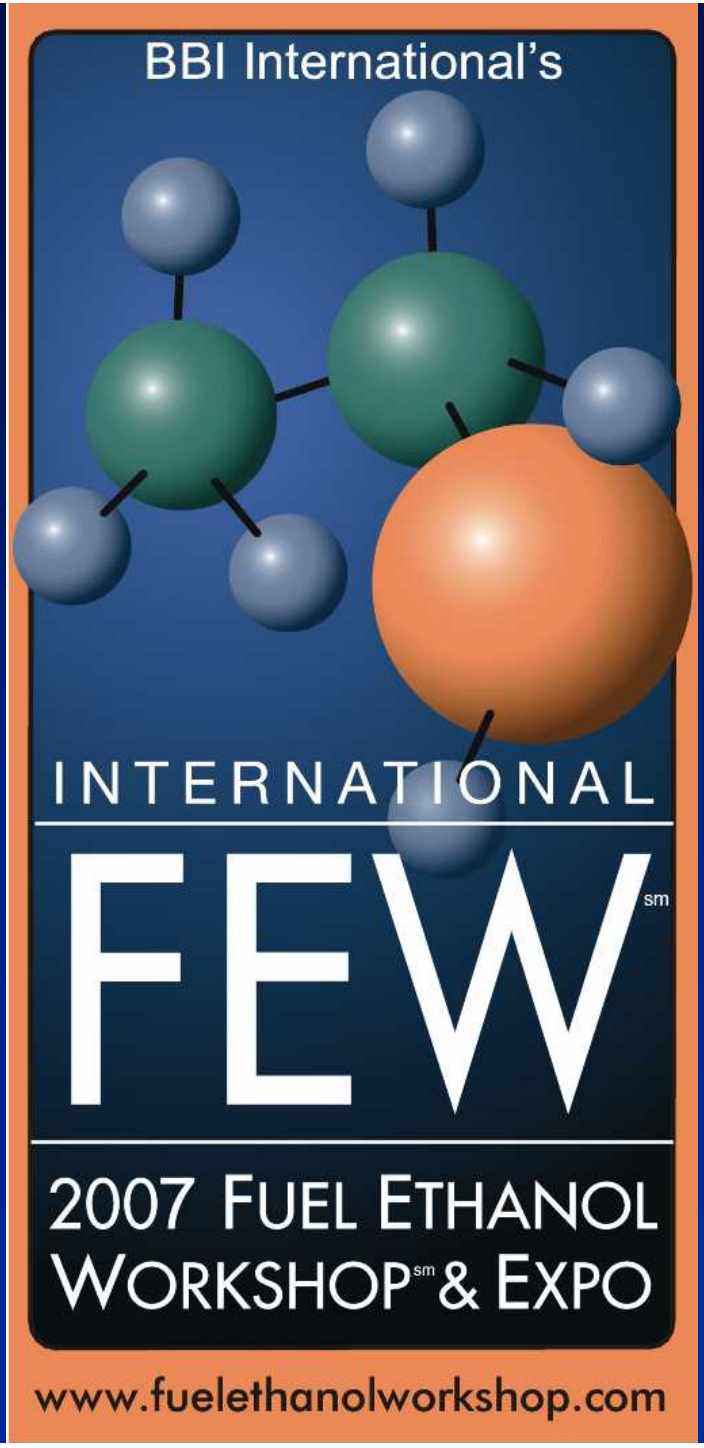
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An Evolutionary Approach to Information Systems and Advanced Control in Fuel Ethanol Processes

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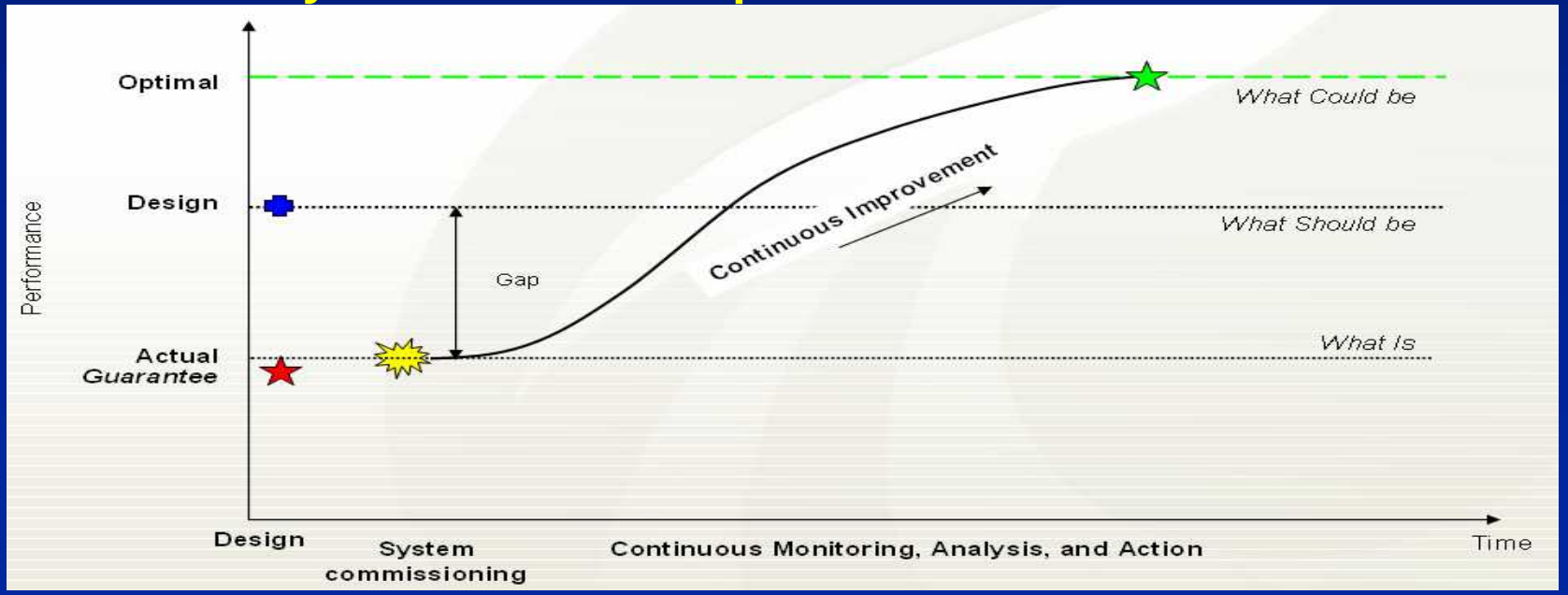
Two Approaches to Advanced Applications

