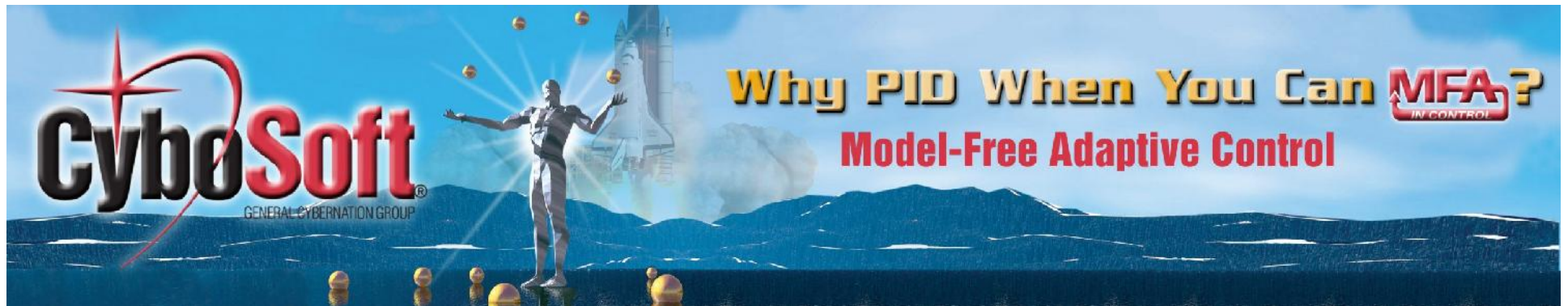




# For Partners and Customers

## Model-Free Adaptive (MFA) Control



[www.cybosoft.com](http://www.cybosoft.com)    [www.cyboenergy.com](http://www.cyboenergy.com)

*May 2017*



# Megatrends - Critical Threats to Us

## Immediate Threats Shrinking glacier and rising sea level

- Global warming,
- Air, water, and soil pollution,
- Explosive growth of population and shrinking natural resources,
- Aging society and increasing healthcare needs.

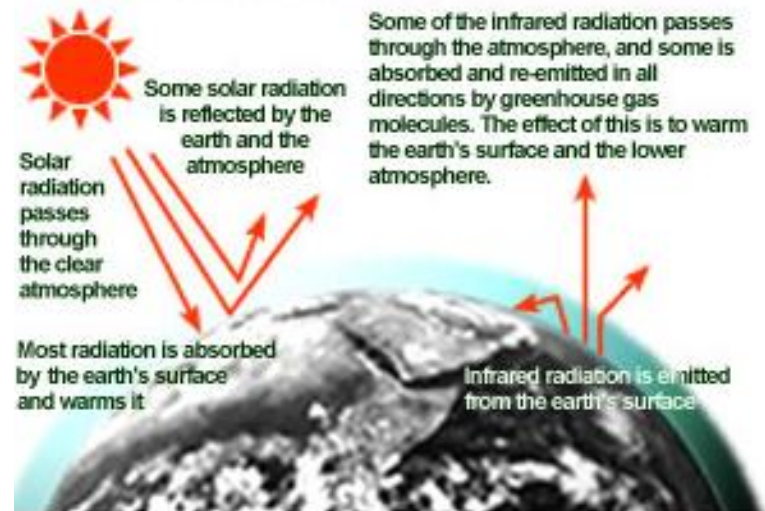


Infusion pump

More frequent and severe hurricanes



### The Greenhouse Effect



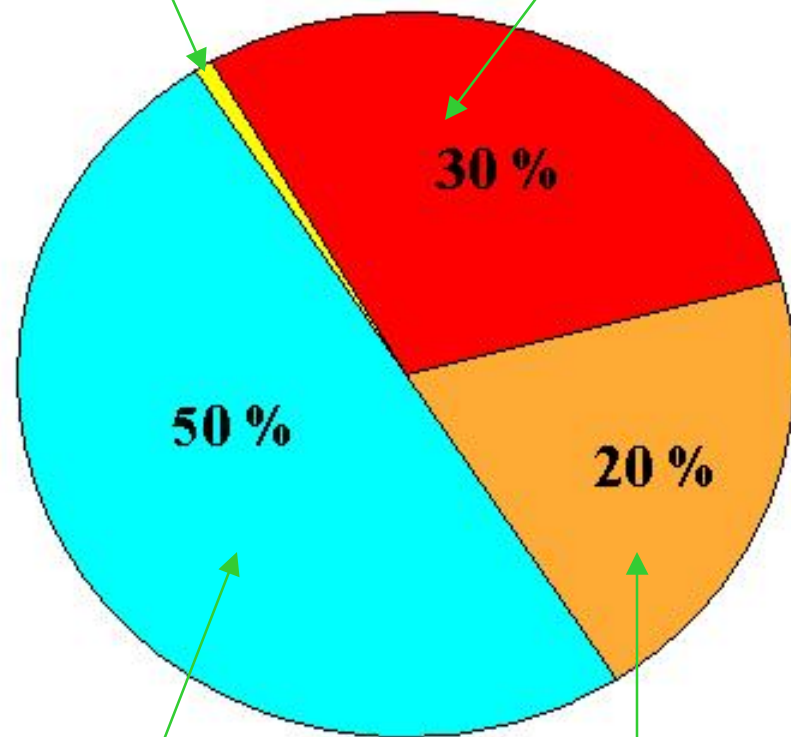


# Control Can be a Big Factor

**Good control will help, bad control will hurt.**

**Model-based control < 1%**

**Manual control**



**PID is fine**

**PID needs manual tuning**

● Poor pH control causes major water pollution in rivers, lakes, ...

● Poor combustion control causes acid rain, shrinking ozone, lung cancer, global warming,...

