For Partners and Customers

Model-Free Adaptive (MFA) Control and AI for the 4th Industrial Revolution

CyboSoft, General Cybernation Group Inc.

MFA IN CONTROL

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August 2023

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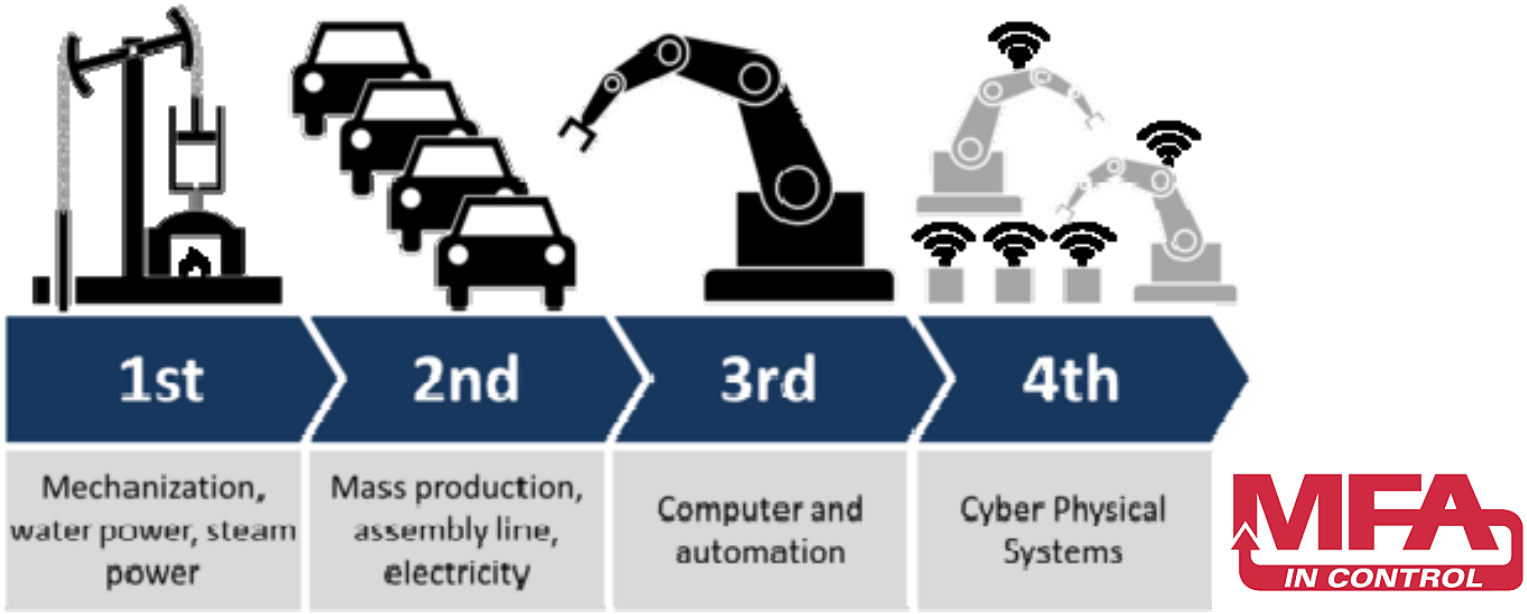
The 4th Gen of Industrial Revolution (Industry 4.0)

Generation of Industrial Revolution

- 1st, 1782 – Mechanization, Water Power, Steam Power.
- 2nd, 1913 – Mass Production, Assembly Line, Electricity.
- 3rd, 1954 – Electronics, Computers, Automation, IT.
- 4th, 2015 –AI, a Smart World, Lights-Out Factories, etc.



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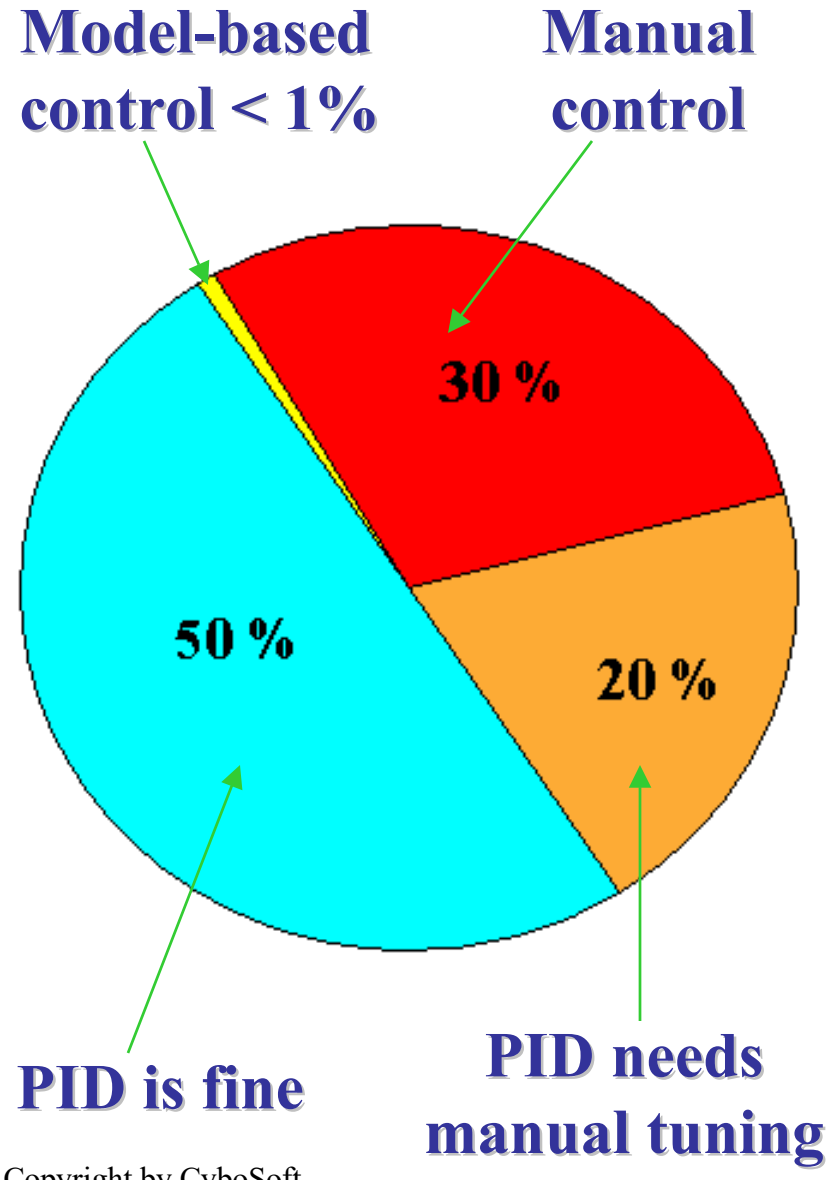
Control Can be a Big Factor



Control Can Play a Key Role in Industry 4.0

- A Smart Factory needs to run by Smart Sensors and Controllers.
- "Unmanned Things" need good Sensors and Controls.
- Control difficulties slow down the adoption of renewable energy and advanced medical devices.
- Control relates to safety, quality, yield, and pollution, etc.

What Can We Do in this New Era?

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Control Tech and Demand

PID controller

- Fixed, cannot control complex systems, needs tuning.

PID Auto-tuning or self-tuning

- Cannot control tough loops no matter how it is tuned.

Model-based controllers

- Need process models, tough to develop and maintain.

Fuzzy controller

- Need to build rules, tough to develop and maintain.

Demand for a Dream Controller

- Easy to use and maintain, controls complex systems.

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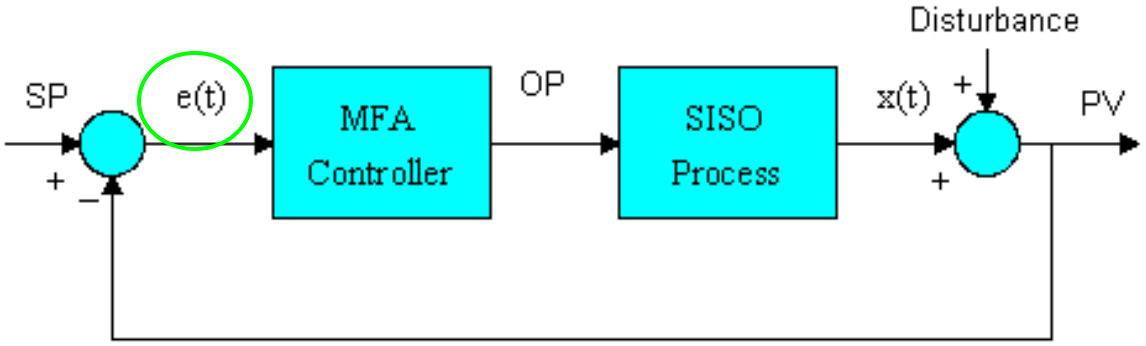
Model-Free Adaptive (MFA) Control



SISO

Control Objective

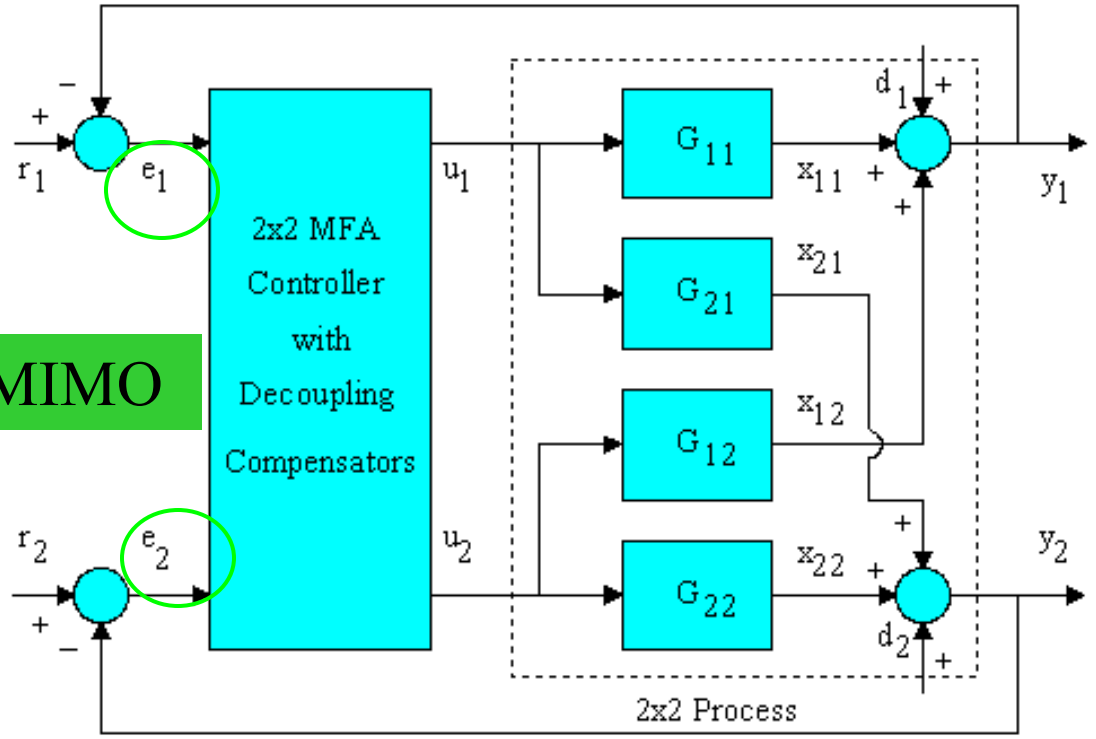
- Controller to produce

OP to force PV to track SP or minimize e(t).