- **Big Bang – Solution**
  - Packaged solution
  - Generally more complex and difficult to maintain
  - Reported higher benefits, generally more costs & "Time to Value"
  - Less flexible and generally harder to maintain over time
  - Summary: sustainability over time is a major challenge- RISK

- **Evolutionary – Continuous Improvement**



Example of an Evolutionary Approach to Energy Management

Level 5 – Rigorous Offline/Online Utilities/Energy Simulation/What-if

3rd party Simulation/Optim packages

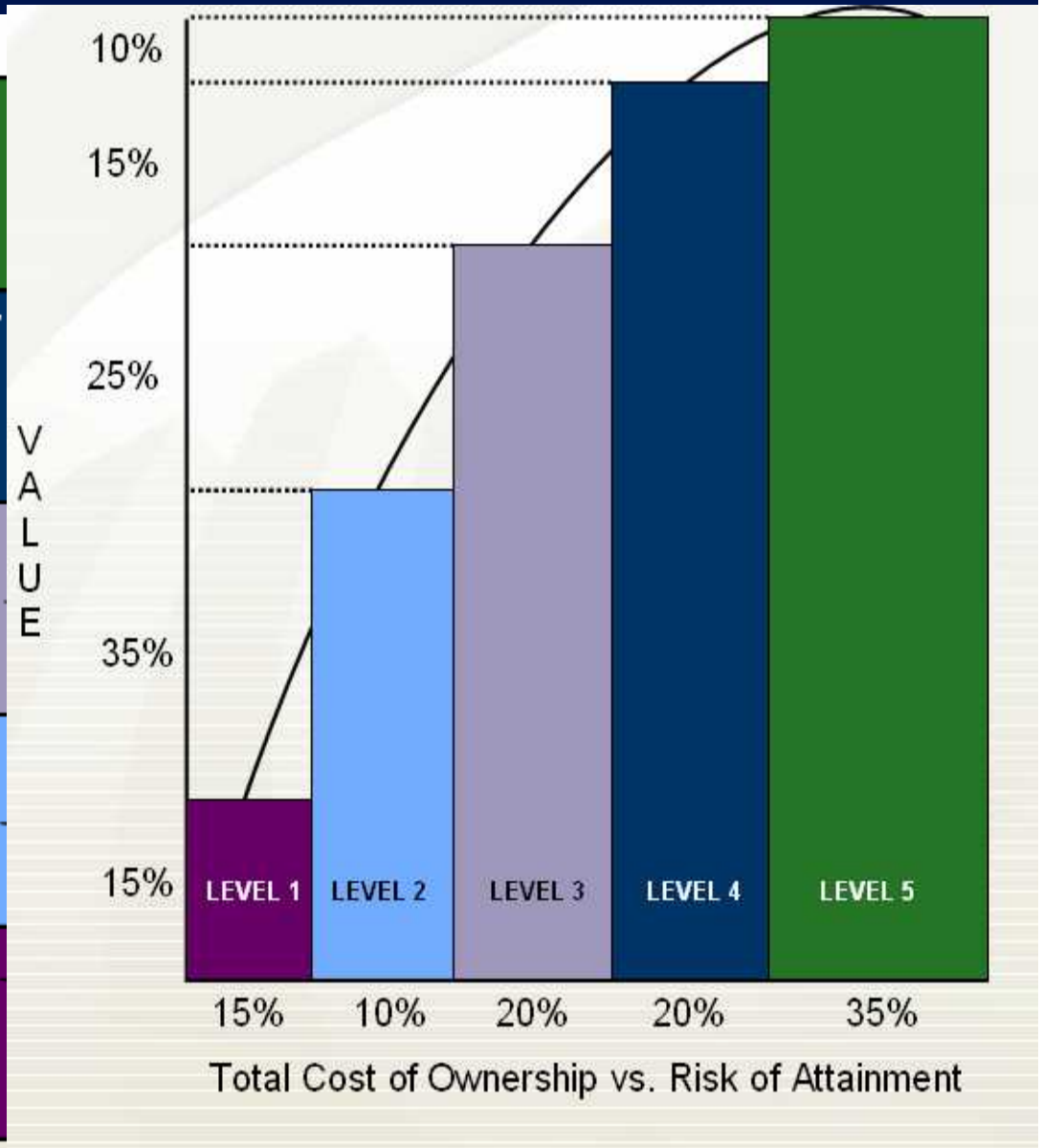
Level 4 – Integration of Third Party Thermal and Data Packages

Standard Interfaces/Libraries

Level 3 – Utilities/Energy System Reconciliation, Validation, and Topology/Context

Level 2 – Utilities/Energy System Calculations and Integration

Level 1 – Utilities/Energy System Displays & Information



Critical Success Factors for This Approach to Work

- **DCS Vendor independent real-time infrastructure**
  - Scalable
  - Robust and evergreen
  - Pervasive connectivity
  - Powerful analytics and visualization capabilities
  - Configurable
  - Enterprise ready and capable
- **A "continuous Improvement, keep it simple" Company philosophy**
  - Vision
  - 80/20 - smaller incremental benefit for a higher up time and ROI over time
  - Baseline, historical, and KPIs over life of assets
  - Culture – the human element
- **A "Champion" who Leverages the real-time infrastructure**
  - Leader
  - Visionary
  - Technical savvy

Basic APC Application Hierarchy

monitoring process variables

monitoring basic regulatory control loops (PID loops)

calculated process variables (e.g., inferred properties)

basic regulatory control (PID loops)

calculated performance variables (e.g., heat exchanger fouling)

advanced regulatory control (e.g., cascade loops, analyzer feedback)

calculated efficiencies (e.g., boiler, compressor)