● 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 to Help?**



# 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.



# Model-Free Adaptive (MFA) Control

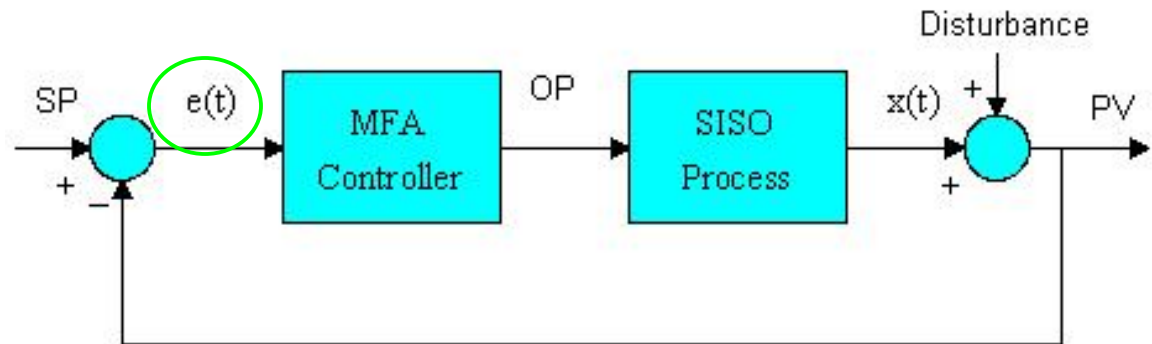


## Control Objective

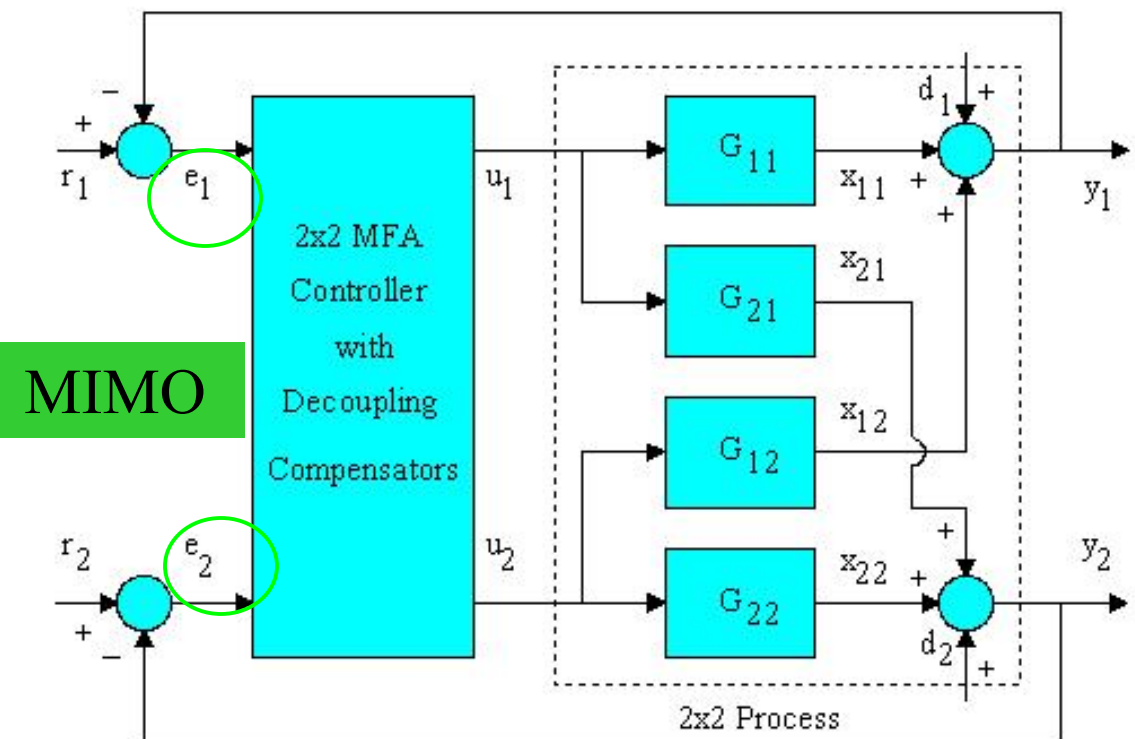
● Controller to produce OP to force PV to track SP or minimize  $e(t)$ .

## MFA controls complex systems

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



**SISO**



**MIMO**

## Inside MFA

### No Model

- A neural network is part of the MFA.

### Adaptive

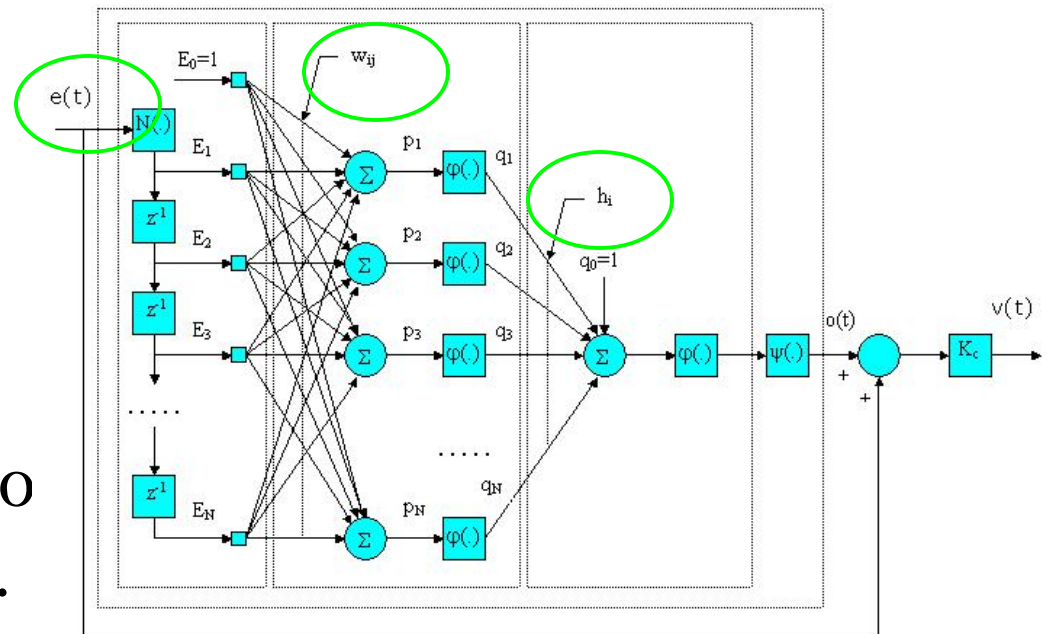
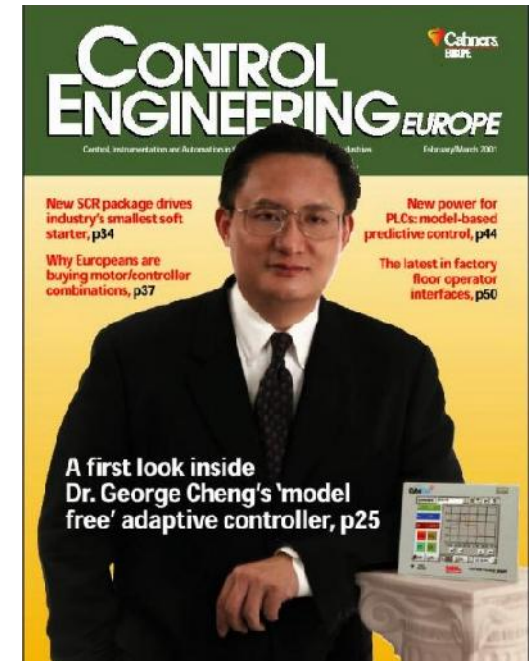
- Weights are updated to help minimize  $e(t)$ .

