop Performance Manager (LPM)** is a comprehensive product addressing base control monitoring and optimization
- It is composed by 3 modules:
 - **Loop Auditing**, for control loop condition monitoring
 - **Loop Tuning**, for computer aided control loop tuning optimization
 - **Plant-wide Disturbance Analysis (PDA)**, for plant disturbances identification and characterization and for root cause analysis



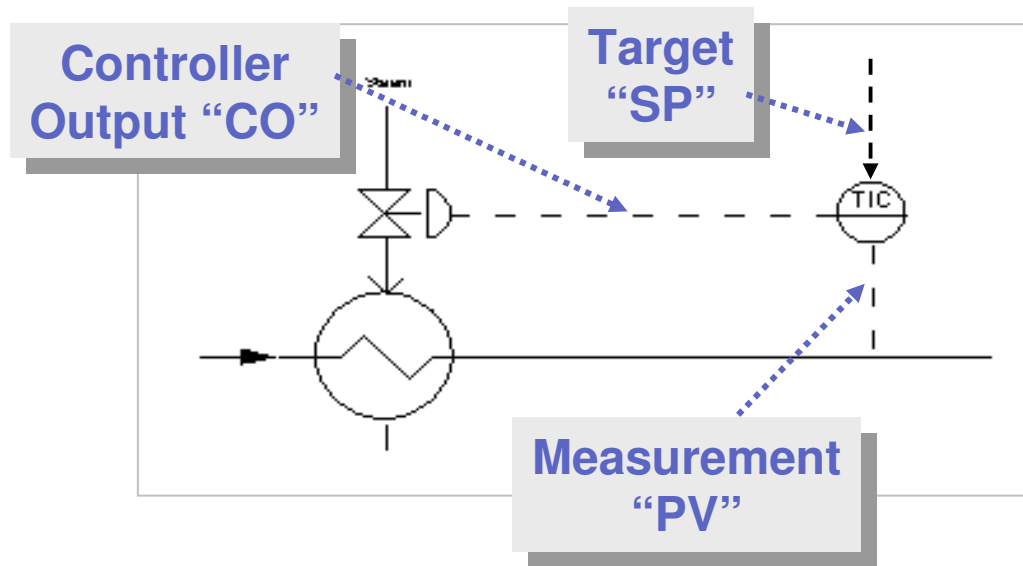
LPM Auditing - General concept

- based on available signals only (SetPoint, PV, CO)
- available information can be incorporated
- performance indices, measures
- inference engine



- suggest remedies

Kinds of Performance Indices in LPM



- Basic statistics
- Data Validity
- Control loop modes
- Tuning Performance indices
- Oscillation indices
- Valve indices
- Nonlinearity indices
- Property indices
- Housekeeping
- Special indices
- Continuous indices

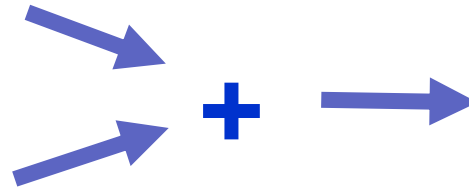
Index	index class
mean loop error	Basic statistics
std loop error (norm)	Basic statistics
std loop error (eng.unit)	Basic statistics
mean PV	Basic statistics
std CO	Basic statistics
skewness control error	Basic statistics
kurtosis control error	Basic statistics
compression test (value)	Data validity
quantization test (value)	Data validity
outlier	Data validity
noise index	Loop modes
ratio CE / CO	Loop modes
automatic mode	Loop modes
saturation	Loop modes
cascade mode	Loop modes
ACF/pred.horizon ratio	Performance
setpoint crossing index	Performance
cascade tracking index	Performance
cascade travel ratio	Performance
Harris index (FCOR)	Performance
oscillation index CE	Oscillation
oscillation index SP	Oscillation
oscillation period	Oscillation
oscillation amplitude	Oscillation
oscillation severity	Oscillation
shut-off PV value	Valve
stiction (correlation)	Valve
stiction (histogram)	Valve
valve travel per hour	Valve
valve reversals per hour	Valve
valve sizing index (10/90 time)	Valve
nonlinearity measure	Nonlinearity
NLI	Nonlinearity
NGI	Nonlinearity
Oscillation symmetry	Nonlinearity
estimated time-delay	Property
master flag	Property
step flag	Property
model fit flag	Property
static gain	Property
prediction horizon	Housekeeping
loop category	Housekeeping
classification value (optional)	Housekeeping
user-defined index # 1	Special
user-defined index # 2	Special
user-defined index # 3	Special
Auto mode (logged)	Continuous
Control error value	Continuous
percentage of saturated (index?)	Continuous



Kinds of Diagnoses in LPM

Performance indices

Auditing Rules



Maintenance Diagnoses

Diagnoses

Tuning Problem

Loop Oscillatory

SetPoint oscillatory

Significant external disturbance

Significant non-linearity

Valve stiction

Valve leakage or zero error

Valve size incorrect

Excessive valve action

Data unreliable

- Indices plus know-how organized in a Root-Cause analysis elaborate **Maintenance Suggestions**
- Diagnoses deal with problems in: **Tuning, Actuators and Sensors, External disturbance**

LPM PID Tuning

- *What* steps are necessary to tune a loop?