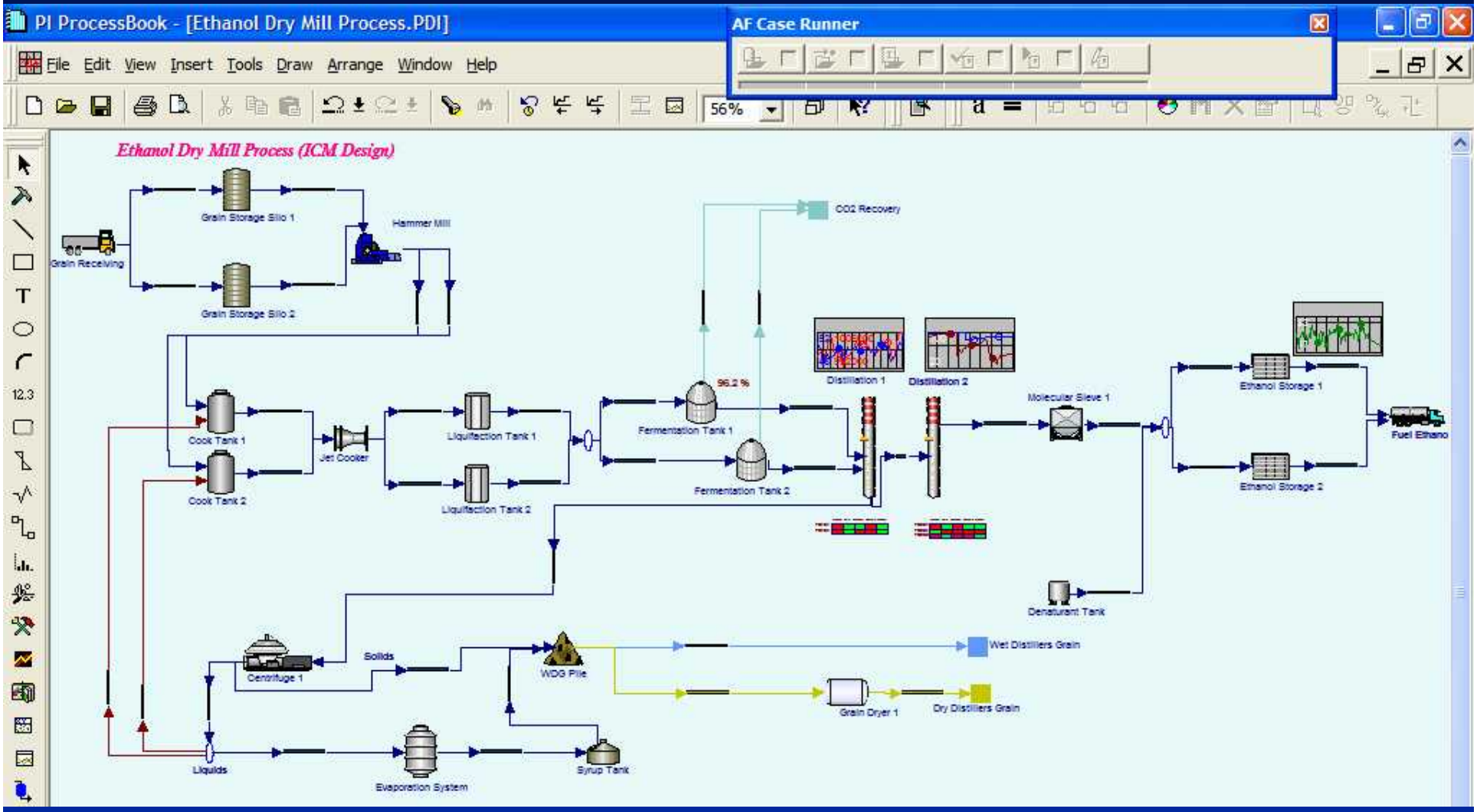
specialized control algorithms (e.g., constraint projection, pass balancing)

model predictive control (single-loop)

calculated key performance indicators (e.g., net cost, profit)

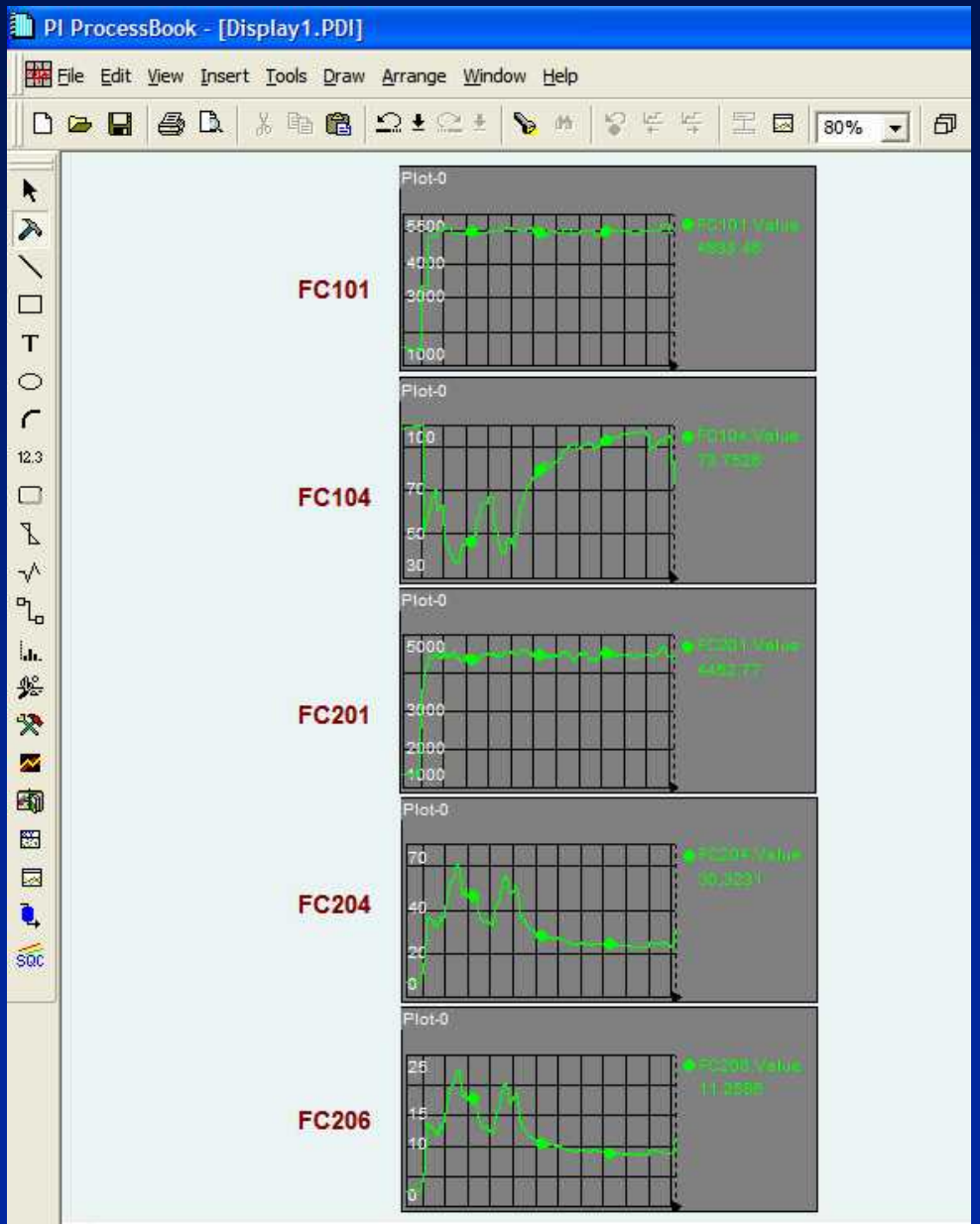
Fuel Ethanol Plant Information System Overview