### Robust

- Provides much wider robust range than PID.

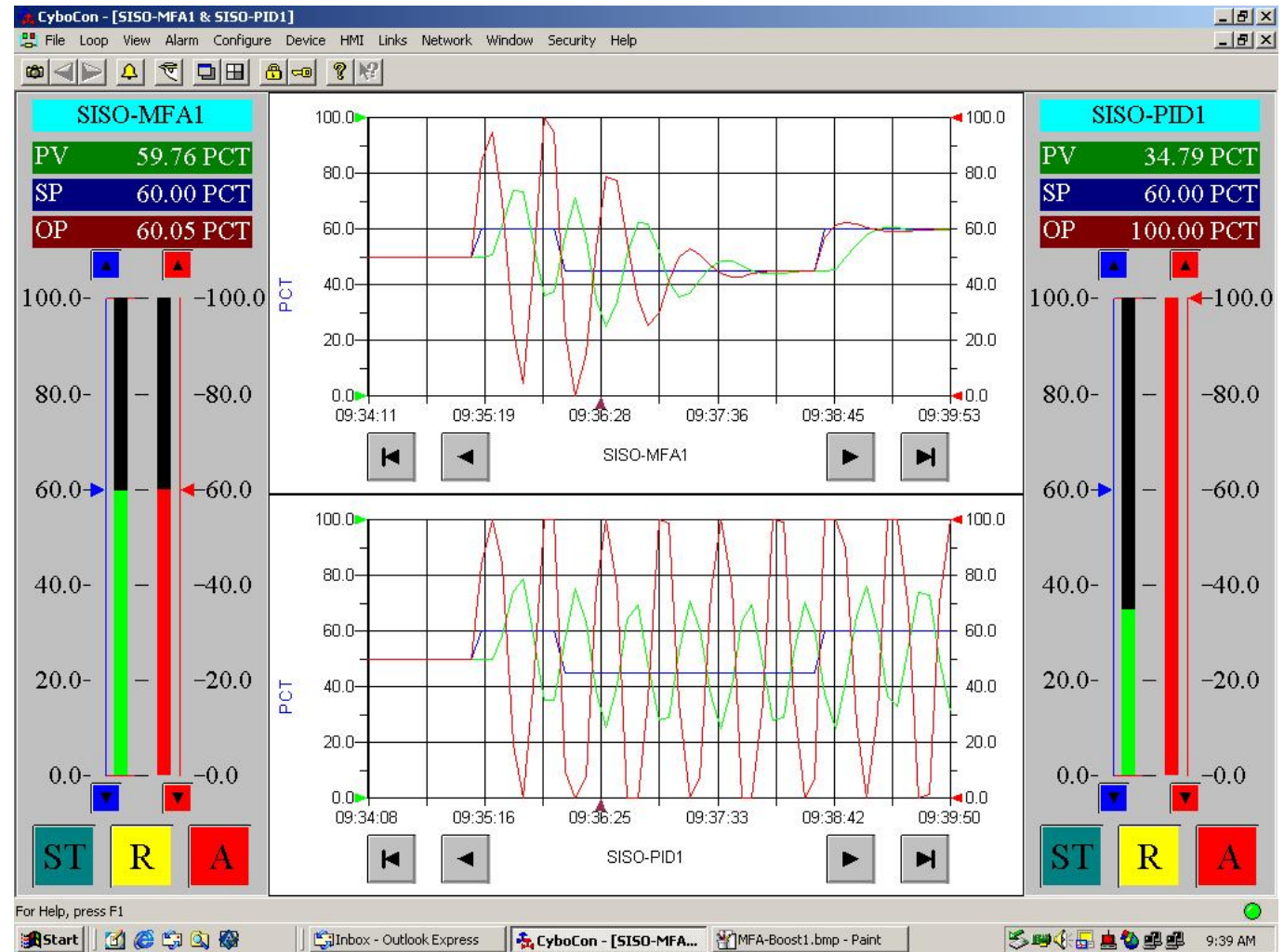
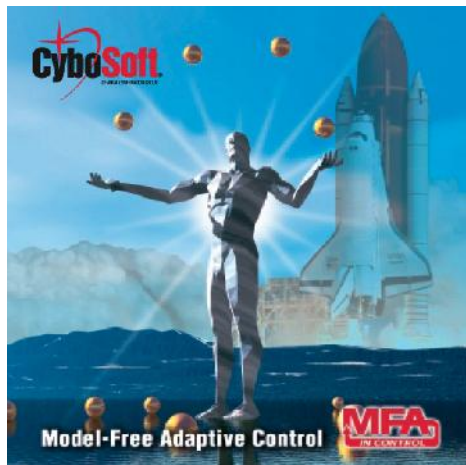
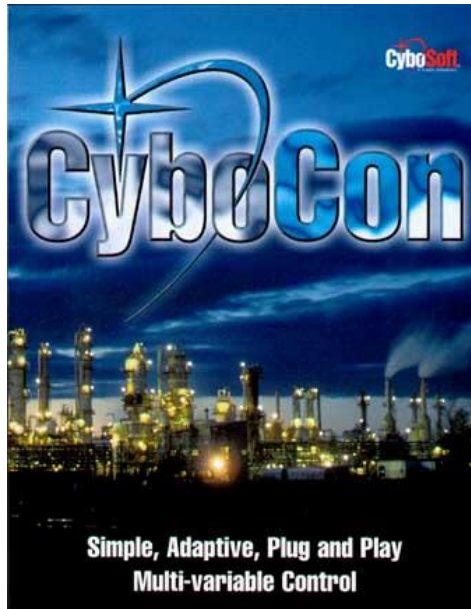
### Speed