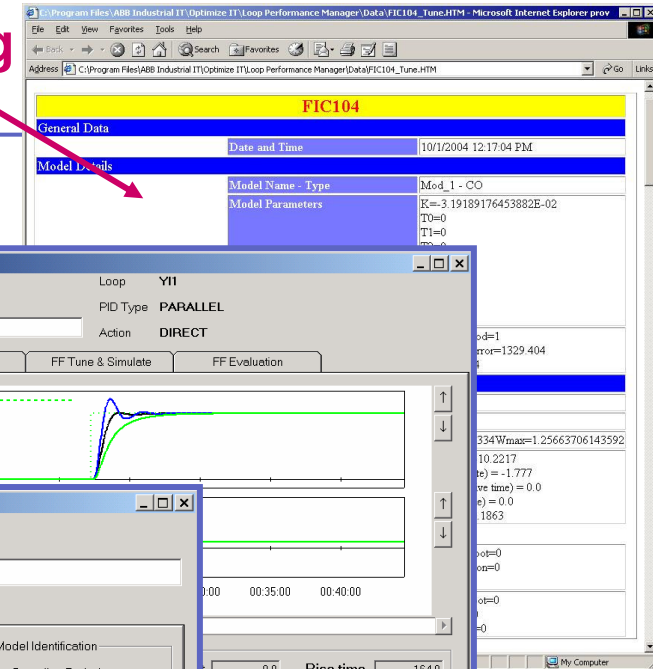
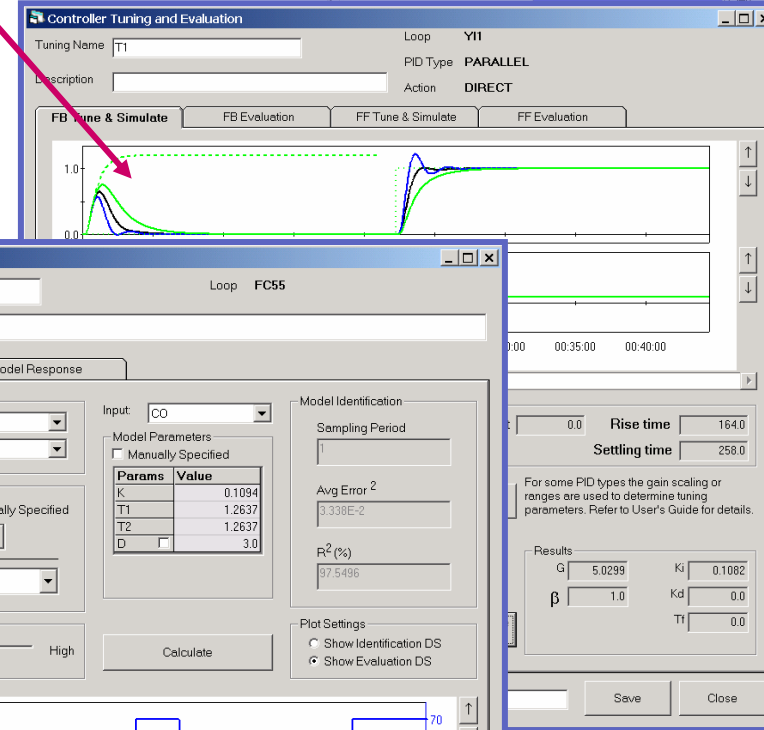
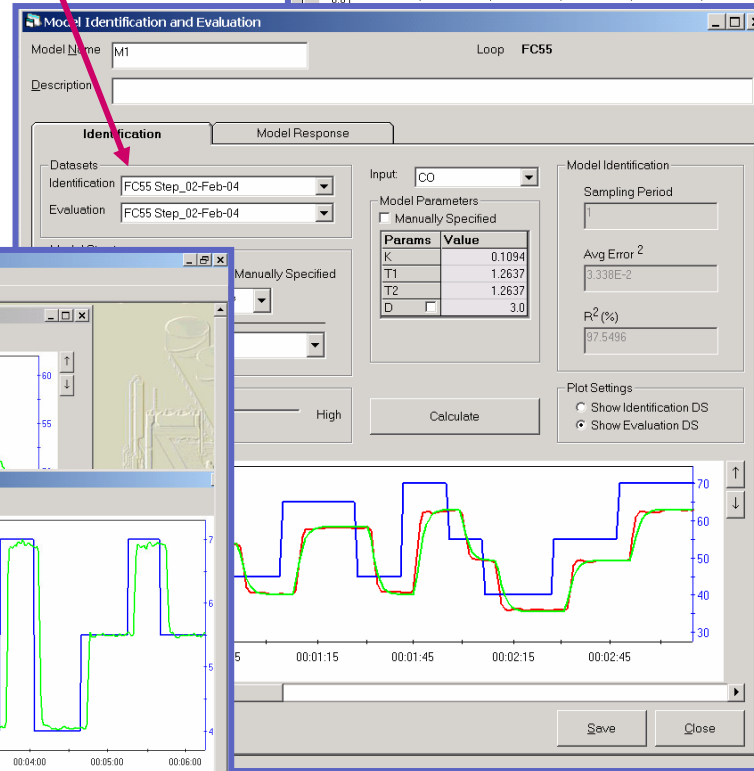
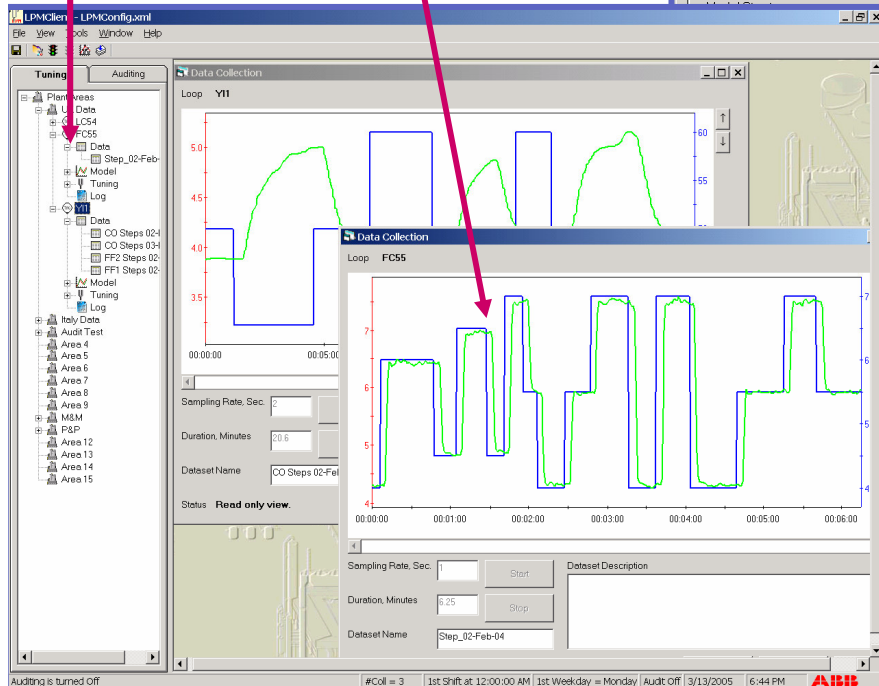
Configure