ICM, Inc. (www.icminc.com)



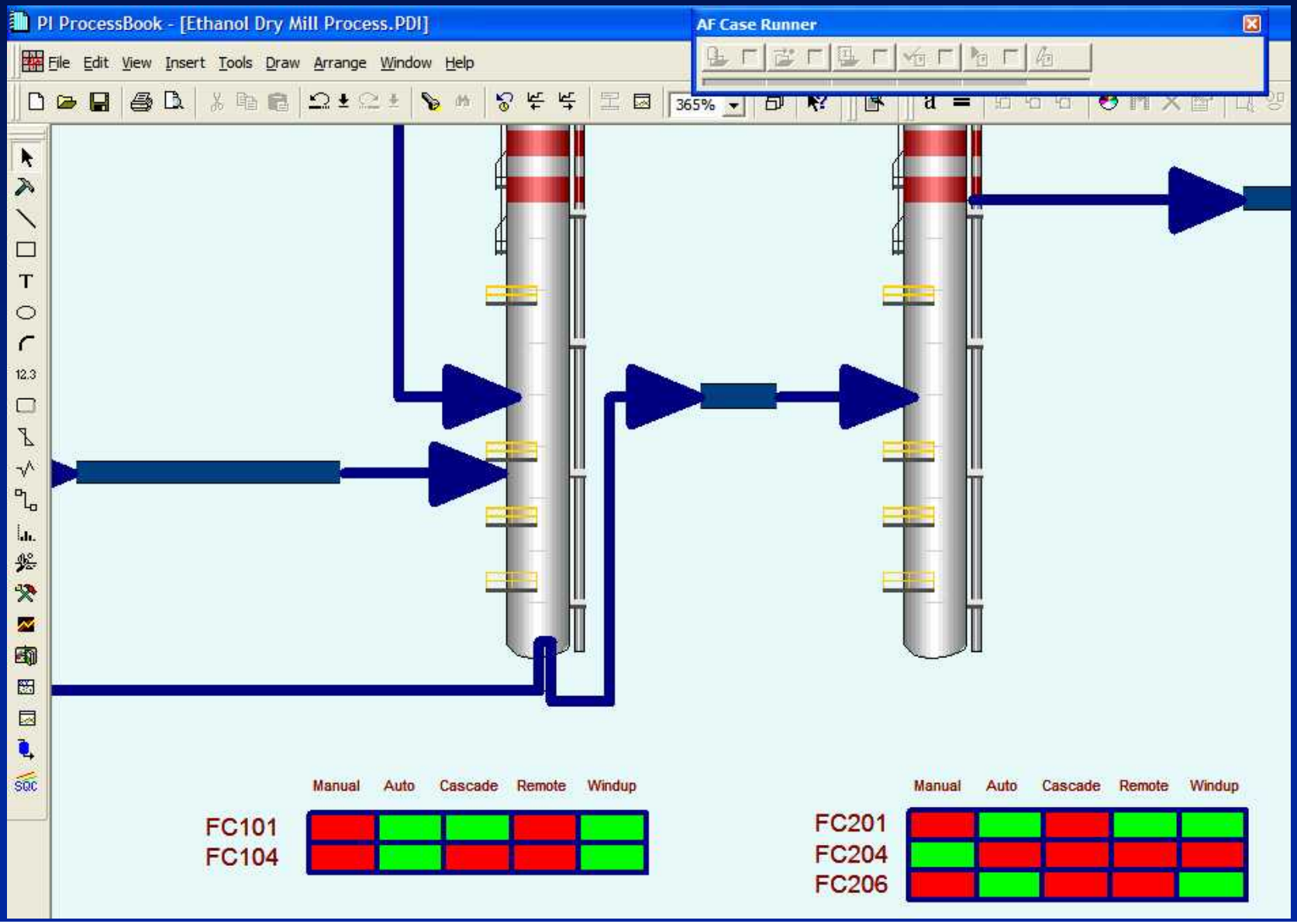
Monitoring Process Variables

visualization of process variables – trend displays



Monitoring Basic Regulatory Control Loops

the basic PID controllers in the DCS or PLC



Calculated Process Variables

engineering calculations and inferred properties

QI101	LP column reboiler duty
QI201	HP column reboiler duty

Basic Regulatory Control

basic PID controllers direct to the valve

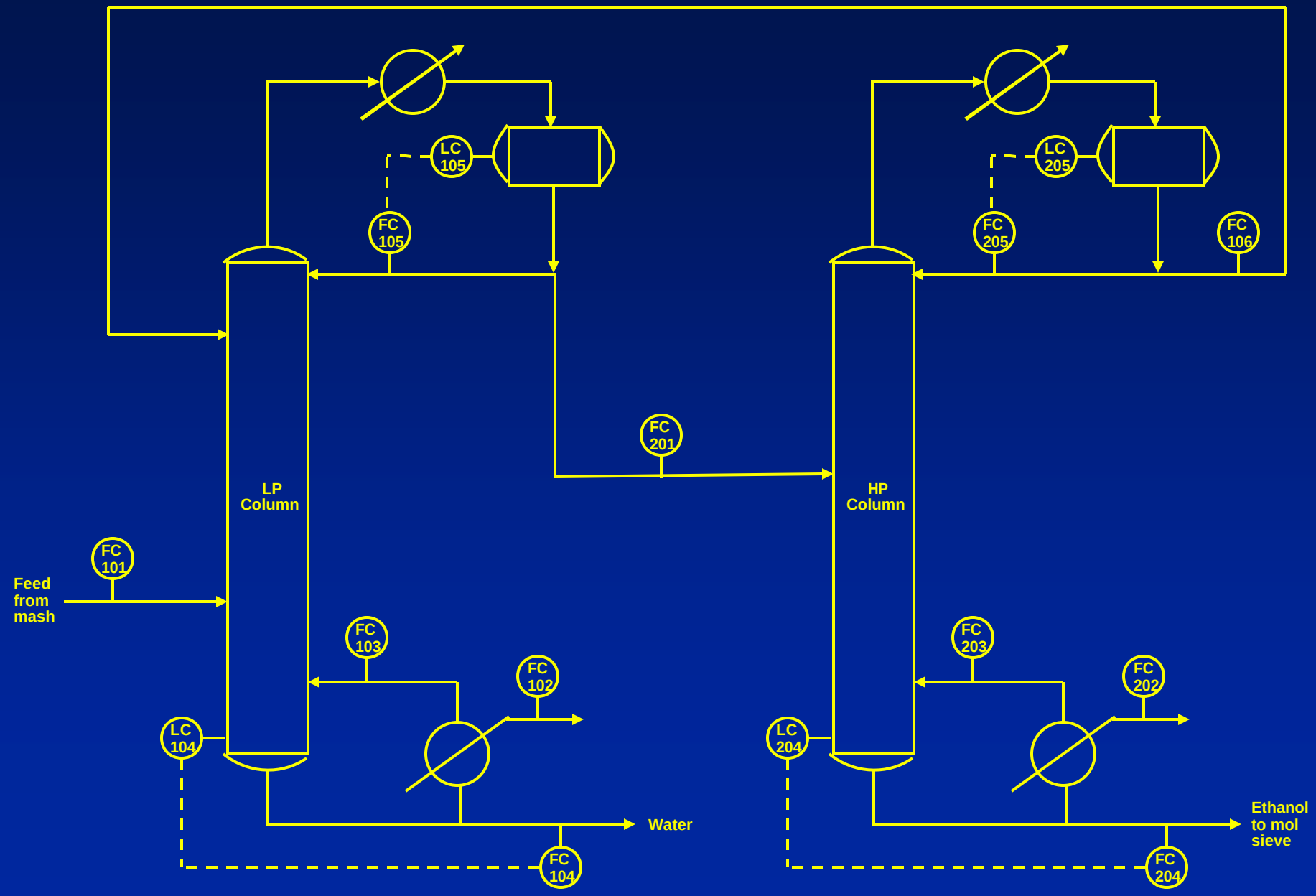
flow

pressure

level

Basic Regulatory Control

critical to all supervisory applications



Calculated Performance Variables