MFA controls complex systems

- No process models;
- No identification;
- No controller design;
- No manual tuning.

MIMO



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Inside MFA – an AI Tech

No Model

- A neural network is part of the MFA.

Adaptive

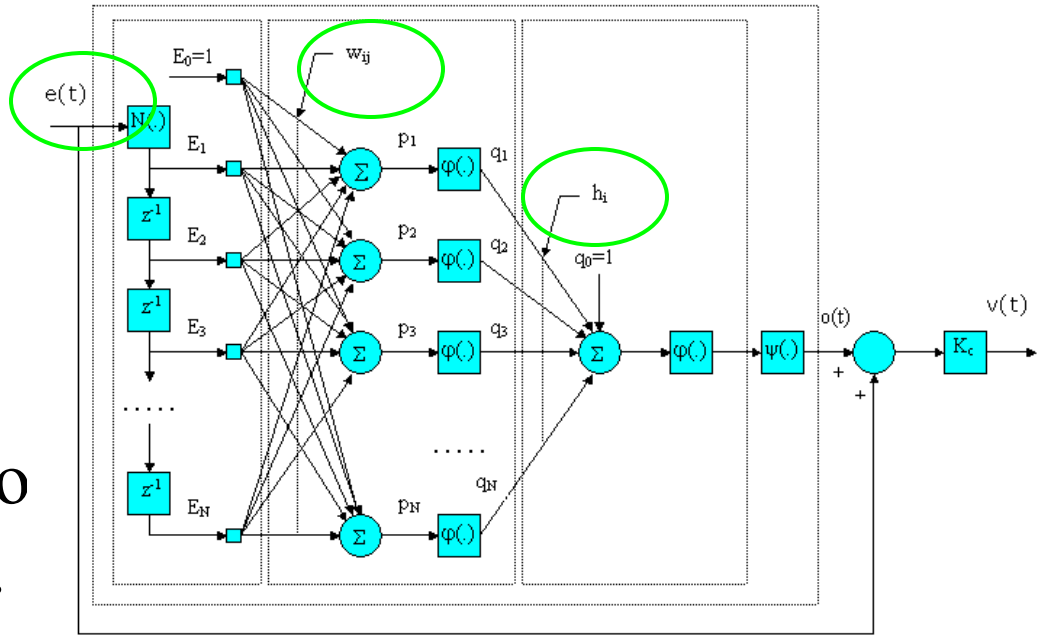
- Weights are updated to help minimize e(t).

Robust

- Provides much wider robust range than PID.

Speed

- Controls immediately, no waiting on model building.



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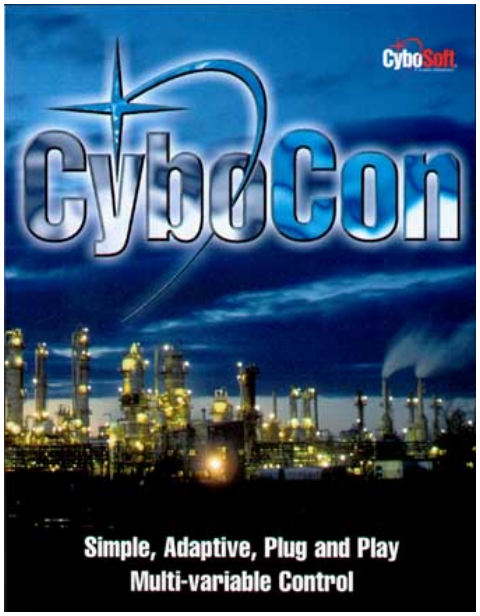
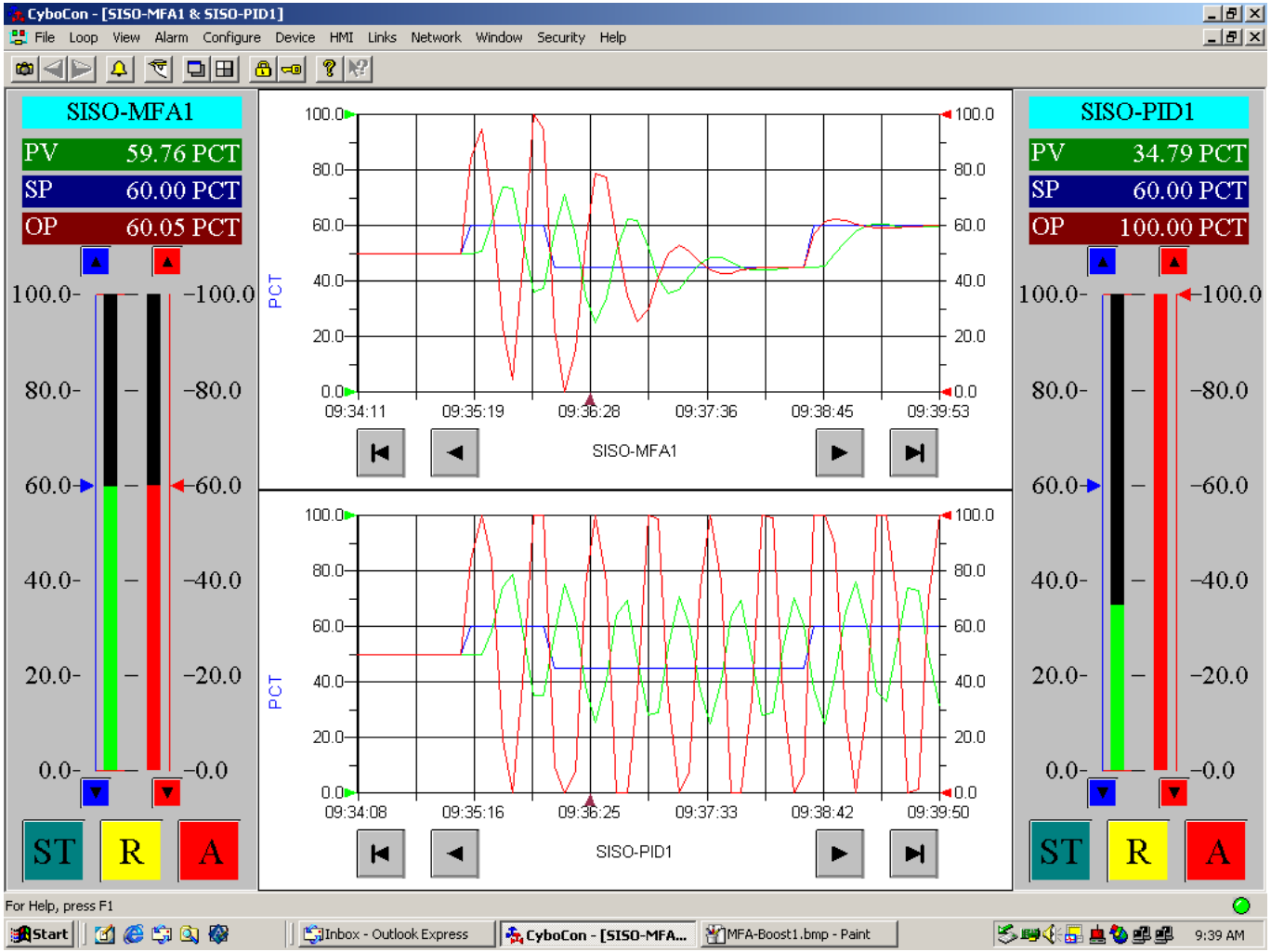
Running CyboCon Demo





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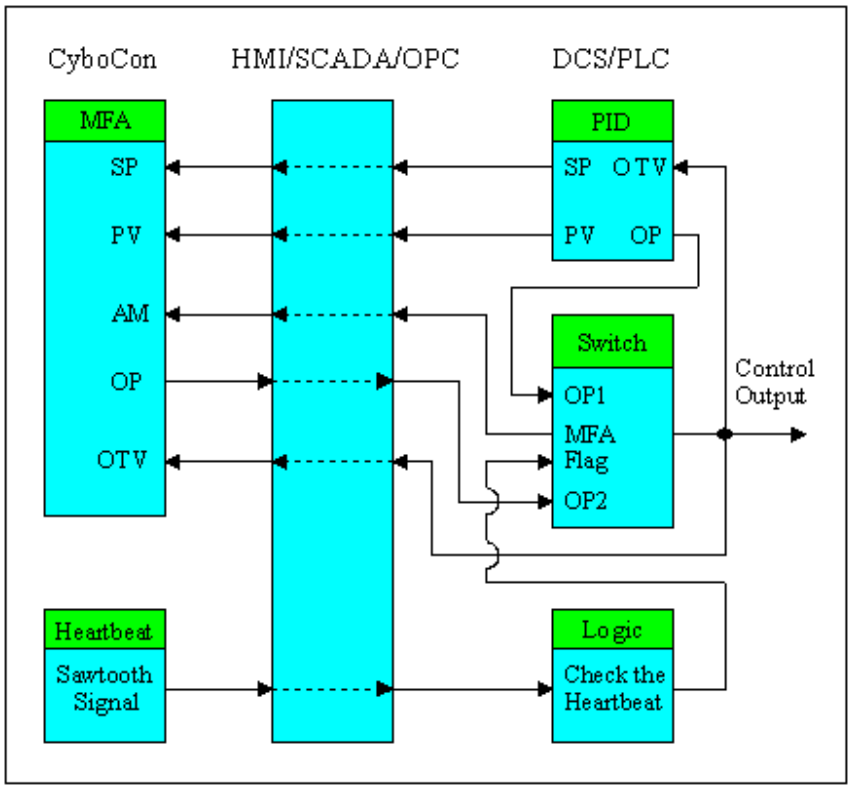
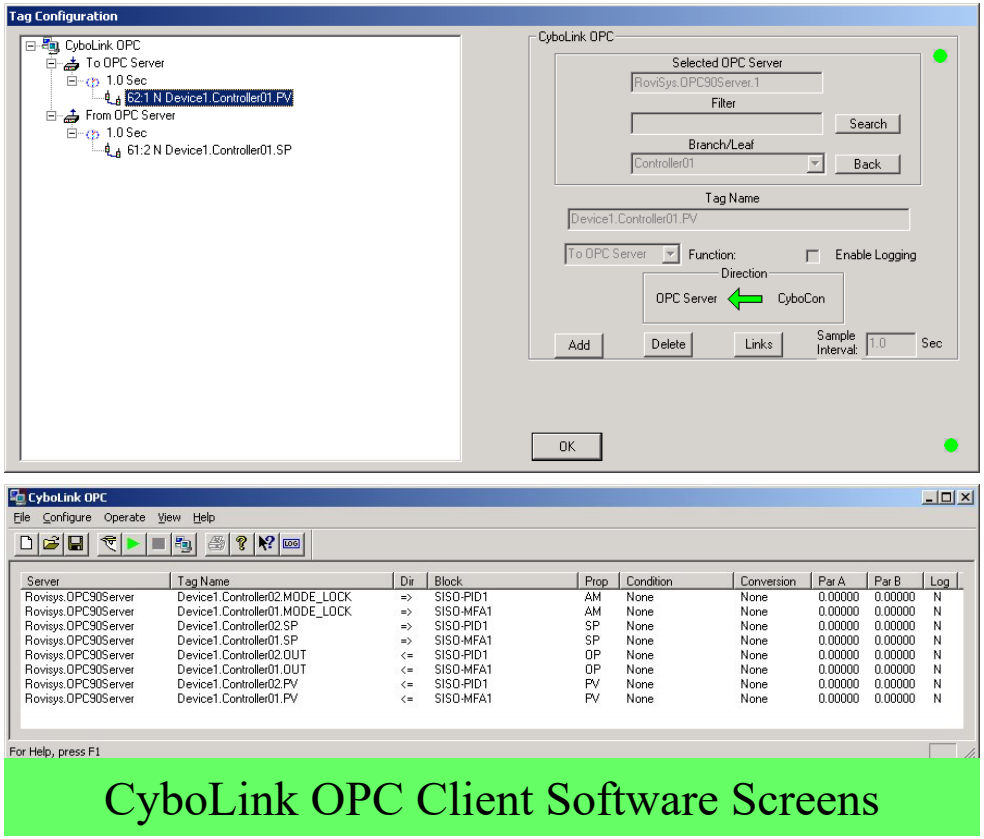
Signal Wiring of CyboCon to DCS





CyboLink OPC Client Software Screens

The Switch block in PLC is to switch between MFA and PID.