Collect

Model

Tune

Log



GE Bayer Silicones

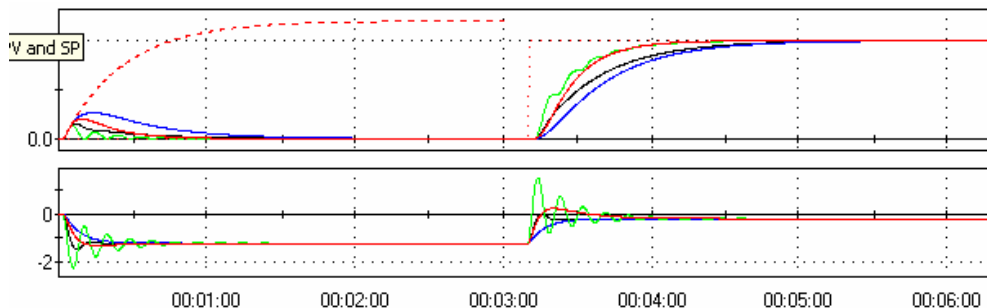


LPM Tuning – Summary



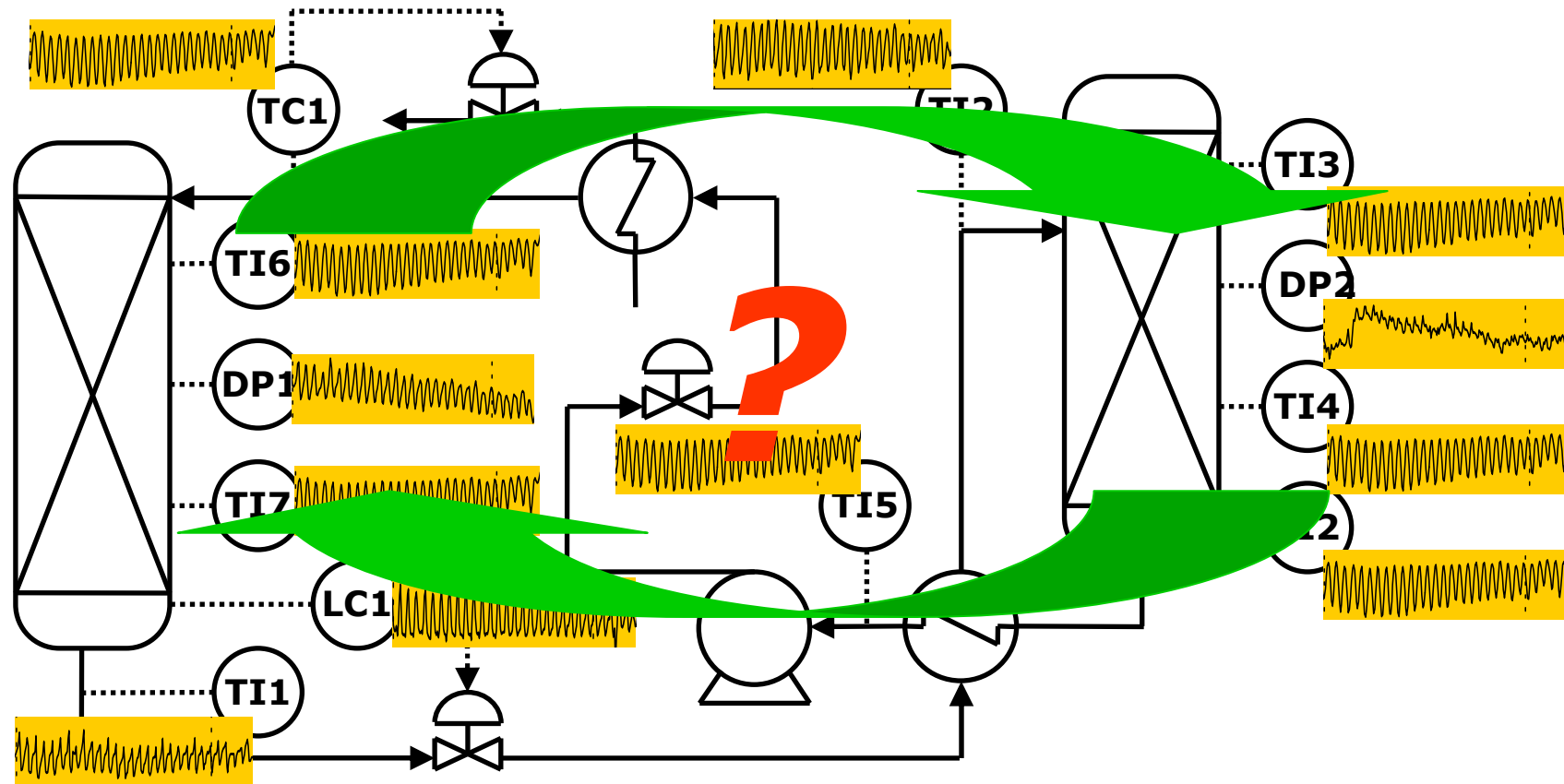
- State of the art Tuning Algorithm, but with user-friendly tool to make Advanced Control Theory accessible to every Plant Engineers
- Ready for every DCS
 - OPC connection
 - Calculated PID parameters (K_p , T_i , T_d) with the definition of your DCS
- Identification with Loop in both Close and Open Loop Mode
- Not only basic PIDs, but also FeedForward and Cascade Loop