- Controls immediately, no waiting on model building.





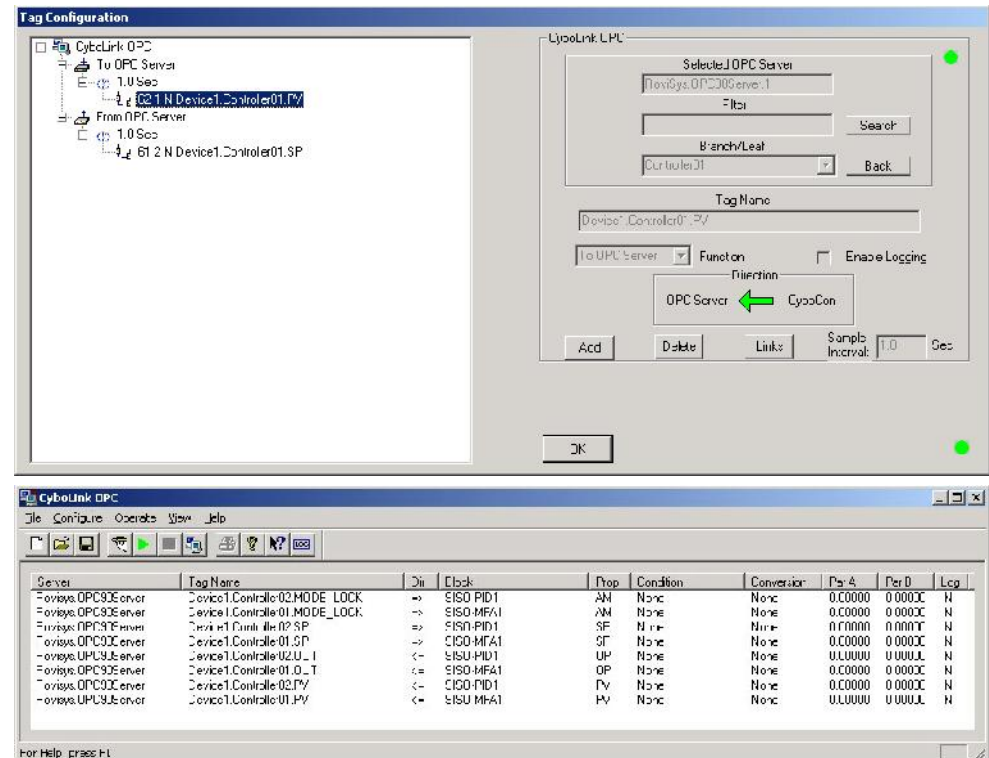
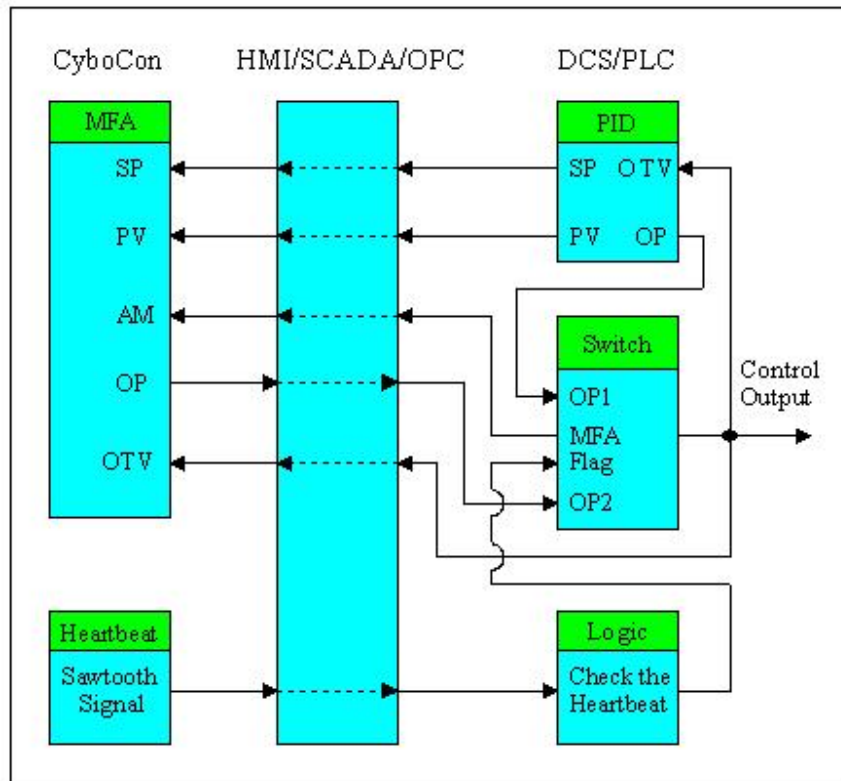
# Running CyboCon Demo