An MFA Button is added to the HMI screen so that the operator can easily switch the system between MFA, PID, or manual control.

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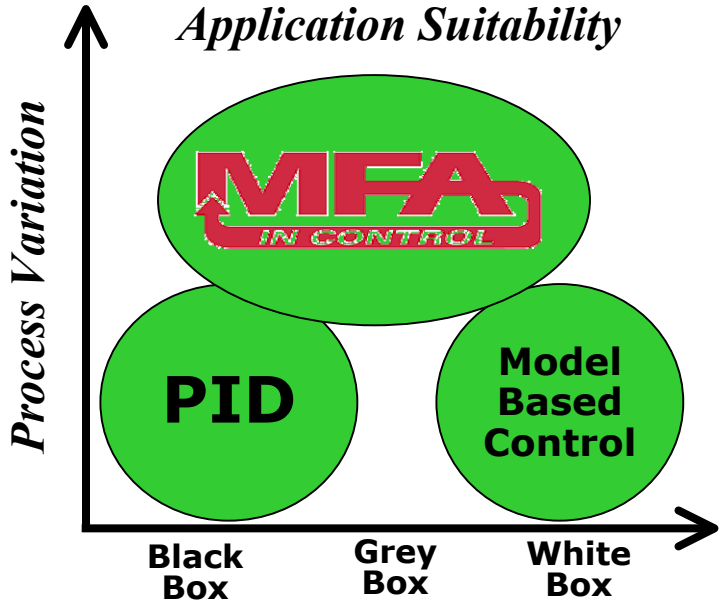
MFA Advantage & Suitability

Item	PID	MBC	MFA
General purpose	Y	N	Y
Adaptive	N	Y/N	Y
No process model	Y	N	Y
No identification	Y	N	Y
No controller design	Y	N	Y
No manual tuning	N	Y	Y
Controls complex systems	N	Y	Y
Easy to use and maintain	N	N	Y



MFA is suitable for Grey box problems, where the process has uncertainties including load, fuel, and dynamic changes, etc.

PID – one algorithm for all, MBC – one algorithm fits one system, MFA – one algorithm solves one control problem.

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MFA Controllers Case Examples

Controller	Control Problems Solved	Application
MFA (Turbo)	Adapts, no manual tuning required.	Building Control.
MIMO MFA	Controls multivariable systems.	Distillation column, multi-zone furnaces, etc.
Nonlinear MFA	Controls nonlinear processes.	Various nonlinear processes
MFA pH	Controls pH processes.	Wastewater treatment.
Anti-delay MFA pH	Controls pH processes with large time delays.	Quench water pH control.
Anti-delay MFA	Controls processes with time delays.	Quality variables.
MFA Flare Control Solution	Can deal with nonlinear, varying time delays, and large disturbances.	Combustion Zone Heating Value, Steam System, etc.
MFA XRT	Can deal with exponentially changing nonlinear behavior.	Exothermal reactor temperature.
MFA Optimizer	Search for min or max in close-loop.	Hydrogen Cyanide.

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MFA Control Solutions at a Glance

Controller Name	Application
MFA for Industrial Flares	Combustion Zone and Vent Gas Heating Value Control to meet EPA 63.670 rules.
MFA for Alumina Process	Closed-loop control for Blow-off A/C or Alpha-K.
MFA for Tire Making Processes	Rubber extrusion and rubber calendaring processes, Breaker Marker, Ply Maker, Extrusion Lines etc.
MFA for Bio-Reactors	Control of pH and dissolved oxygen (DO) at different cell growing stages.
MFA for Managed Pressure Drilling (MPD)	Control of surface back pressure, flow, standpipe pressure and bypass pressure.
MFA for Wafer Furnace	Can decouple interactions among temp zones with tight setpoint tracking.

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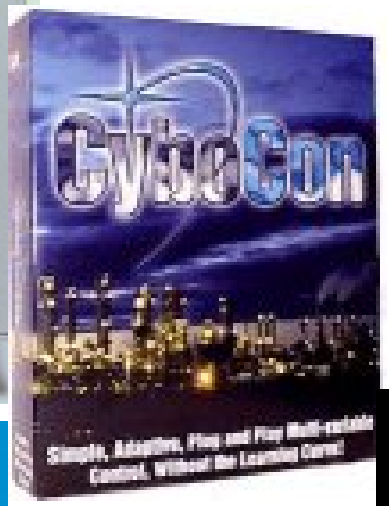
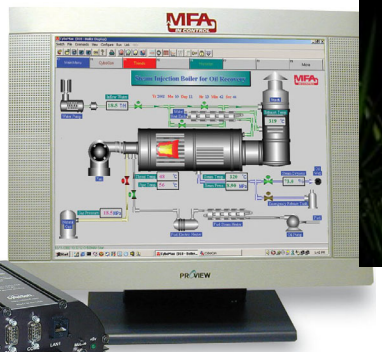
Recognized for Continuous Innovation





Prestigious awards validate the impact of MFA to the industry.

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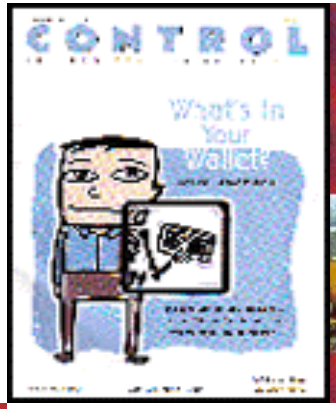
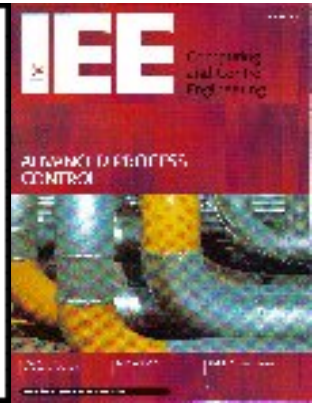
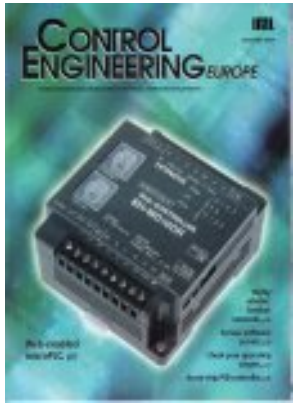
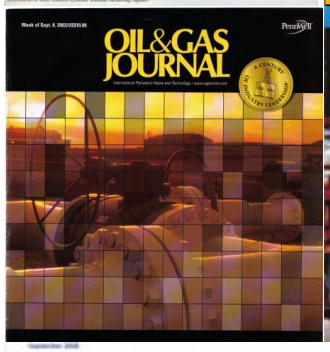
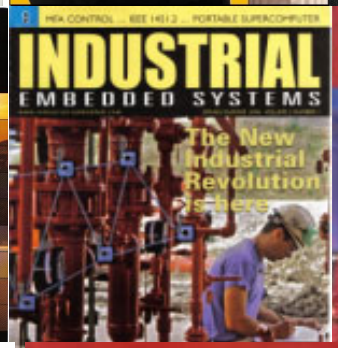
MFA Publications

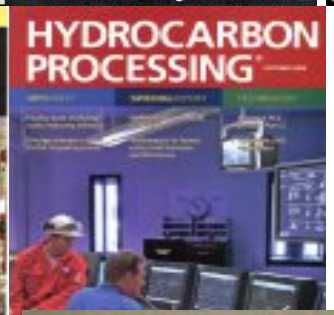


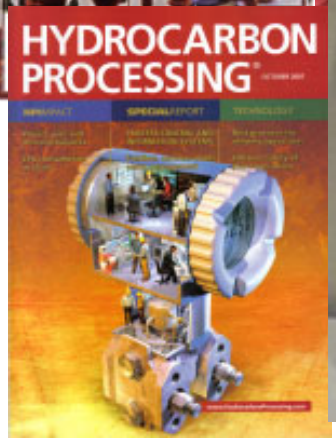


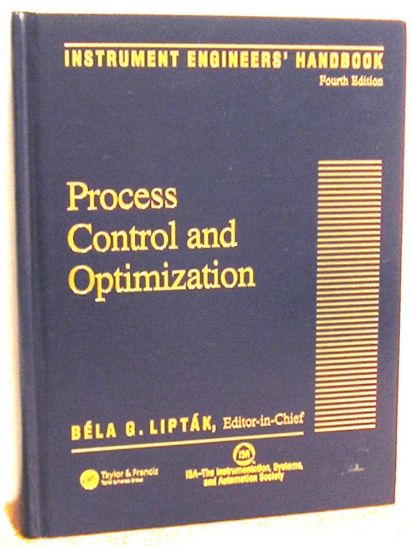


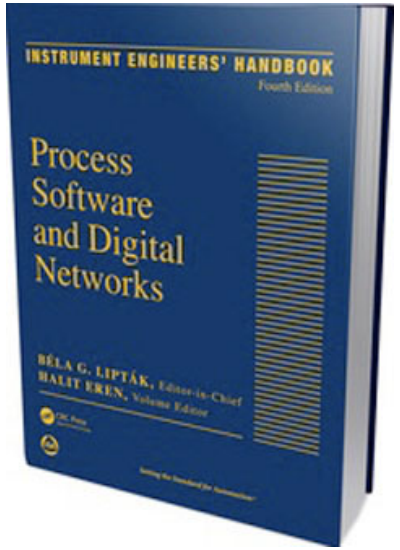












MFA control has been included in these acclaimed "Bible" books of instrument and control engineering.