Control Tuning becomes easy, fast, profitable



Plant-Wide Disturbance: The Problem

Plant-wide disturbances in chemical plants act on many process variables



© ABB - 13 Disturbances can propagate counter flow because of recycle and thermal integration

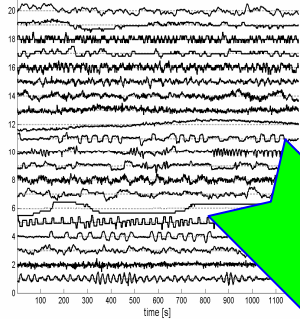


GE Bayer Silicones



LPM-PDA: an Offline tool for Process Troubleshooting

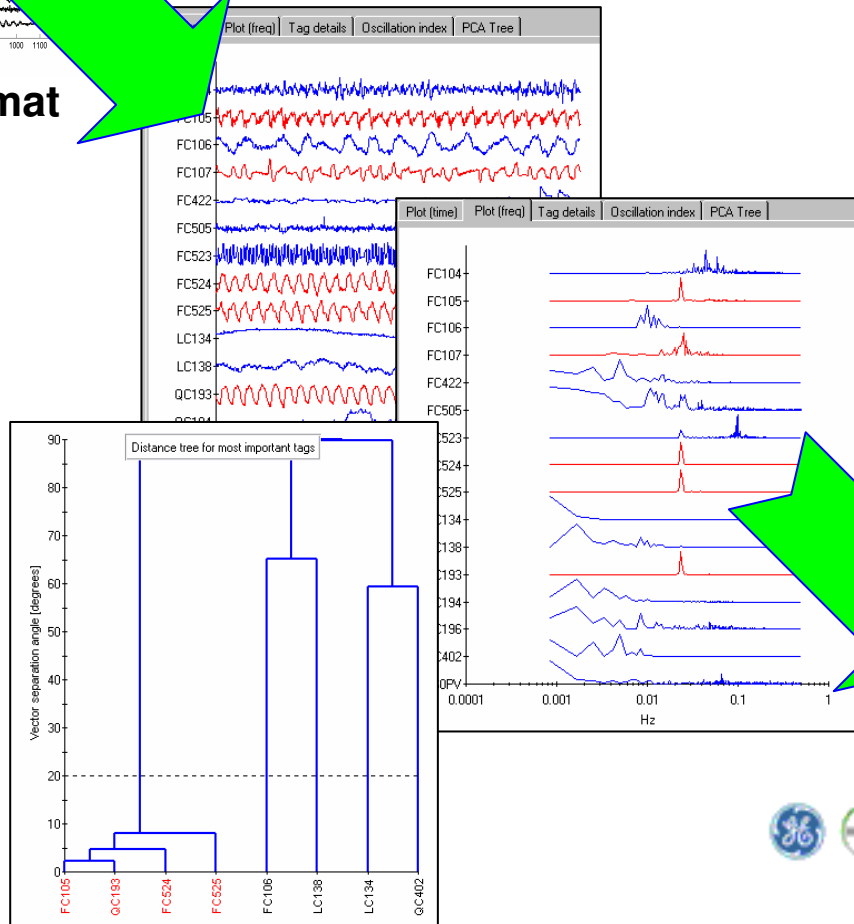
■ Data Import



.txt, .csv, .xls, .mat

■ Loops Clustering based on:

- Oscillation frequency
- Principal Component Analysis (PCA) on Power Spectrum



■ Root Causes Identification

Cluster: oscCluster3 (5)

Time window: Automatic (first 12-25 cycles)

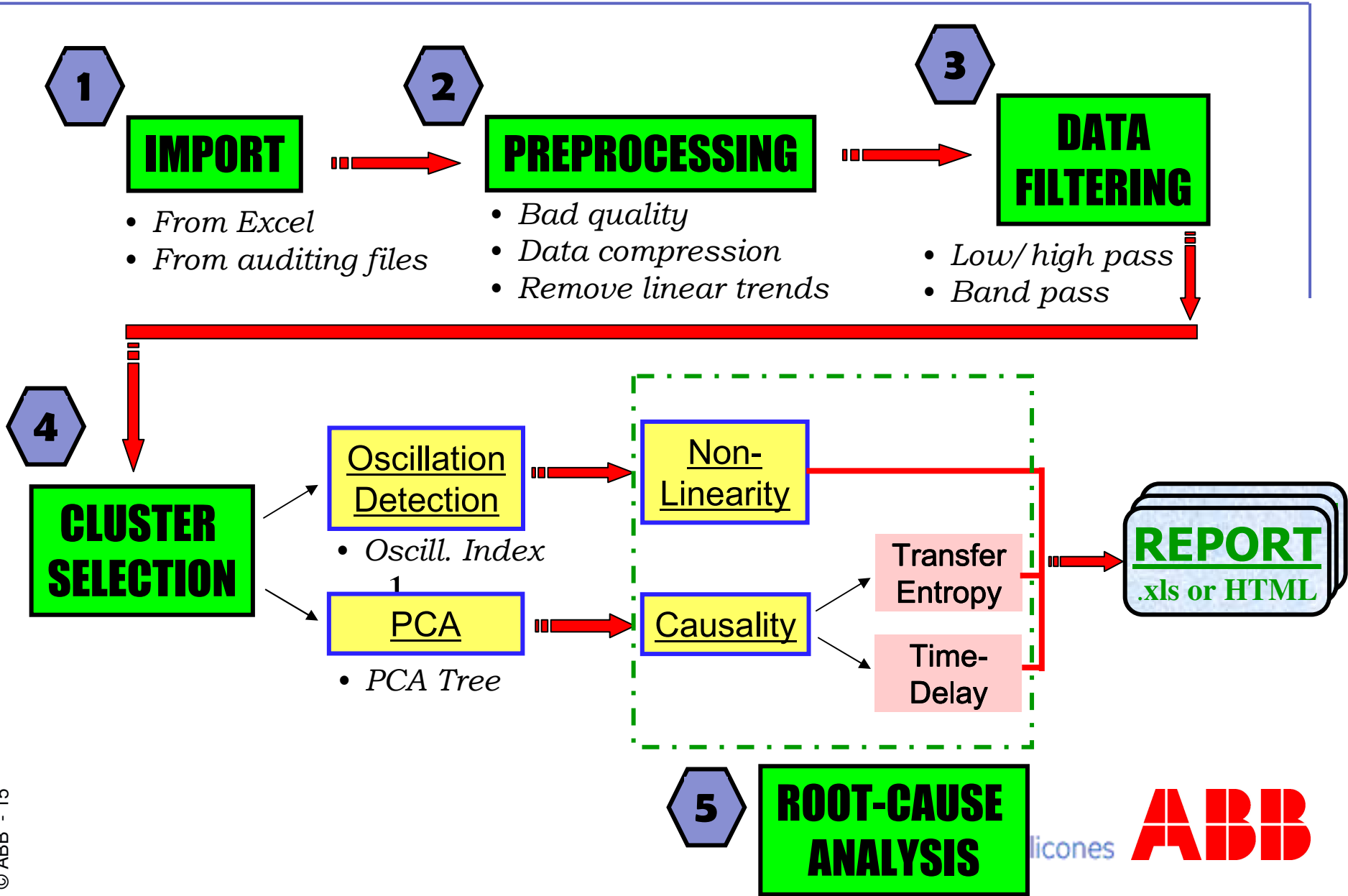
Samples in statistical simulation: quick estimate (25)

Analyse Root Cause

Tag Name	Linear	Non Lin Inde
QC193	non linear	4.8
FC105	non linear	2.29
FC525	non linear	1.47
FC524	non linear	1.28
FC107	linear	0.59