# Signal Wiring of CyboCon to DCS



CyboLink OPC Client Software Screens

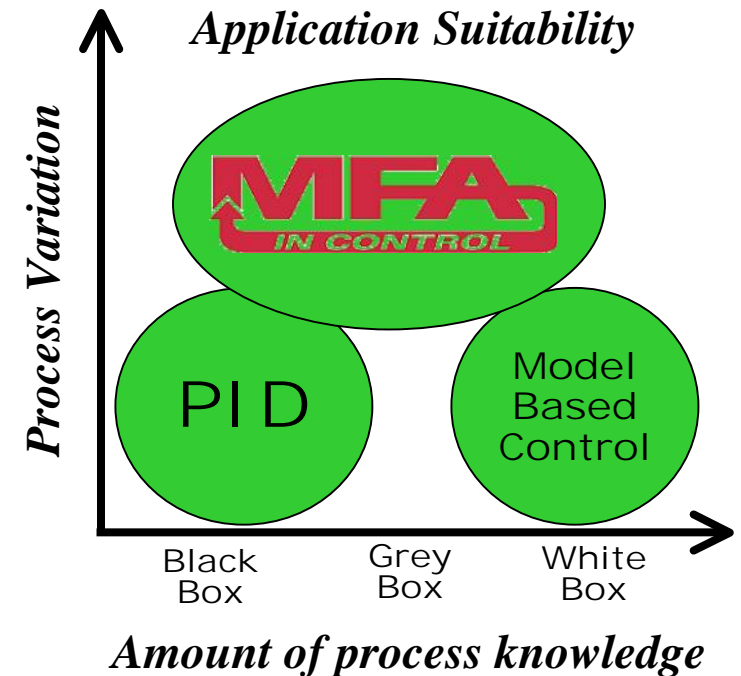
The Switch block in PLC is to switch between MFA and PID.

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



# 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

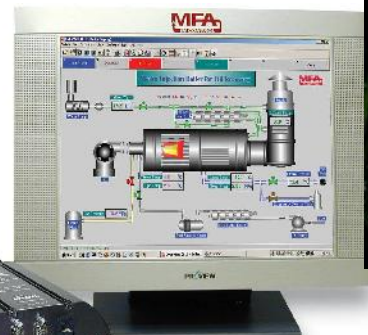
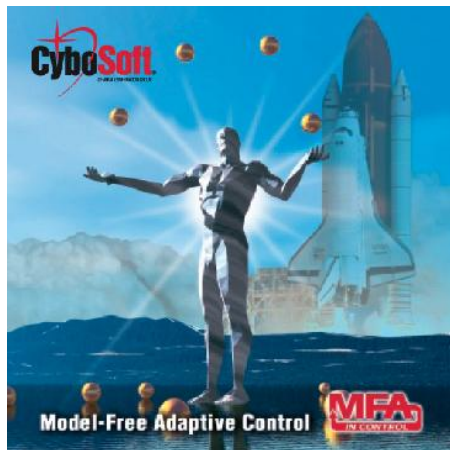
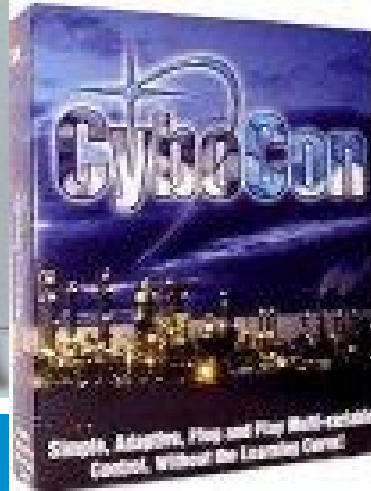


MFA is suitable for Grey box problems, where the process has uncertainties including load, fuel, and dynamic changes, etc.