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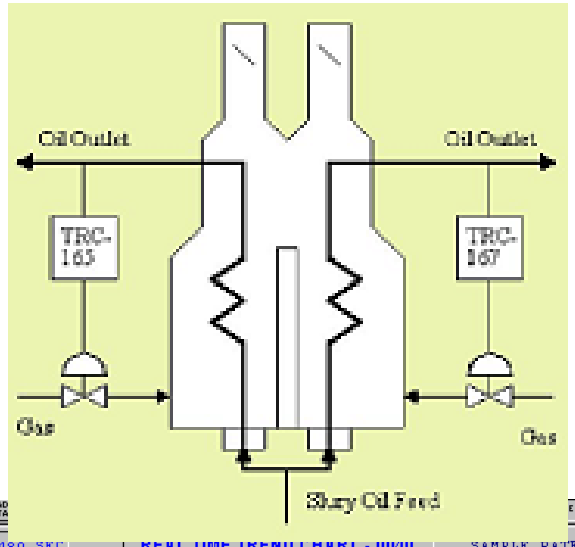
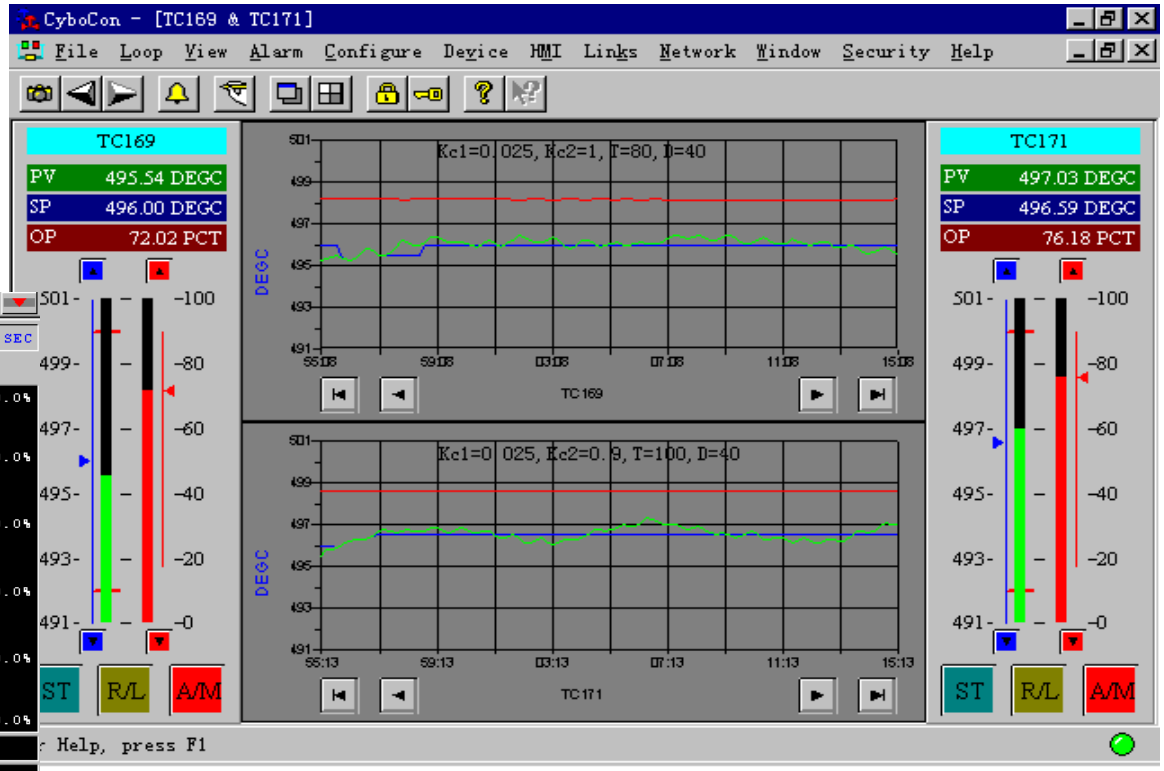
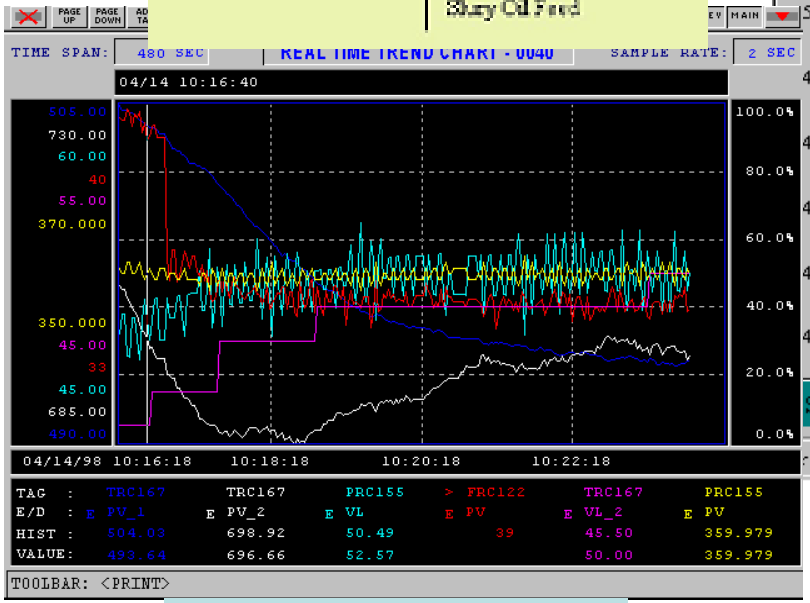
MFA on Coking Furnaces

Multi-zone temp control using MIMO MFA



In MFA Control





In Manual Control

Article in
Hydrocarbon Processing, Dec 1999

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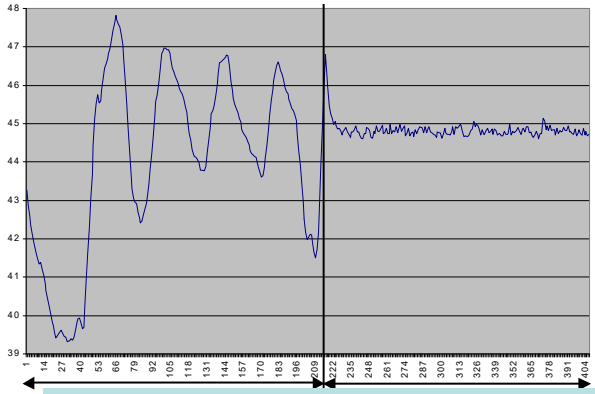
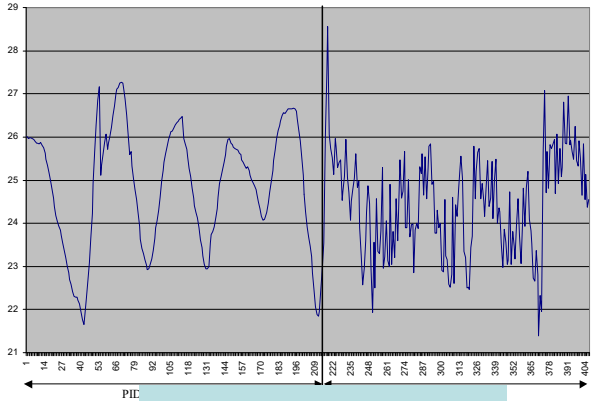
MFA on Air Separation Unit

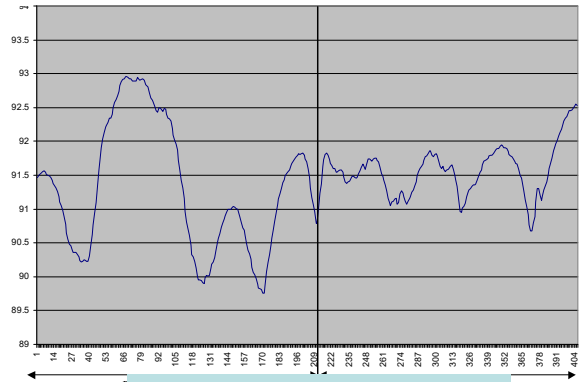
Quick ROI featured in Control Magazine, May 2001



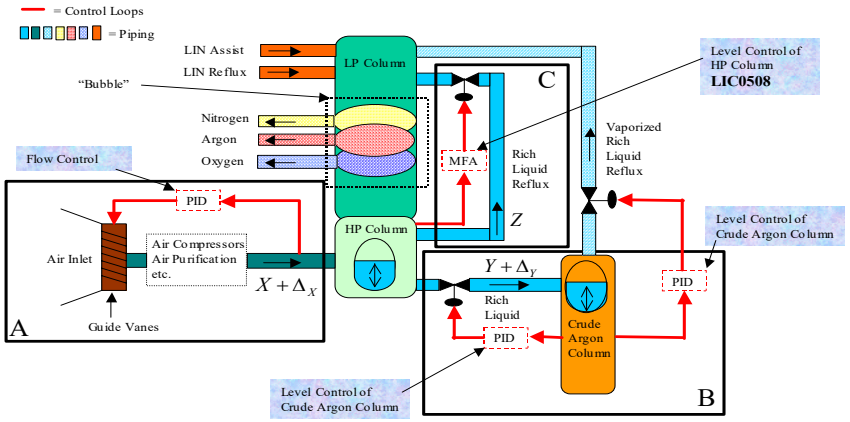
Key process variable



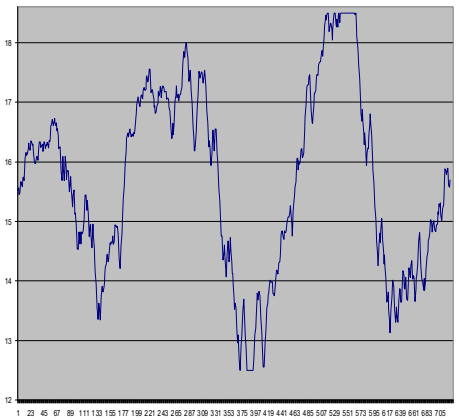
Reflux flow

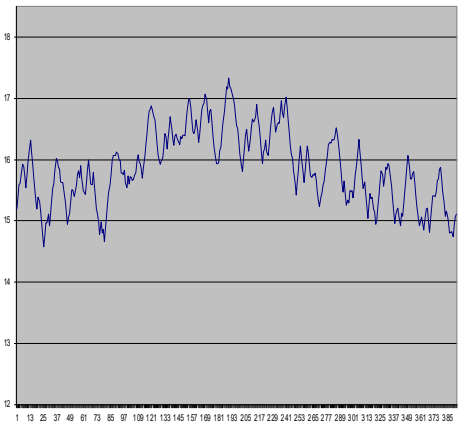


Argon purity



ASU Process





Argon yield increased by 20%

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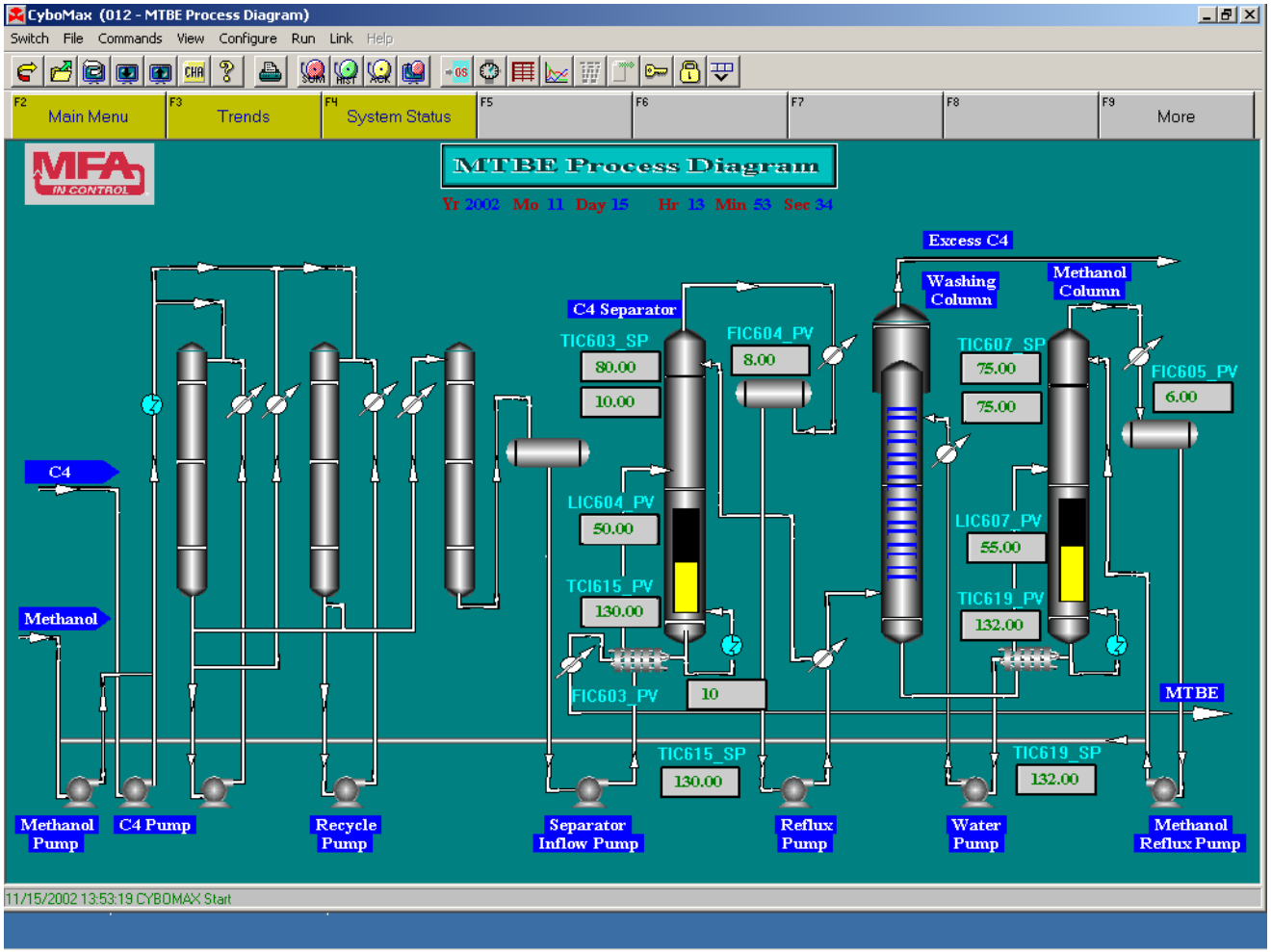
MFA on Distillation Columns