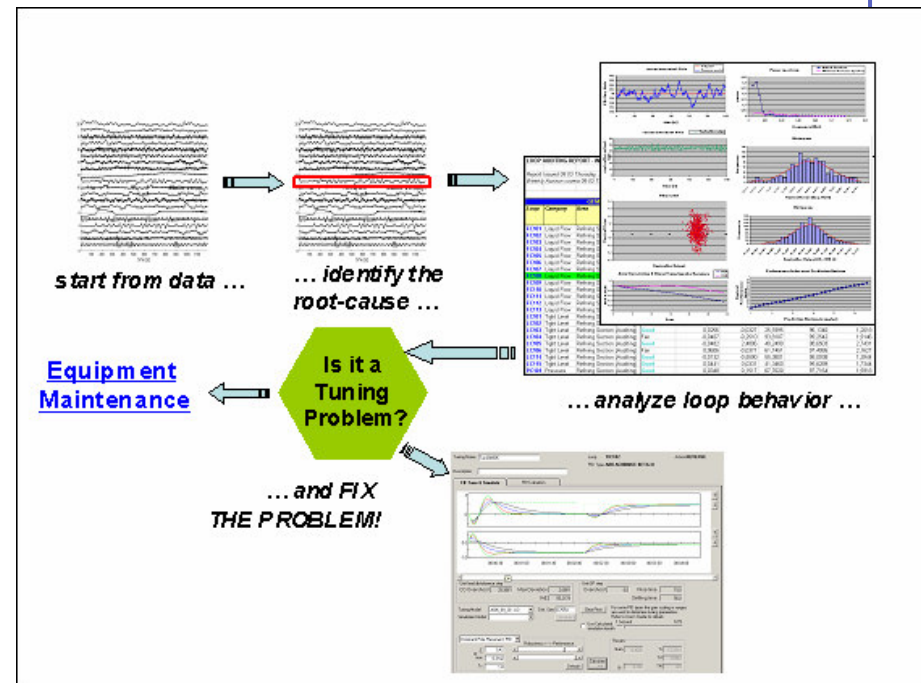


PDA Flow-Diagram



The LPM Conceptual Workflow

- The main idea behind LPM is to provide a **single** tool which can help control and maintenance engineer in their daily duty
- When something abnormal happens:
 - Start from normal time trends and data
 - Use **PDA** to identify possible root-cause
 - Use **Auditing** detailed loop information to diagnose why the problem has happened
 - If the problem comes from PID performance, use the **Tuning** feature to optimize it



Agenda



An Innovative Approach to Control Loop Performance Assessment

- Why Control Loop Condition Monitoring?
- Introducing Loop Performance Manager



A Case Study on a Chemical Plant

- The GE – Bayer Termoli Plant
- LPM Application
- Example and Overall results



GE Bayer Silicones



GE-Bayer Termoli Plant



GE-Bayer Termoli Plant

Manufacturing Technology

- Silanes production of monomers based on Trichlorosilane (*Silanes 1*)
- Silanes production of monomers based on Trimethoxysilane (*Silanes 2* and *GreenTyre*)
- Urethane Additives production of siloxane copolymers
- Silicone Fluids production of silicone antifoams and emulsions



GE Bayer Specialties srl



Automotive

Electronics

Construction

Textile and leather

Domestic Applications

Personal
Care

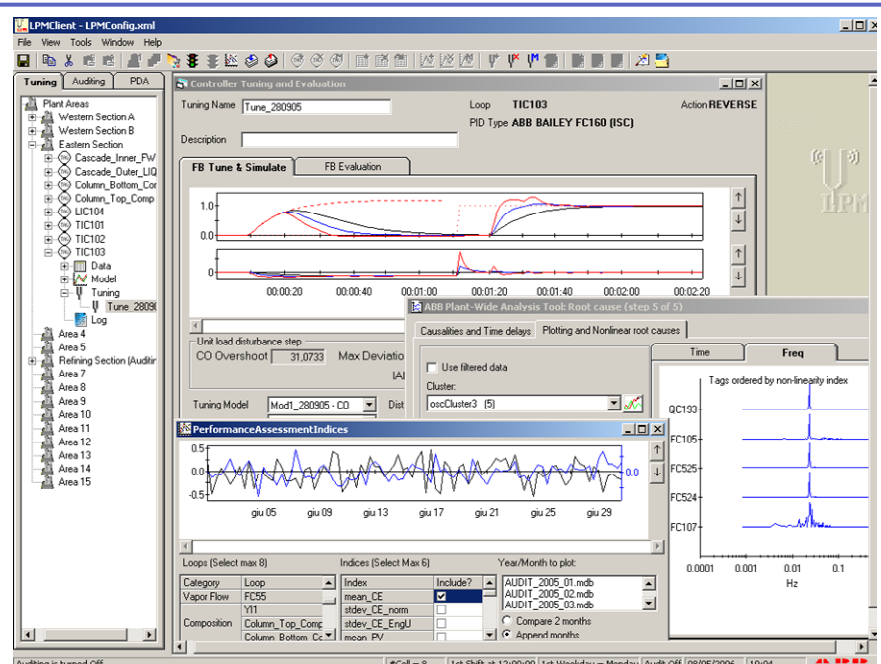
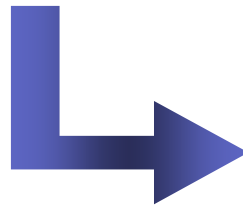


Healthcare



Project Background

- Complex chemical process
- More than 500 PID loops
- In early 2006 Company Headquarter launched a 6- σ program (“*Stable Operations*”) to:
 - Increase quality consistency
 - Reduce energy consumption (up to 10%)