usually refer to process equipment state of well being

heat exchanger fouling

$F = Q/Q_{clean}$

furnace pass fouling

$F = Q/Q_{clean}$

distillation column flooding

$F = f(L/V \text{ or } \Delta P)$

Advanced Regulatory Control

DCS or PLC control blocks on top of the basic PID loops

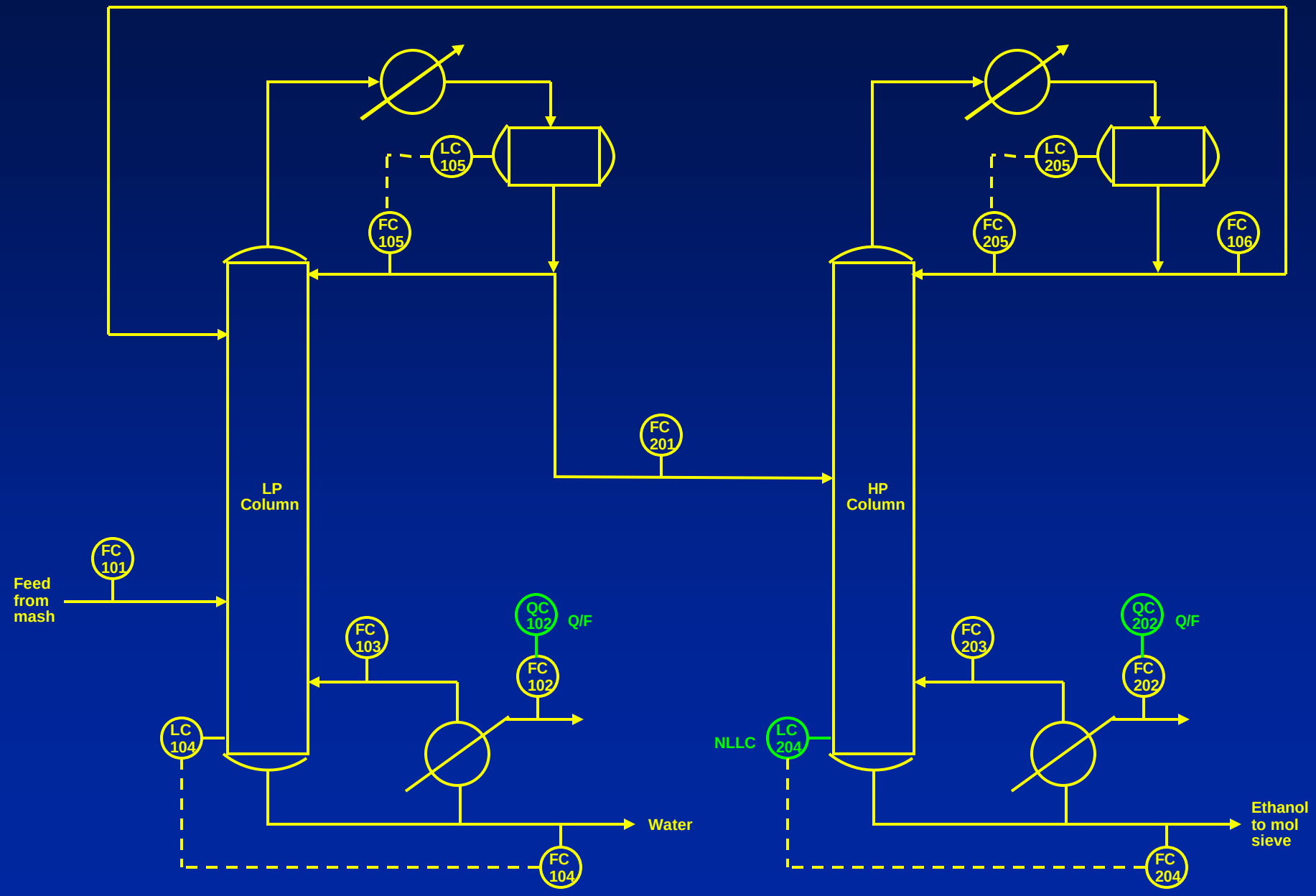
single-loop cascades
- e.g., T to F

feedforward controllers
- L/L to the PID error

select logic controllers
- hi or low

nonlinear level controllers
- gap, vee

Advanced Regulatory Control



Calculated Efficiencies

efficiency is a measure of performance of a piece of equipment

boiler efficiency

E = f(T, Q, gases)