Article featured in Hydrocarbon Processing, Oct 2004



A 2x1 MFA controls bottom temp and critical tray temp.

Robust MFA controls column level with reduced interruption to material and energy balance.

Achieved smoother operation and production efficiency and yield.

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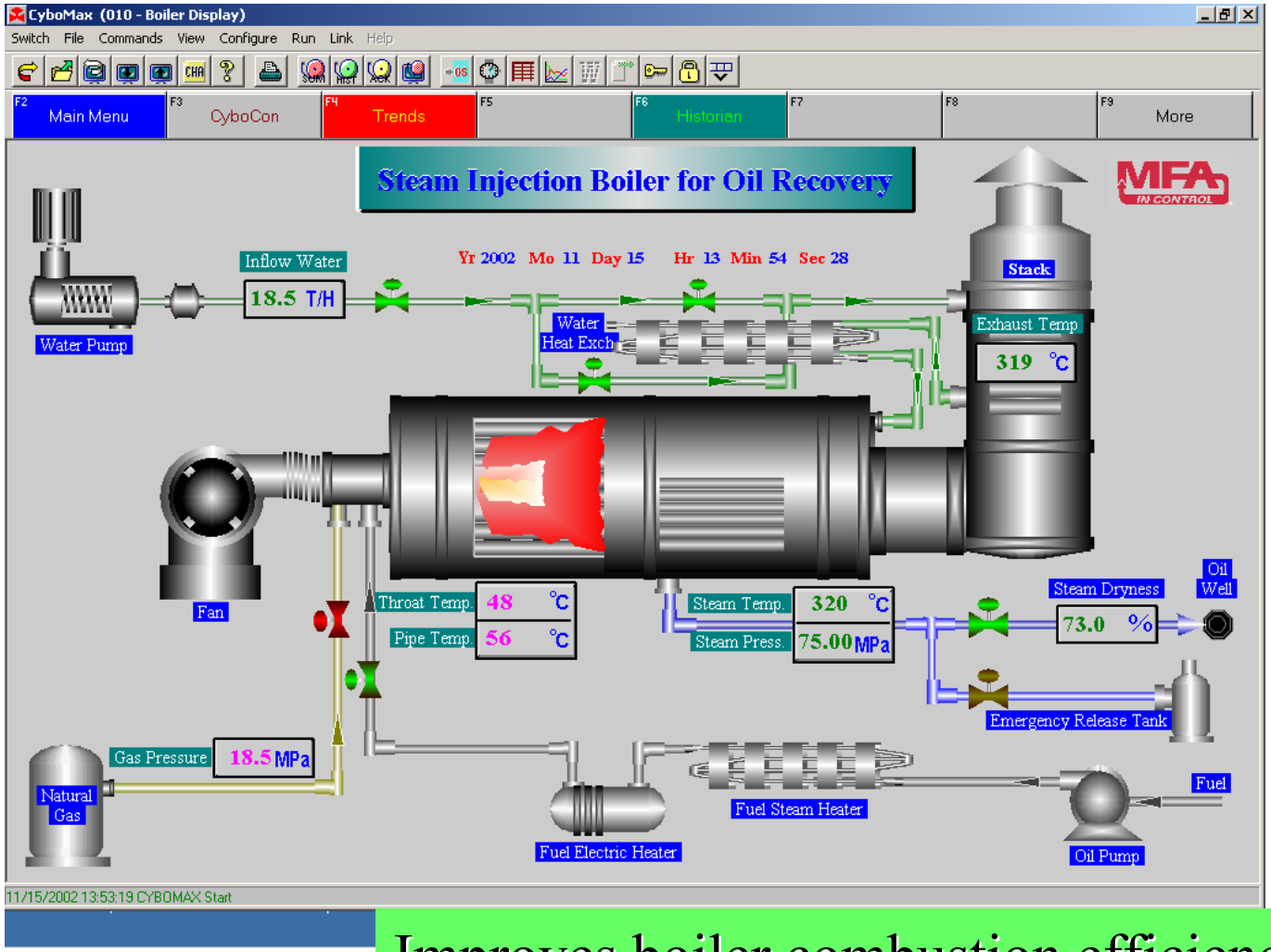
MFA on Oil Recovery Boilers

Article in Oil & Gas Journal, Sept., 2003



Soft-sensor measurement of steam dryness in CyboMax to monitor the steam quality.

MFA control of steam dryness, temp, pressure, with optimal fuel-and-air ratio.

Improves boiler combustion efficiency and produces consistent quality steam for higher oil yield.

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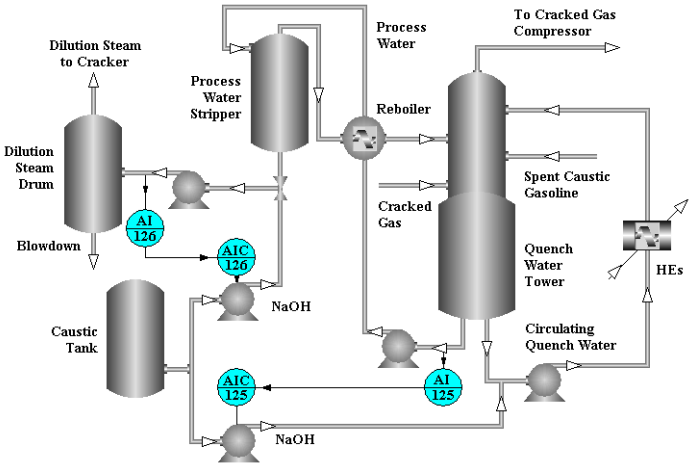
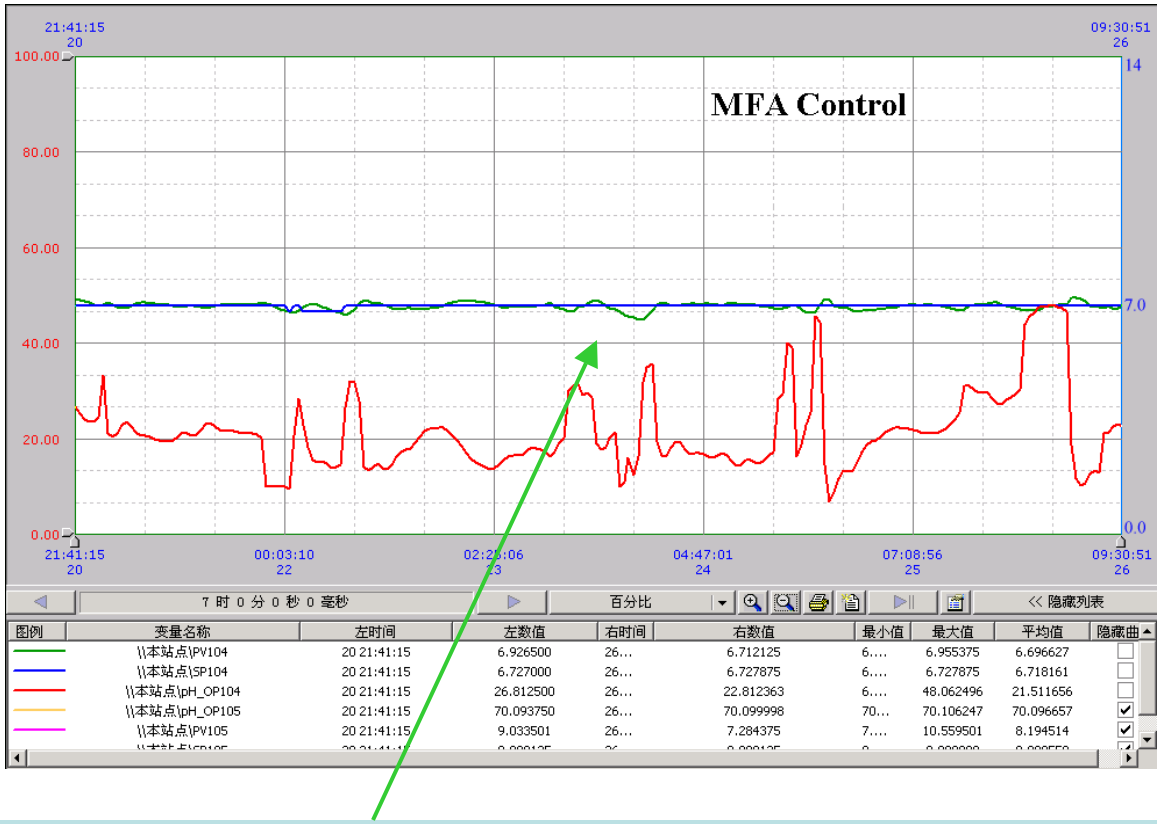
MFA Quench Water pH Control

Article in Hydrocarbon Processing, Oct, 2007



Tightly controls ethylene quench water pH by using Anti-delay MFA pH Controller to deal with **nonlinear problems as well as large and varying time delays.**



Sharply reduced chemical reagent consumption, equipment corrosion, and maintenance cost.

pH process has a 30 minute delay. Trend shows 12 hours of data. MFA produced control signals in the range of 7% to 50% to make significant adjustments to the caustic flow in order to keep the pH (green) under control with only 0.28 variation range.