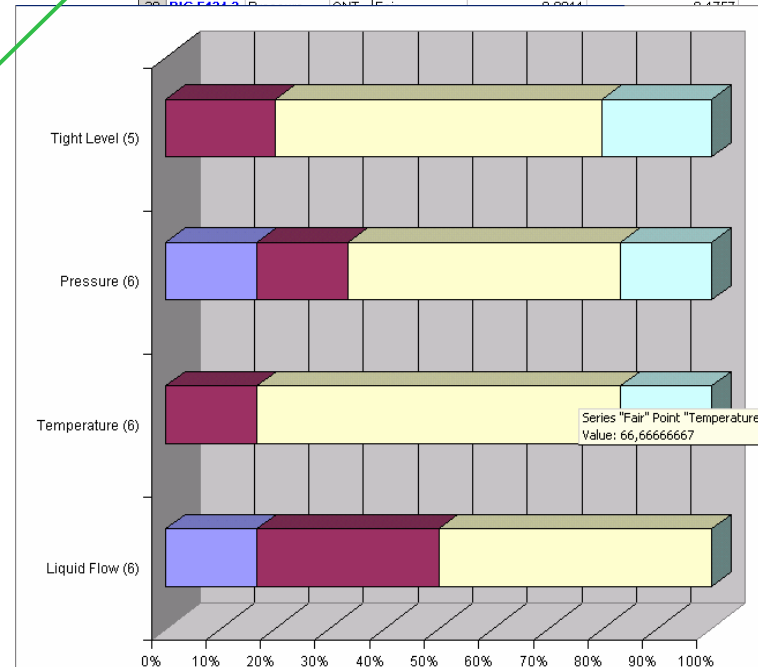


Improving basic automation performances identified as a key action

Project Development

- LPM Tuning allowed a single Control Engineer to retune more than 250 loops (TIC, FIC, PIC, LIC and pH) in less than 3 weeks
- After re-tuning activity, LPM Auditing has been turned on to check control performance
- In the last 6 months, LPM Auditing has remained up and running, producing reports every week and month
- Custom reports configured for each main process area
- Example:
 - Report dated May 21st on Process Area named CNT
 - Loop **PIC-D117-1** is rated “Poor”
 - Loop **PIC-C123-6** is rated “Excellent”

Loop	Category	Area	Performance	mean loop error	std loop error (norm)
FIC-P109-1	Liquid Flow	CNT	Excellent	-0,2758	0,7329
FIC-P109-2	Liquid Flow	CNT	Good	-0,0021	0,1404
FIC-P102-1	Liquid Flow	CNT	Fair	0,0370	1,0106
TIC-D113-2	Temperature	CNT	Fair	-0,0015	0,1474
PIC-D117-1	Pressure	CNT	Poor	-3,6995	0,1416
PIC-D117-2	Pressure	CNT	Good	0,0003	0,0506
PIC-D117-1	Pressure	CNT	Poor	-3,6995	0,1416
TIC-E116-1	Temperature	CNT	Fair	0,0001	0,0061
TIC-E145-1	Temperature	CNT	Good	0,3352	0,2435
FIC-C123-3	Liquid Flow	CNT	Good	-0,0014	1,3423
TIC-C123-2	Temperature	CNT	Fair	-0,0406	0,2805
LIC-C123-1	Tight Level	CNT	Fair	0,0770	3,5120
FIC-C123-7	Liquid Flow	CNT	Fair	-0,2048	2,1003
TIC-C123-5	Temperature	CNT	Fair	0,0000	0,0056
LIC-E130-1	Tight Level	CNT	Fair	0,0000	0,0048
LIC-P132-4	Tight Level	CNT	Good	-0,1548	3,3165
PIC-C123-6	Pressure	CNT	Excellent	-0,0016	0,2042
PIC-E130-4	Pressure	CNT	Fair	-1,5727	0,7048
LIC-E134-1	Tight Level	CNT	Fair	0,0013	0,0591
FIC-C133-3	Liquid Flow	CNT	Fair	-2,2933	0,2868

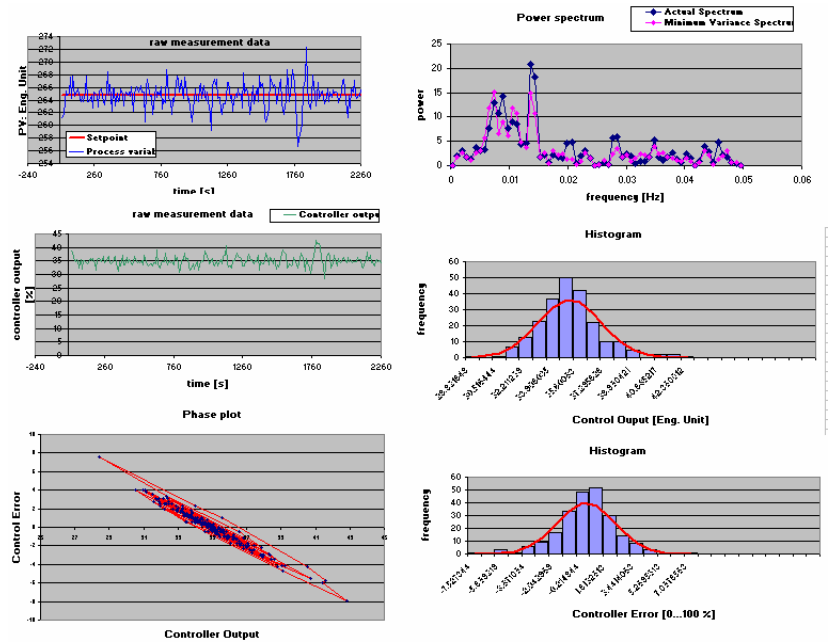


Understanding Control Loop Performances

- Comparing Diagnosis it is easy to spot a main difference
 - **Maintenance Suggestion**: check Valve Size
- For deeper insight look at Indices:
 - Worse performing loop has:
 - a much bigger mean loop error
 - An higher oscillation index with a period of about 7 minutes (negative values mean no oscillation)