compressor or fan efficiency

E = f(load curve)

natural gas efficiency (mscf/gal)

electrical efficiency (kwh/gal)

Specialized Control Algorithms

came from the APC vendor companies

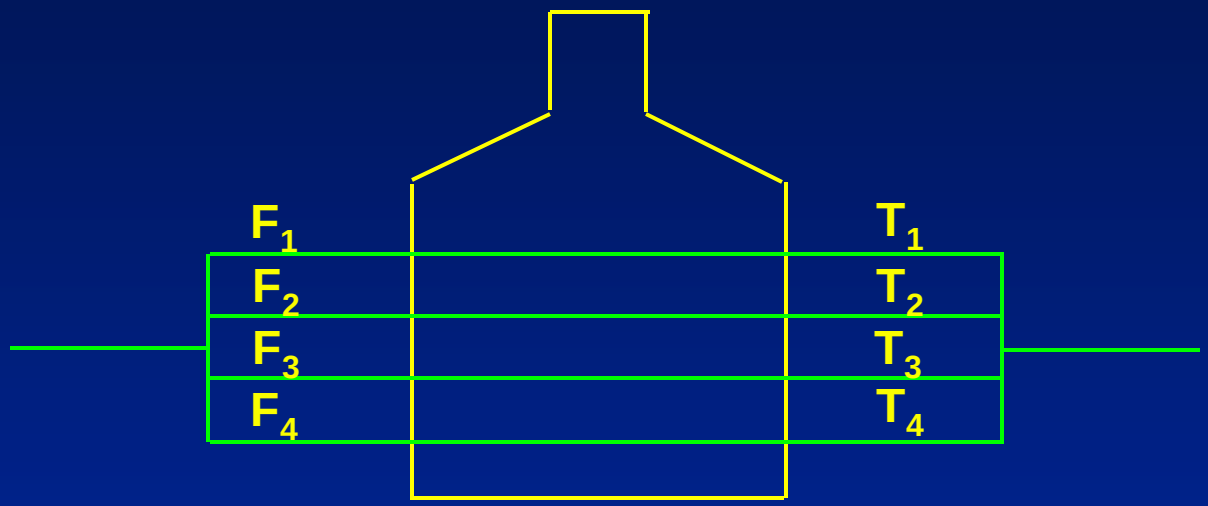
pass balancing

constraint projection

evolutionary optimization

Pass Balancing

equalize pass outlet temperatures



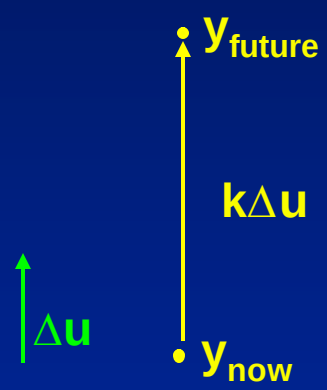
$$T_{avg} = (\Sigma T_i)/n$$

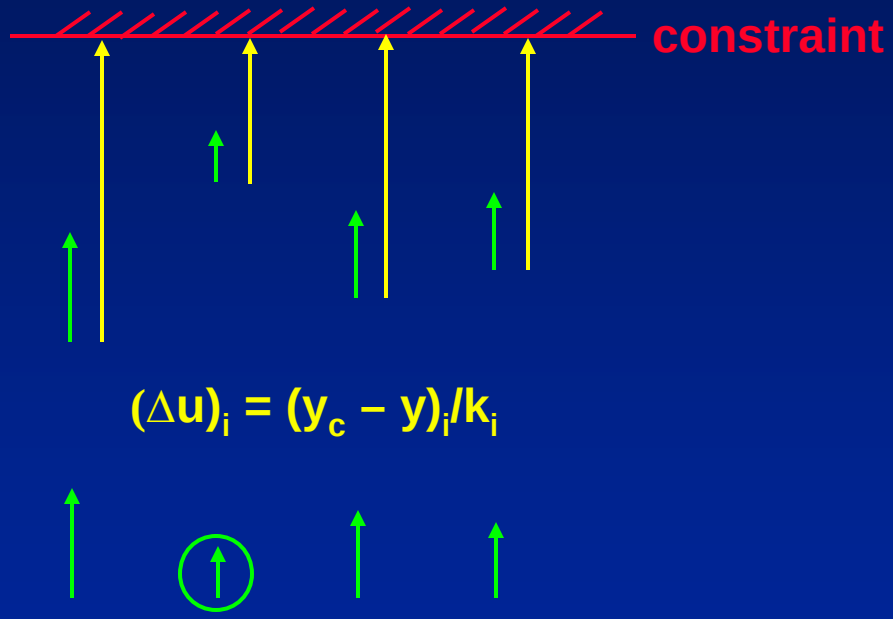
$$\Delta F_i = a*(F_i/\Sigma F_i)*(T_i - T_{avg})$$