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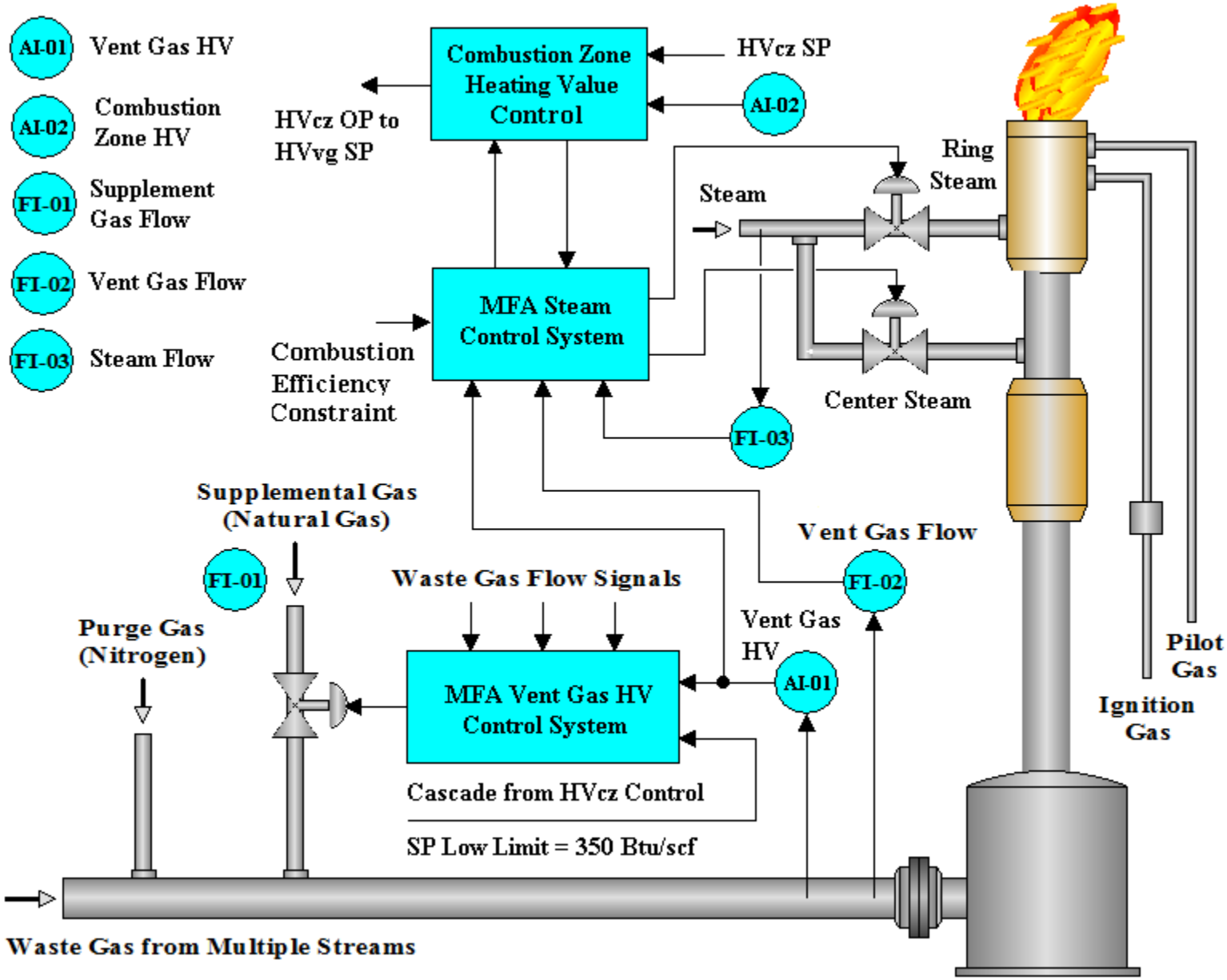
MFA Control for Steam Assisted Flares



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MFA in Siemens Adaptive BAS

MFA in Siemens' APOGEE Building Automation System (BAS)

- Control supply air temp, return air temp, pressure, flow, and humidity of AHU.
- Easy configuration for various buildings, climate zones, and varying conditions…
- Controller manual tuning not required.

APOGEE BAS

Benefits and Impact

- User - better comfort, energy savings.
- Siemens - technician time savings, and sharper competitive advantage.

Since 2006, about 100,000 new MFA controllers are launched by Siemens every year.

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MFA for Auto-Drilling

Nabors Industries' DrillSmart Auto-Drilling System – MFA in NI cRIO

- MFA controls Rate of Penetration, Weight on Bit, and Differential Pressure.
- For horizontal and lateral drilling for different rigs under varying operating conditions.
- Controller manual tuning not required.

Benefits and Impact

- Safer, more efficient oil&gas well drilling.
- Much easier lateral drilling operations.
- Sharper competitive advantage.
- Major impact to world oil&gas exploration

In 2018, about 800 systems are in operation.

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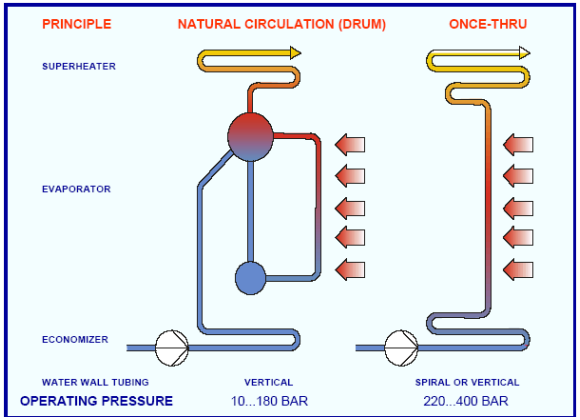
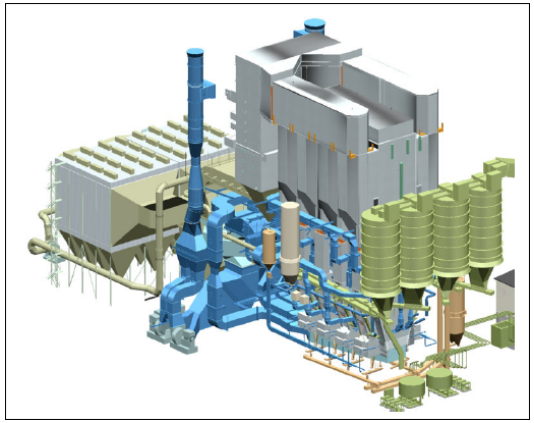
CyboSoft's DOE Grants

- 1. SBIR Phase II Grant: Intelligent Control of Advanced Power Generation Systems Using Model-Free Adaptive Control Tech.

OT Supercritical Boiler



Circulating Fluidized-bed Boiler



Goal: Deliver maximum-energy-efficiency, near-zero-emissions, fuel-flexibility, and multi-products.

- 2. SIBR Phase II Grant: Intelligent Actuation Control Using Model-Free Adaptive Control Technology.
- 3. SBIR Phase I Grant: Intelligent Industrial Furnace Control Using Model-Free Adaptive Control Technology.

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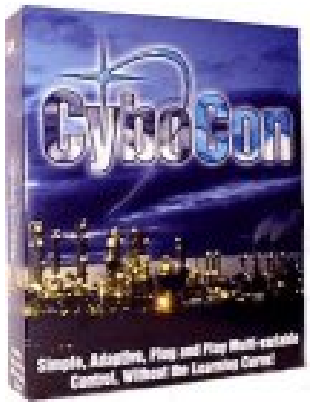
CyboCon in ControlLogix Compute Module

CyboCon HS (High-Speed) Software

- High-speed CyboCon MFA control software can run in Rockwell ControLogix Compute Module in Windows 10.
- CyboLink for ControlLogix software allows high-speed communication between CyboCon HS and the PLC through its backplane. Control loop rate is up to 1 millisecond.
- A seamless integration with ControlLogix, it is ideal for high-speed mission-critical process and equipment control.



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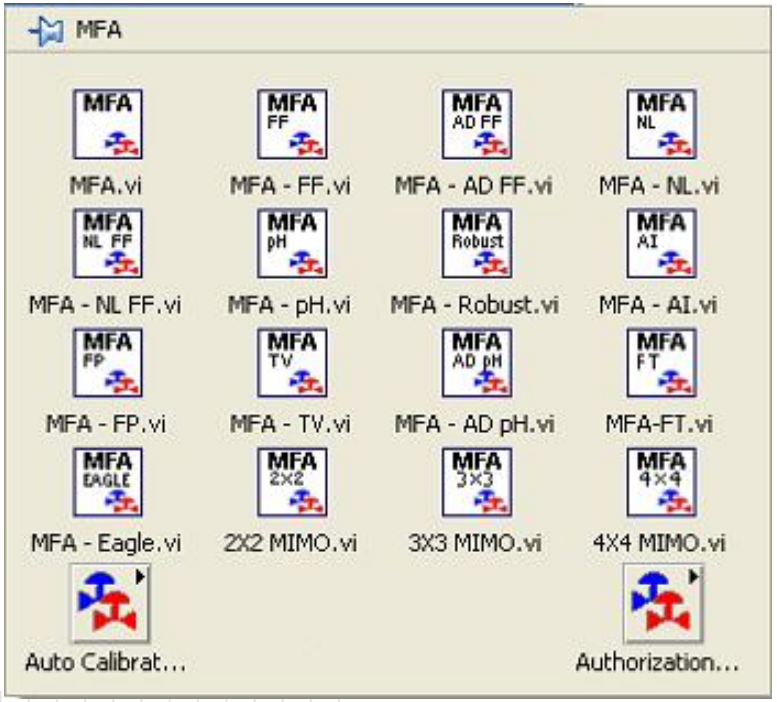
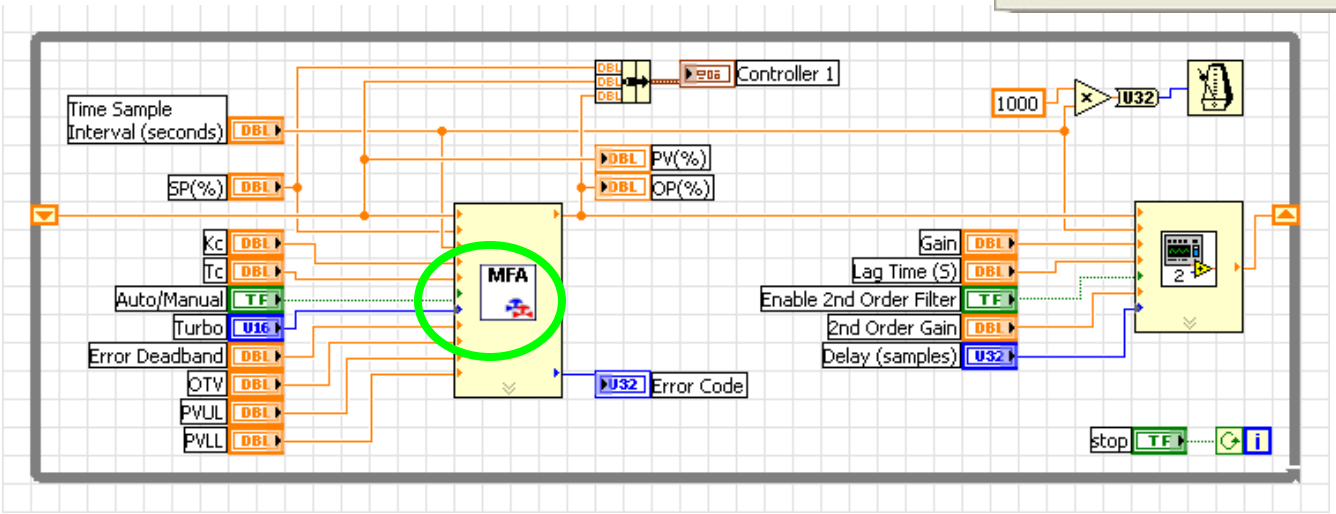
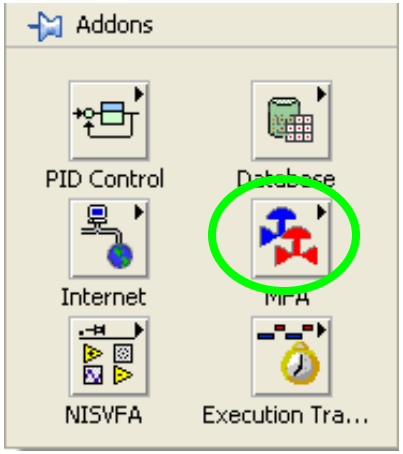
Embedded MFA in NI LabVIEW

MFA Control Toolset for LabVIEW Software

- MFA VIs for LabVIEW and RT.
- On the LabVIEW Addons Palette, click the MFA Icon.
- MFA VIs will pop up.
- Select the appropriate MFA VI for your LabVIEW program.