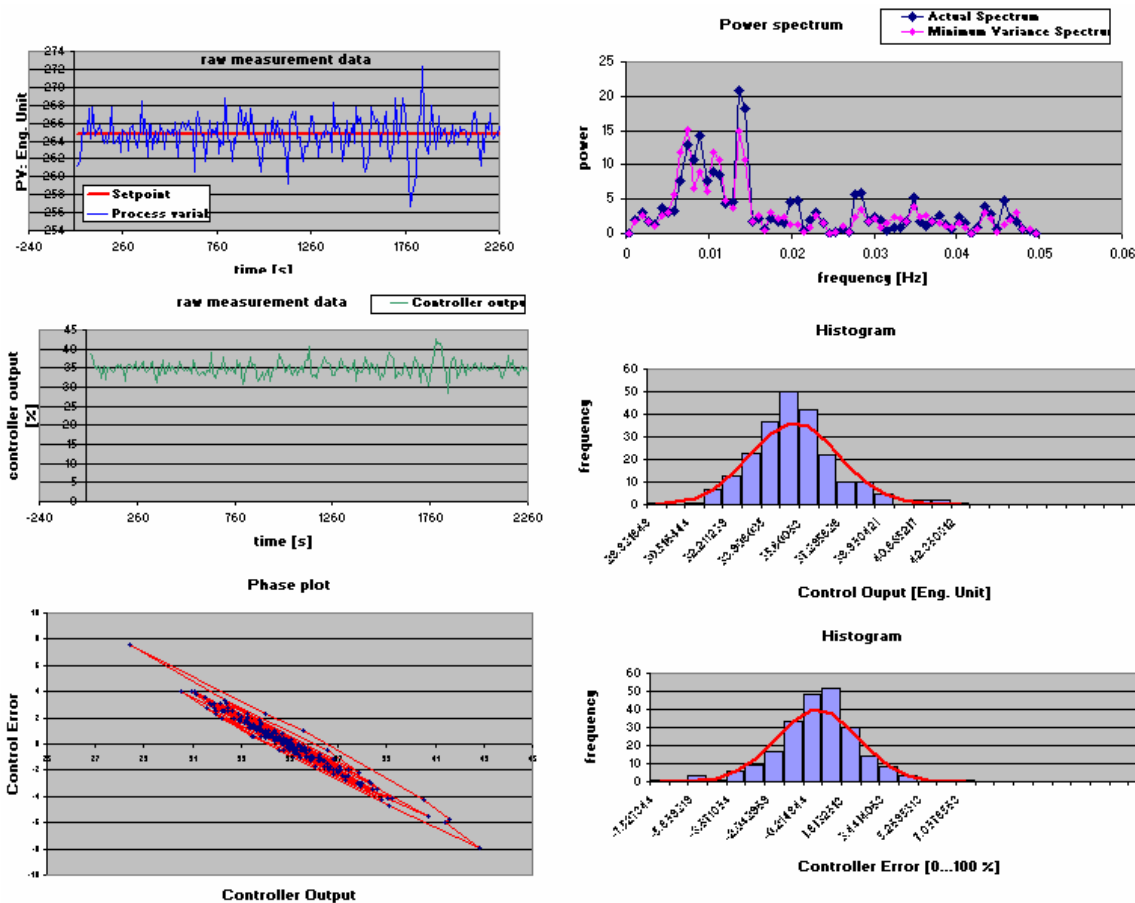
Loop Diagnoses	PIC-C123-6	PIC-D117-1
Overall Performance	Excellent	Poor
Tuning problem	0%	5.88%
Loop oscillatory	0%	100%
SetPoint oscillatory	0%	0%
Significant external disturbance	n.a.	n.a.
Significant nonlinearity	n.a.	0%
Valve stiction	n.a.	0%
Valve leakage or zero error	n.a.	n.a.
Valve size incorrect	0%	85%
Excessive valve action	20%	0%
Data unreliable	0%	0%

Loop Indices	PIC-C123-6	PIC-D117-1
mean loop error	-0.0016	-3.69
std loop error (norm)	0.20%	0.14%
CO saturation index	0.0000	99.6000
setpoint crossing index	39.3250	0.0000
Harris index	0.9475	0.0005
oscillation index CE	-0.86	0.39
oscillation period	n.a.	401.9 s
oscillation amplitude	n.a.	44.97%



Understanding Control Loop Performances

- Additional details can be recovered configuring the Detailed Loop Reports, where a number of analysis (both in Time and Frequency) are available on the last data collection



Overall Results

- The experience gained at the Termoli GE - Bayer Specialties Plant has been extremely positive:
 - The Tuning feature has allowed a single skilled engineer to complete in less than a month a task otherwise worth several months without the proper support
 - Auditing is running silently in background making available reports each week without requiring any manpower effort
 - Reports can be consulted to verify operation performances if and when needed
- Plant engineers have estimated that the better control performances obtained in the project are allowing to save 5% of the methane used for process steam generation



Thanks for Your Attention