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



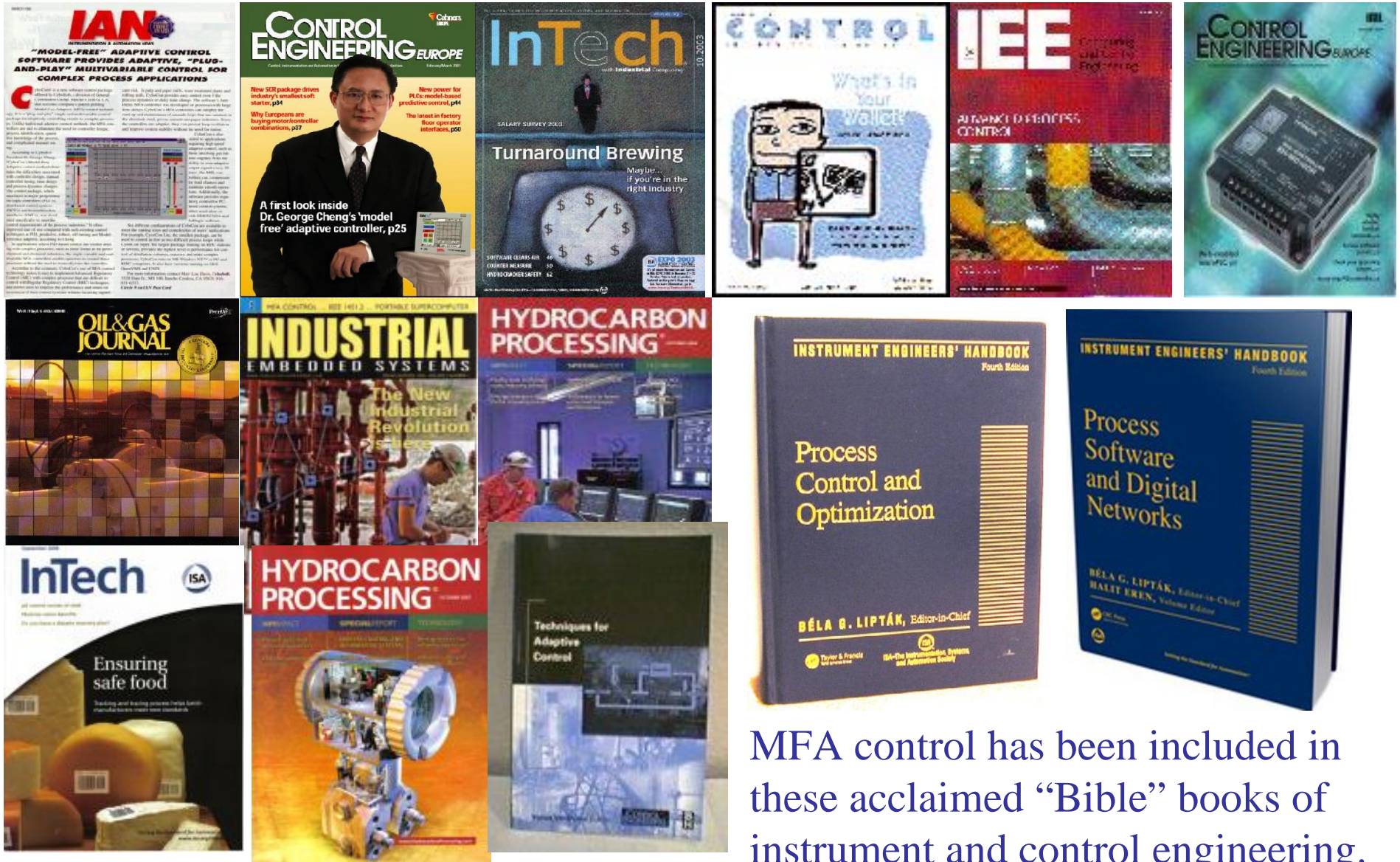
# Recognized for Continuous Innovation



Prestigious awards validate the impact of MFA to the industry.



# MFA Publications



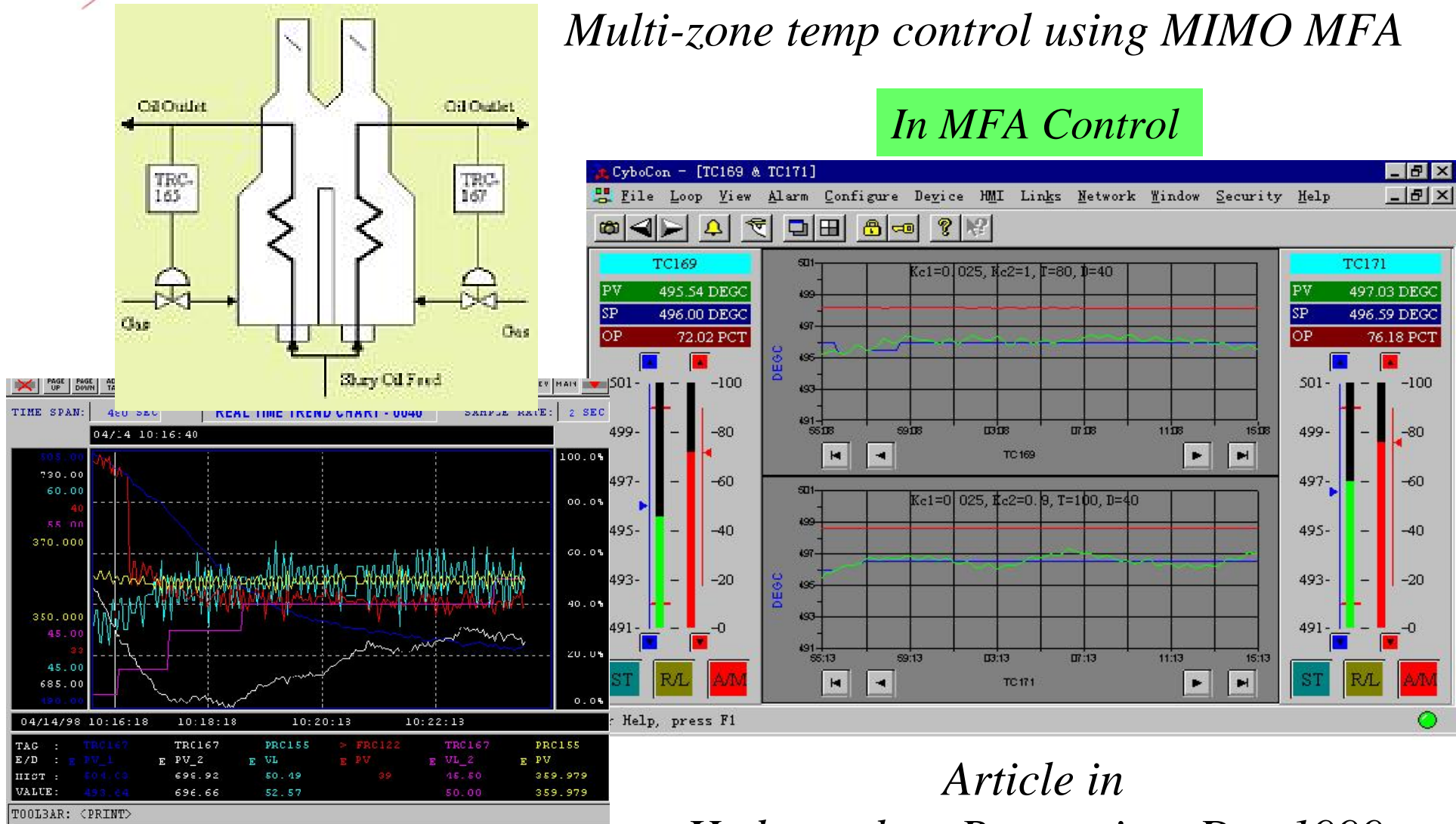
MFA control has been included in these acclaimed “Bible” books of instrument and control engineering.



# MFA on Coking Furnaces

*Multi-zone temp control using MIMO MFA*

*In MFA Control*



*In Manual Control*

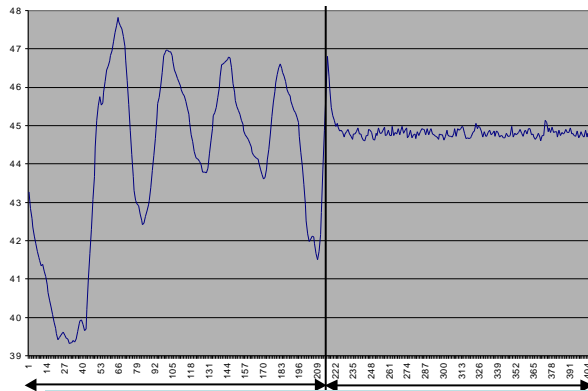
*Article in  
Hydrocarbon Processing, Dec 1999*