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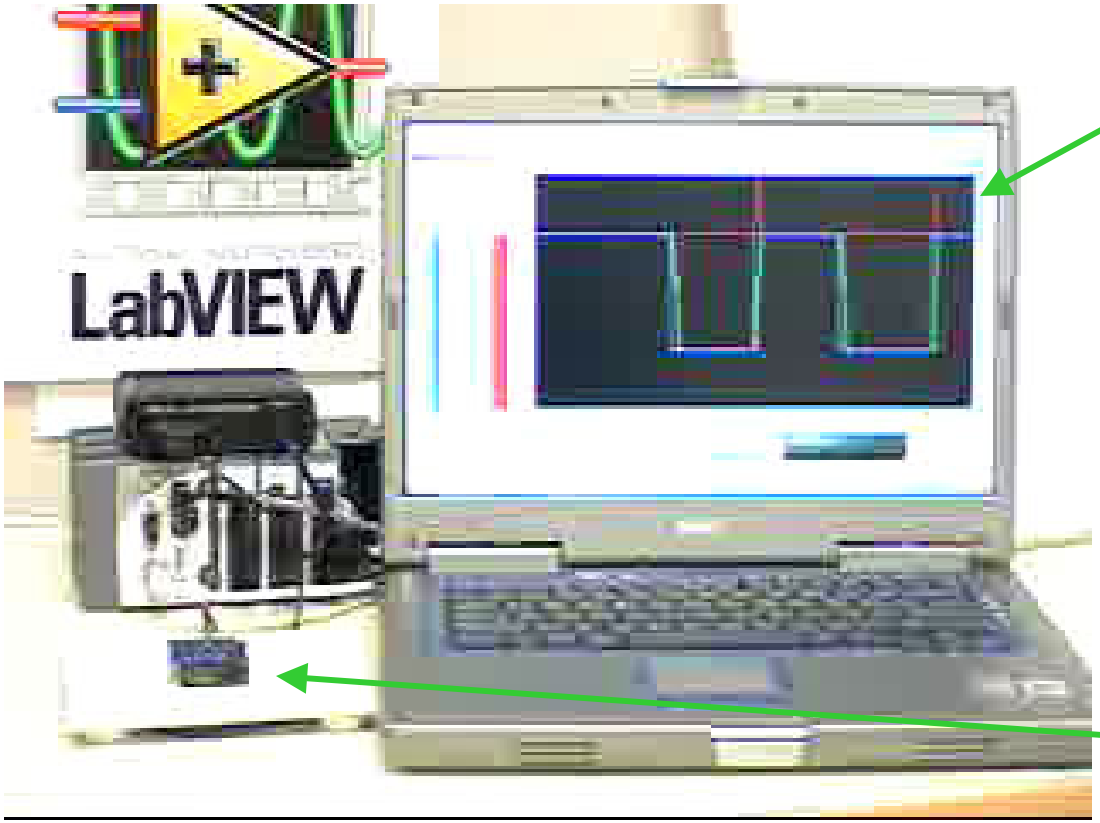
MFA Motion Control on Piezo Motor

MFA Eagle Controller

- Runs in NI cRIO FPGA at 100 KHz (10 microseconds).
- Controls a piezo motor with load changes.
- No process model nor manual tuning required.



Turn the PC speaker on and click on graph to run video.

Result: Consistent control performance. PV tracks SP tightly when load changes.

Blue – Setpoint (SP)

Green – Process Variable (PV)

Red – Controller Output (OP)

Demo: a piezo-motor by Physik Instrumente

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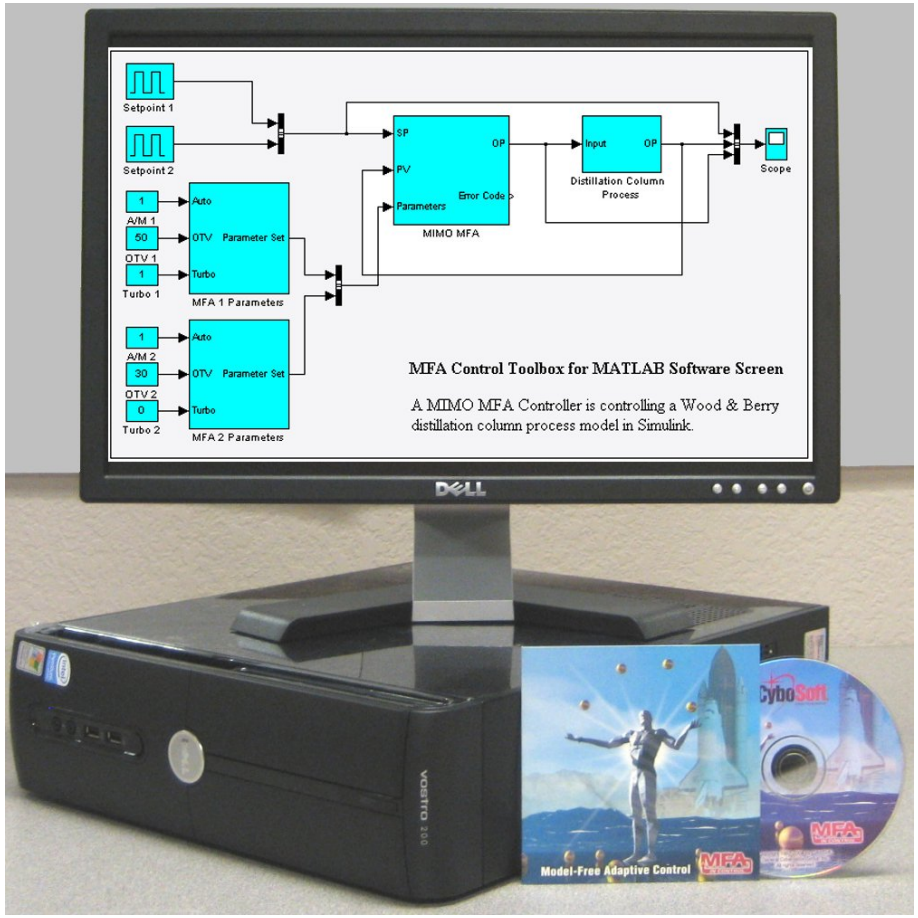
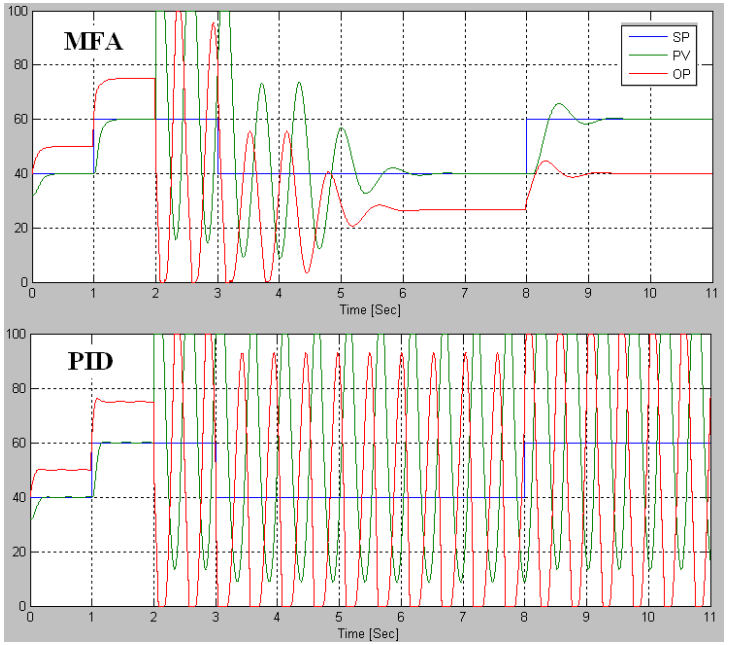
MFA Control ToolBOX for MATLAB



MFA Control ToolBox for MATLAB Software

- Embedded MFA controllers inside MATLAB/Simulink as S-functions. A seamless integration.
- The only simulation software for which a number of field-proven, real-time control products of the same family are available.
- Reduces R&D cost, risks, and time to market.



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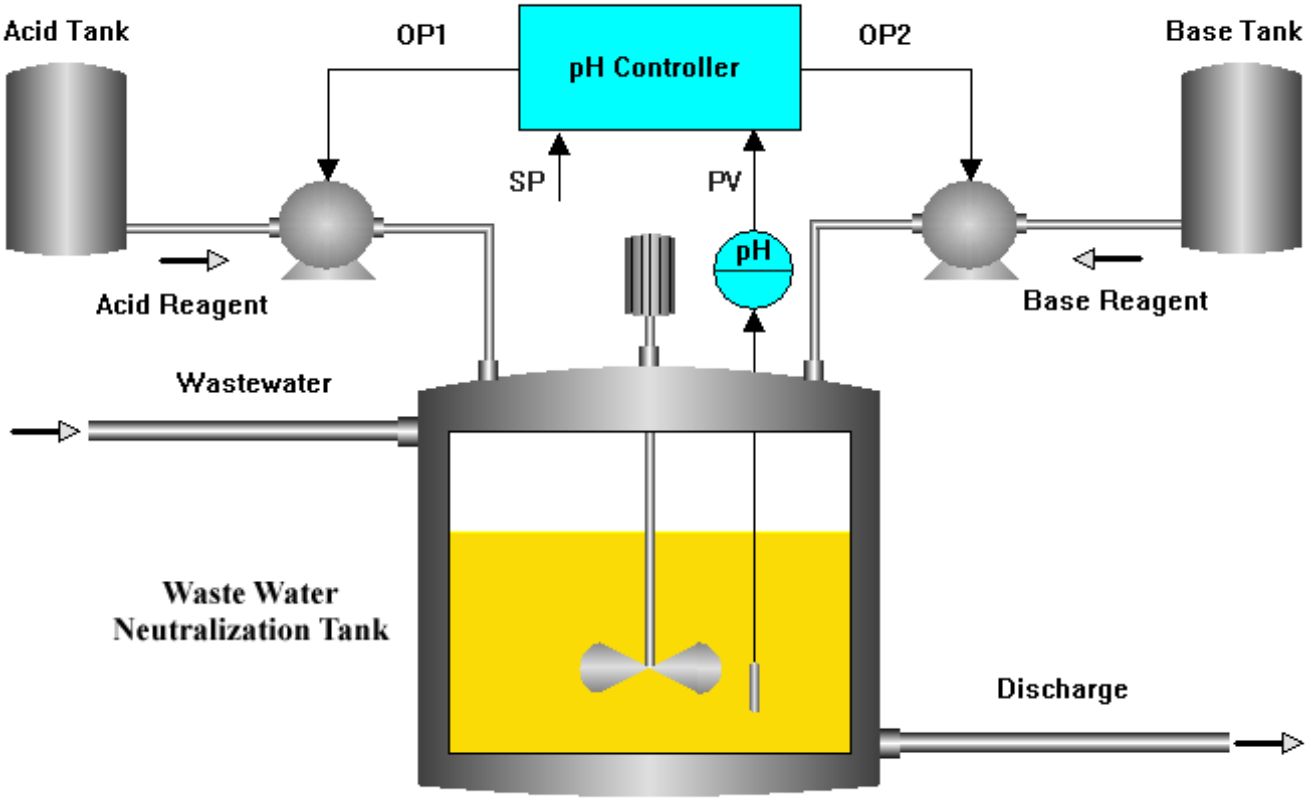
pH Modeling and Control Simulation Software

Why Use Real-Time Process Models?