$$\Sigma\ \Delta F_i = 0$$

Constraint Projection

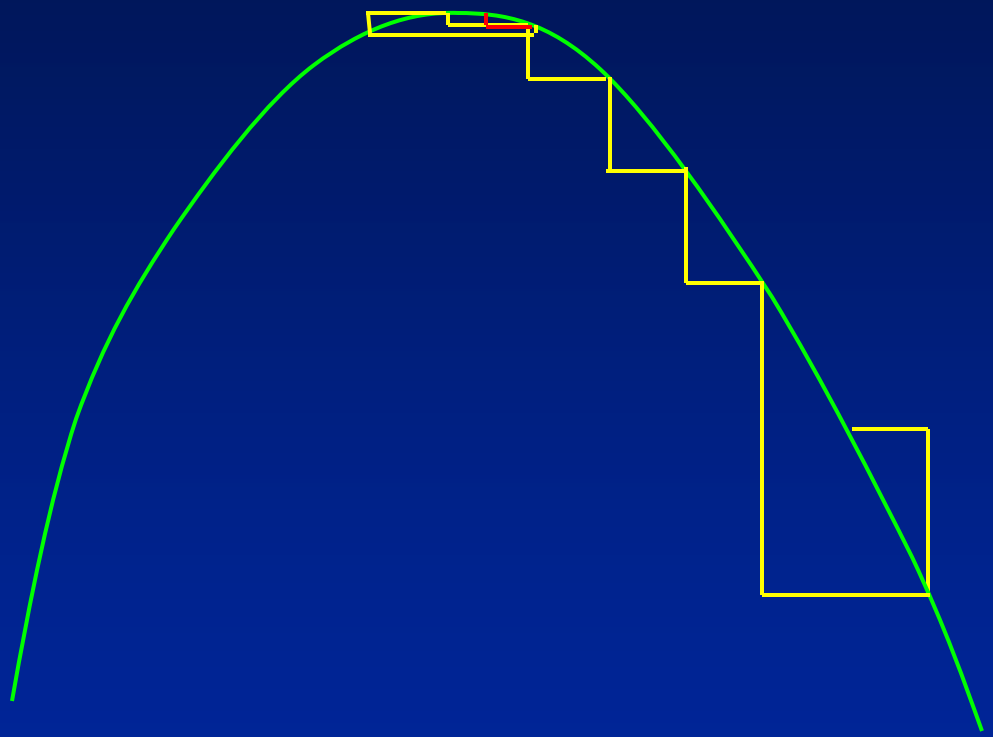
projects future outputs





Evolutionary Optimization

improves objective function value



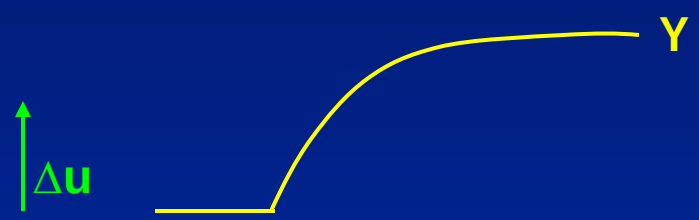
objective function

Model Predictive Control

uses a dynamic response model of the process

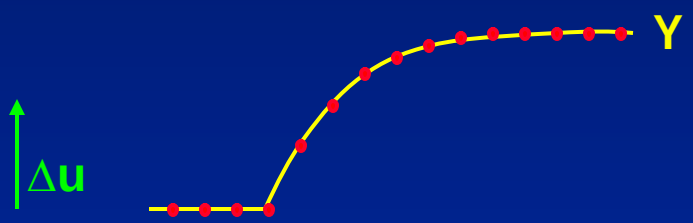
Model Predictive Control

uses a dynamic response model of the process



Model Predictive Control

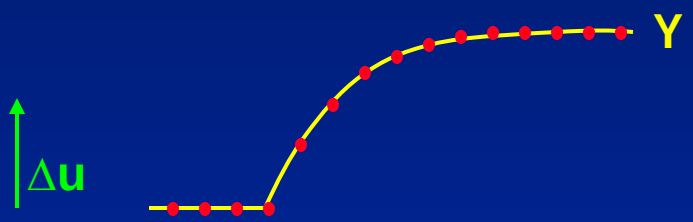
uses a dynamic response model of the process