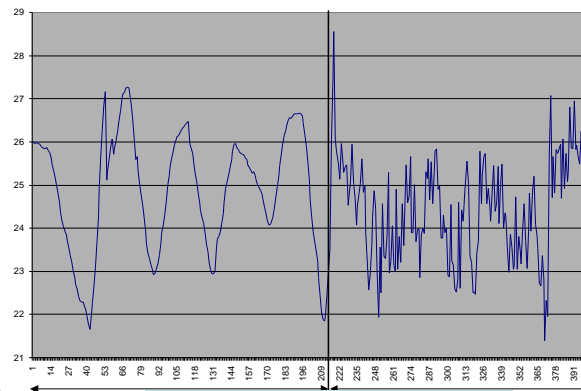
# MFA on Air Separation Unit

*Quick ROI featured in Control Magazine, May 2001*



**Key process variable**

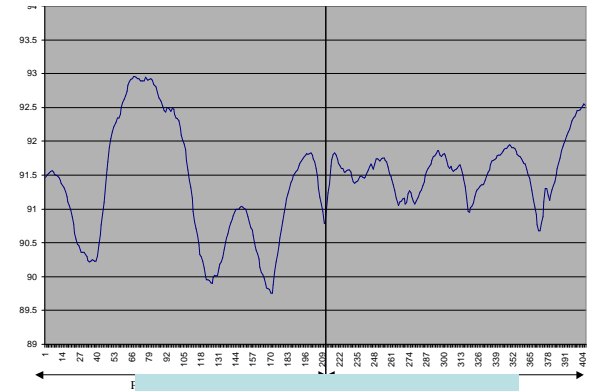
HP Column Level Control in Air Liquide Burlington Air Separation Unit (ASU)



**Reflux flow**

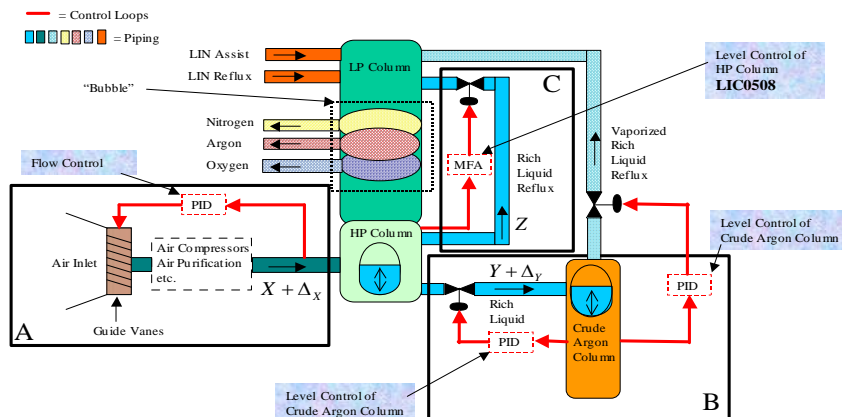
Argon Flow using MFA comp

Control

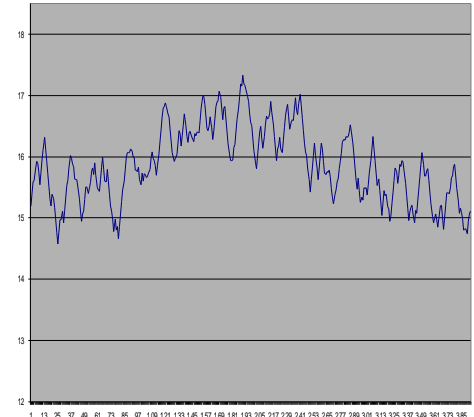
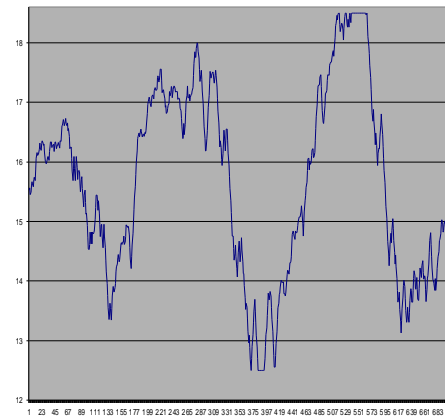