- A real-time process model can be used as a "Virtual Process" to simulate a real process with minimal setup time and cost.



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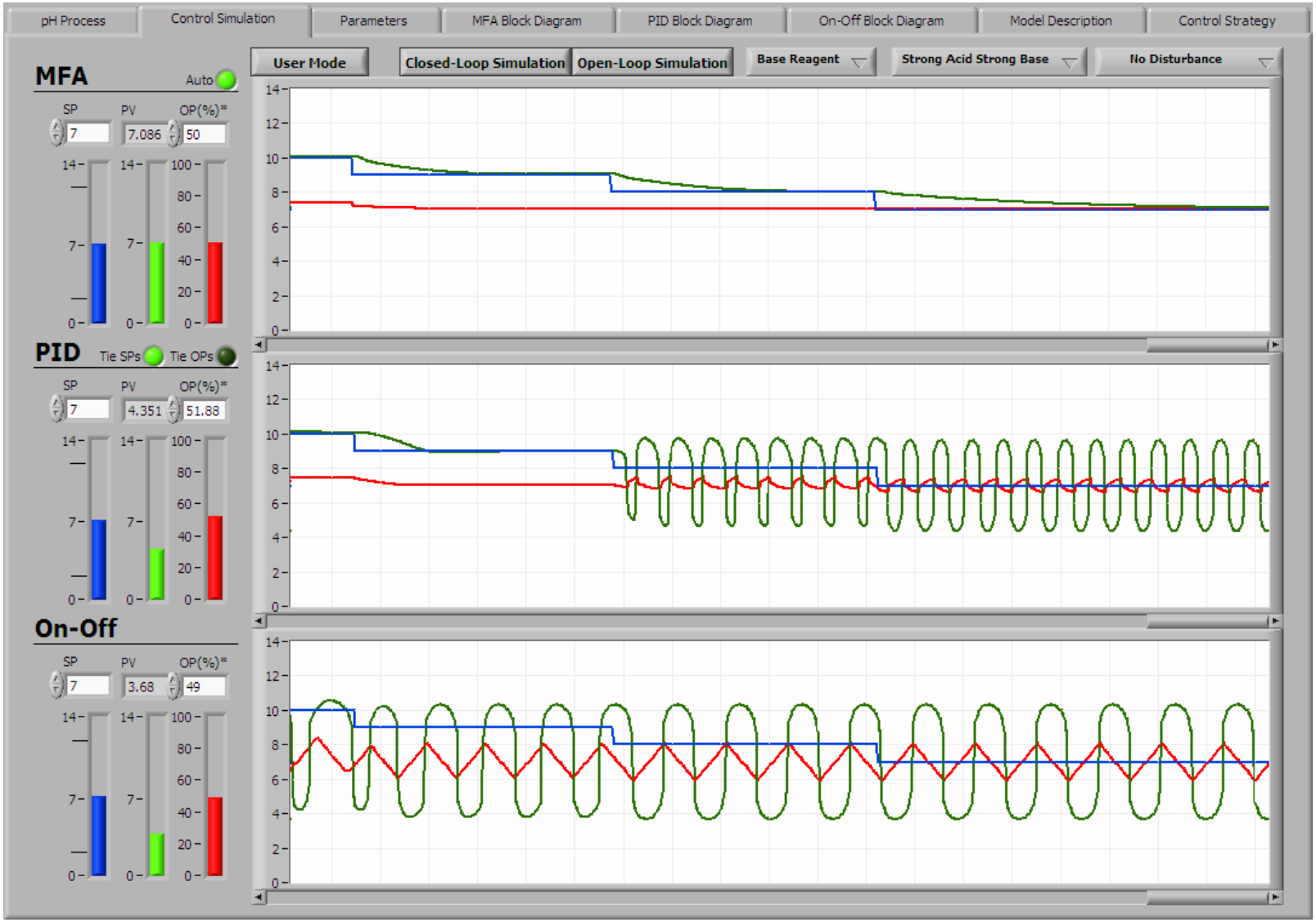
Closed-Loop SASB pH Control Trend



Base Reagent, Direct-Acting

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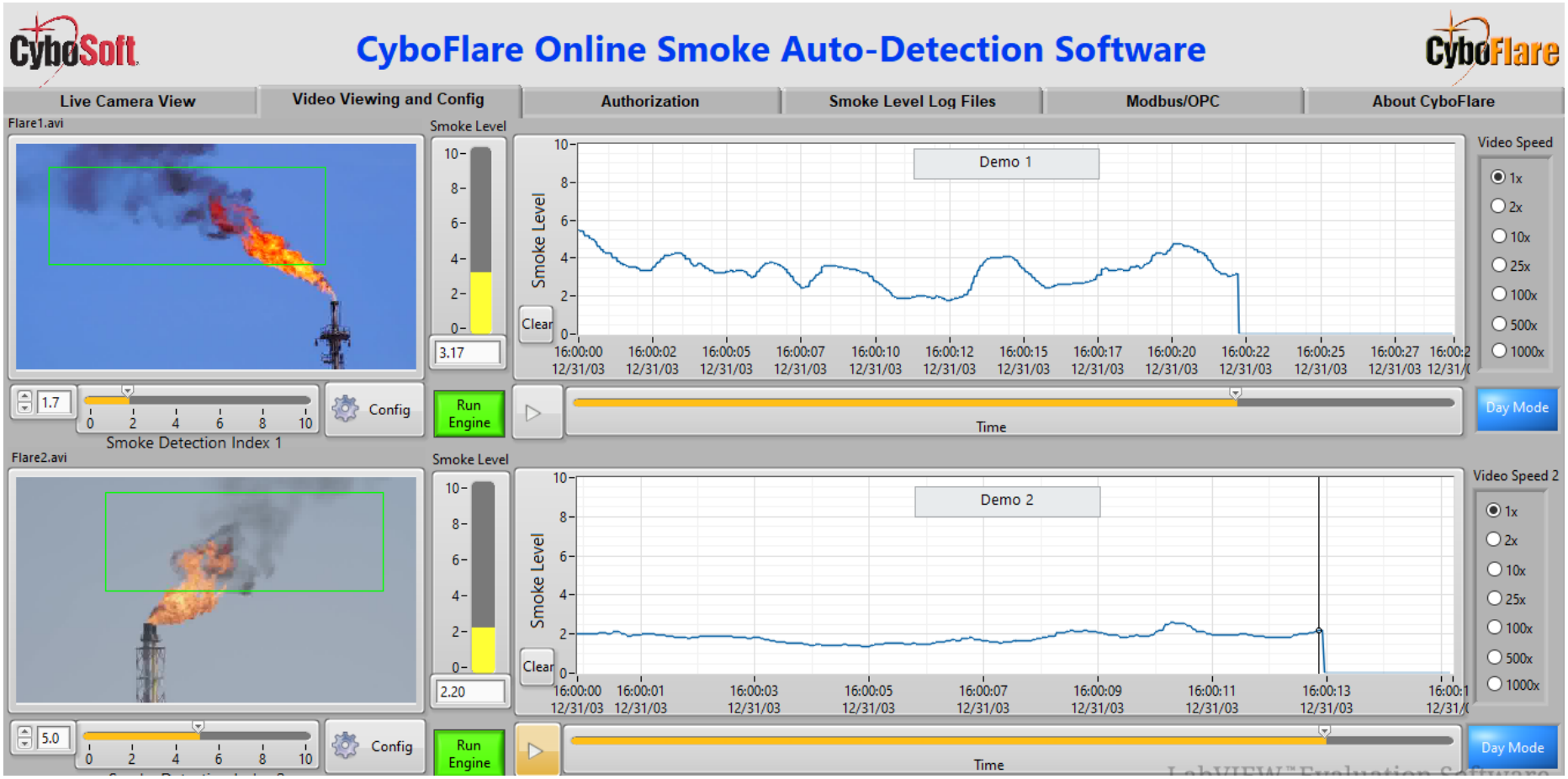
CyboFlare Online Software



CyboFlare Online can connect to 2 video cameras for smoke auto-detection in real-time. The Smoke Level values and EPA Alarms are sent to DCS to assist the plant to comply with EPA rules at all times.

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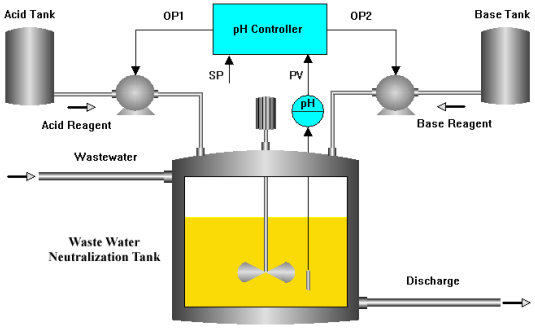
CyboSoft Offerings

MFA Control Software and Solutions

- CyboCon MFA Control Software,
- MFA Control Toolset for LabVIEW,
- MFA Control ToolBox for MATLAB, and
- Embedded MFA Control Software.

AI and Virtual Plant Software Family

- CyboFlare Smoke Auto-Detection Software.
- Real-time pH process modeling and control simulation software.
- Real-time flare process modeling and control simulation software.



Training, Consulting & On-Site Commissioning

- Training and consulting for building advanced control systems, and smart flare monitoring systems. on-site commissioning.

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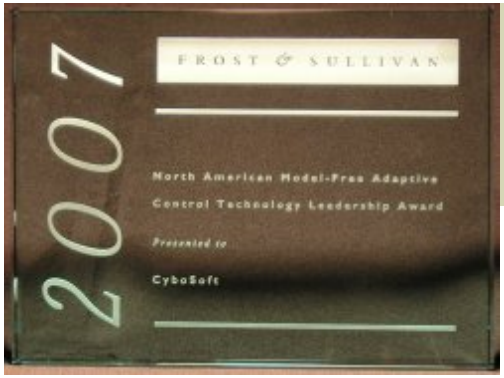
Value = Competitive Advantage

MFA delivers predictable economic results

- No more controller loop tuning,
- Most efficient use of energy and materials,
- Minimal human interaction or downtime,
- Maximum yield and minimal waste and pollution,
- Fast return-on-investment (ROI),
- An enabling tech for high-tech equipment and products.



2007 North American Frost & Sullivan Award for Technology Leadership

CyboSoft

MFA promises to end PID-dominated era.

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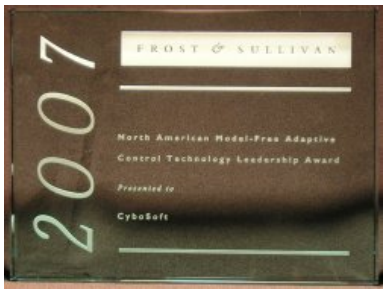
About CyboSoft

- Founded in 1994, CyboSoft is the leader in control technology serving the worldwide process control, building control, and equipment control markets.
- CyboSoft's patented Model-Free Adaptive (MFA) control technology for automatically controlling physical processes is a major breakthrough. No other comparable technology possesses all the attributes of MFA.
- MFA is the only commercially successful smart controller that does not require mathematical models. It is well suited for the Era of 4th Industrial Revolution where everything is to be "Smart".

MFA IN CONTROL



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CyboInverter

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