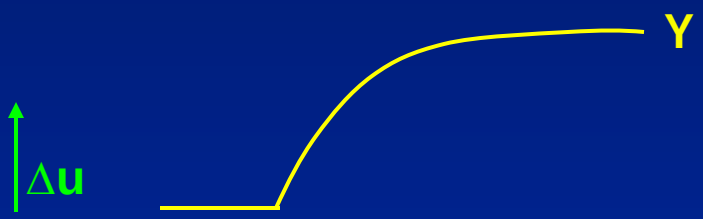
$Y = S\Delta u$

Model Predictive Control

uses a dynamic response model of the process

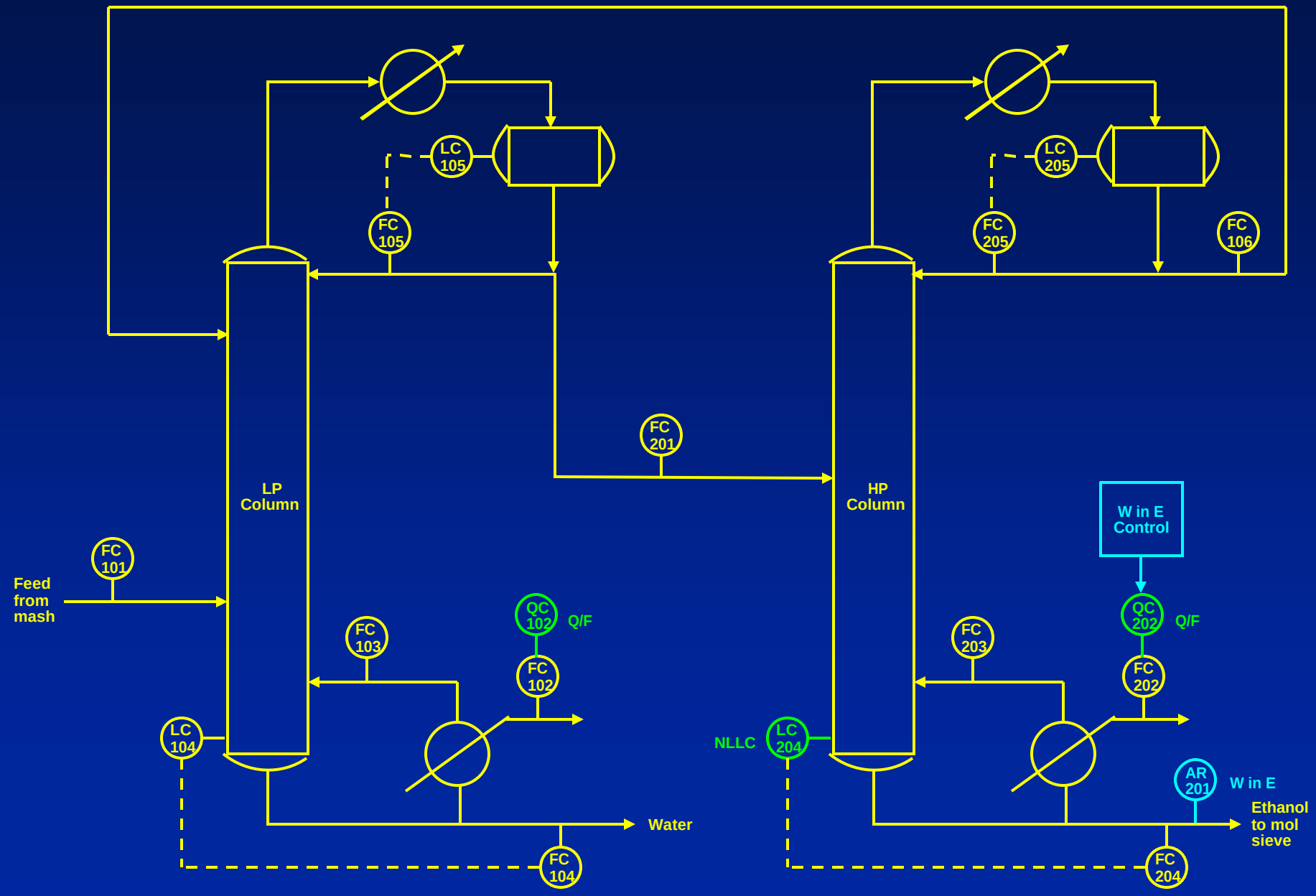


$Y = S\Delta u$



$\Delta u = (S^T S)^{-1} S^T Y$

Model Predictive Control



Calculated Key Performance Indicators

a calculated variable that is deemed to be “key”

distillation specific reboiler duty

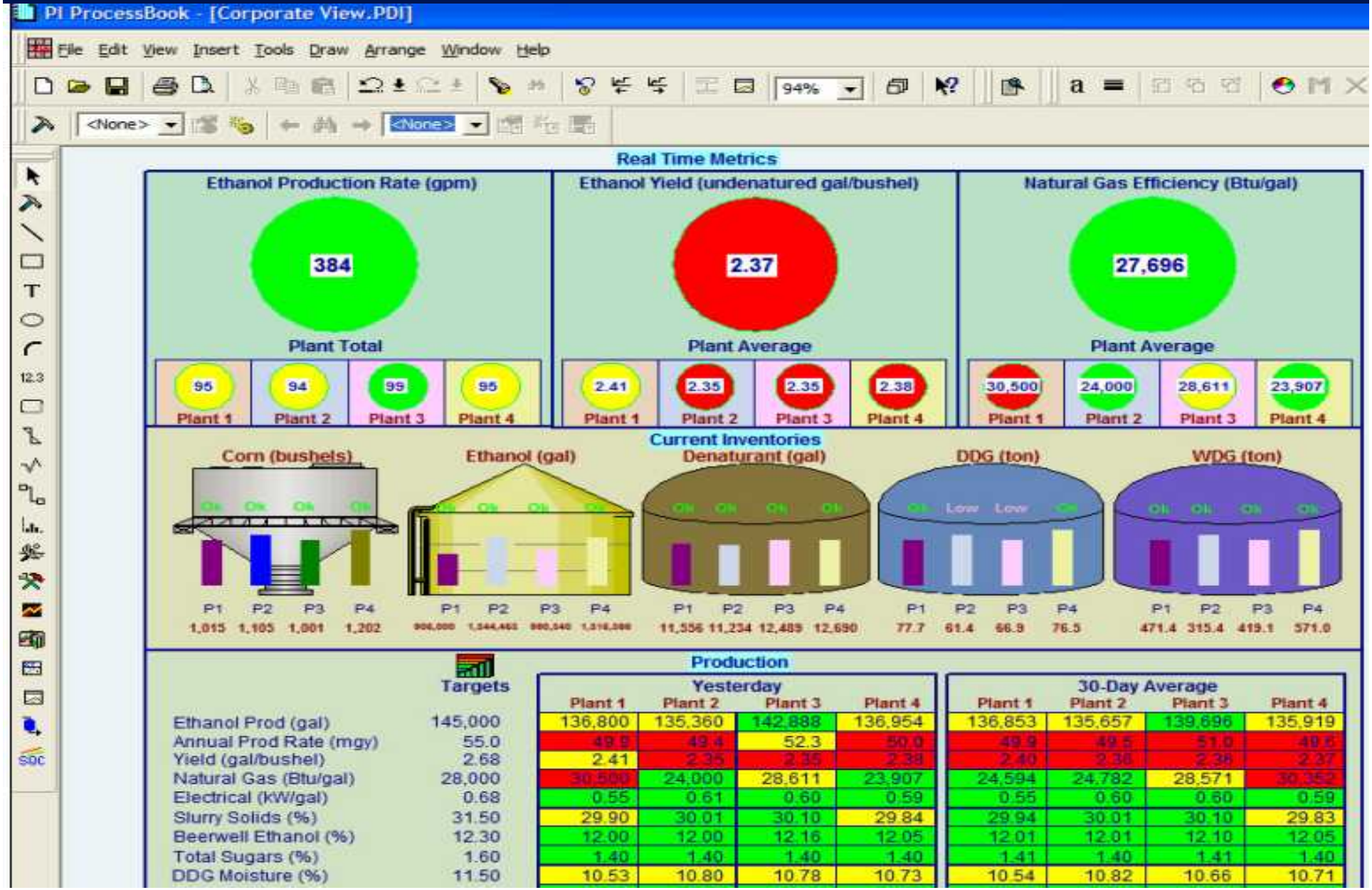
molecular sieve energy

evaporator/dryer product moisture

ethanol yield

ethanol moisture

KPI Examples



Summary

- Evolutionary vs Big Bang/Complex Applications
- Importance of a DCS neutral real-time infrastructure
- Establish a Culture of KISS and Continuous Improvement
- Applicable in all Application Areas
  - APC
  - Energy Management
  - Environmental Monitoring and Compliance
  - Conditioned Based Maintenance
- Do not Underestimate the Power of Real-Time historical Information