**Argon purity**

• MFA Control



**ASU Process**

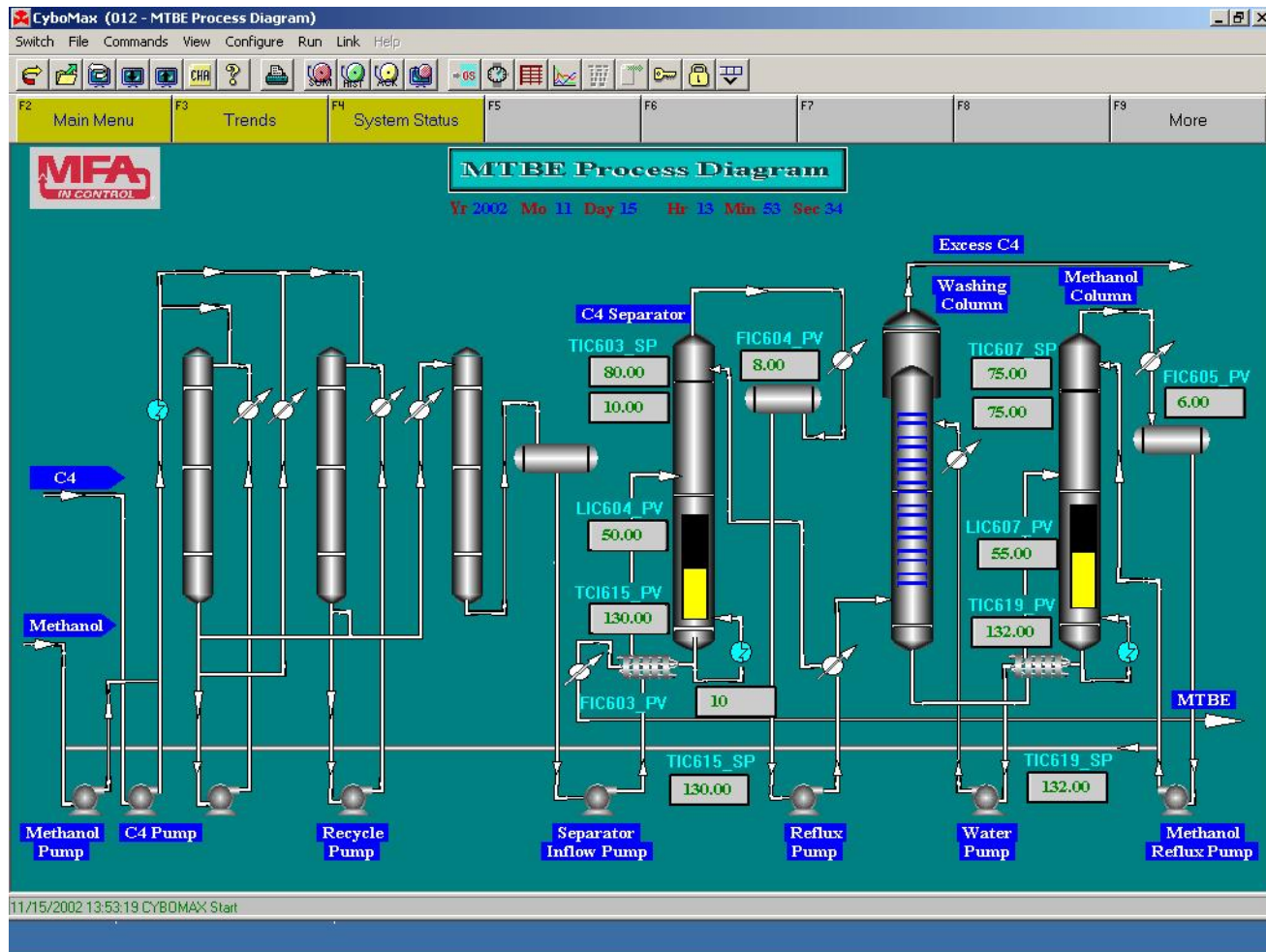


**Argon yield increased by 20%**



# MFA on Distillation Columns

*Article featured in Hydrocarbon Processing, Oct 2004*



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

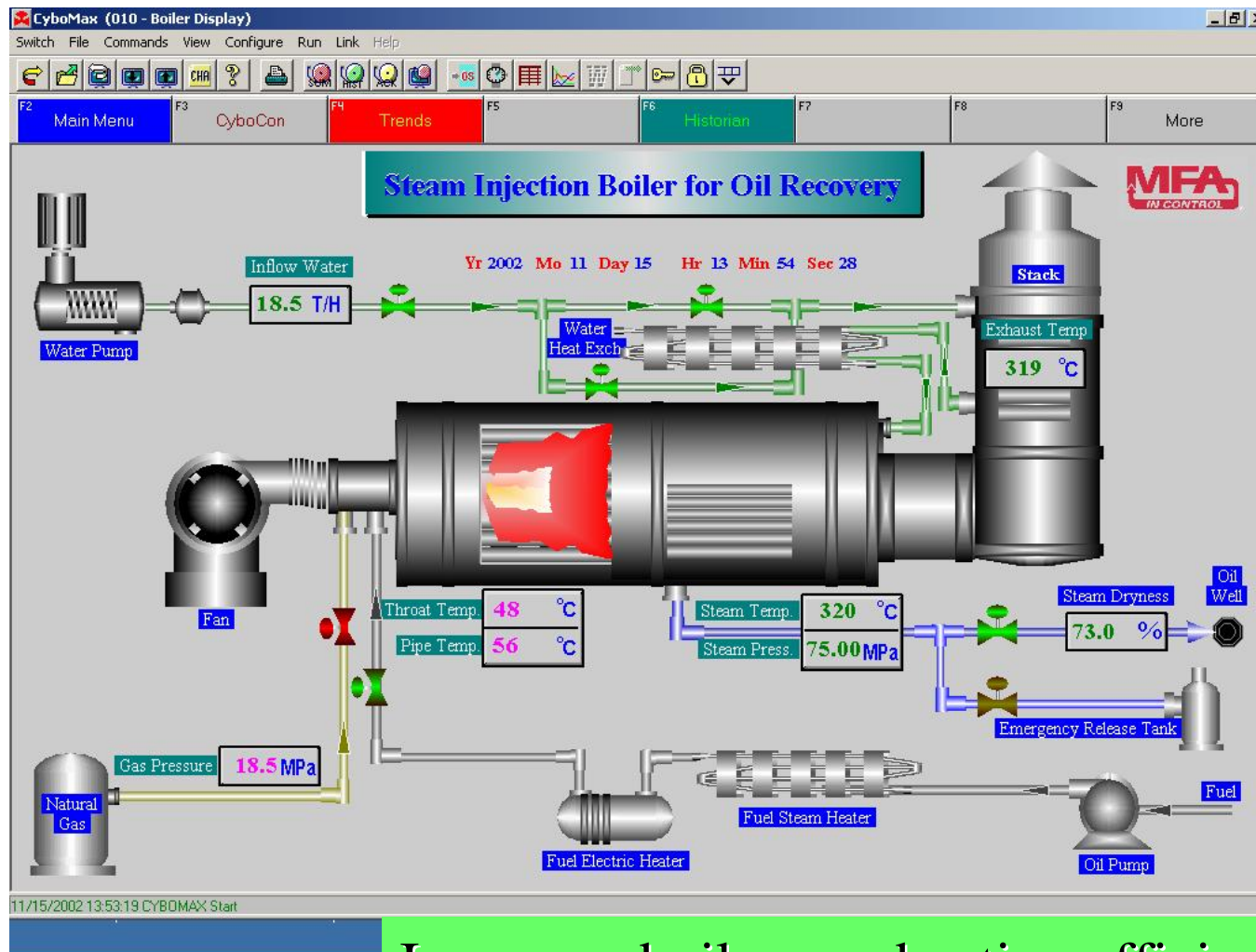
Robust MFA controls column level with reduced interruption to material and energy balance.

Achieved smoother operation and production efficiency and yield.



# 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.

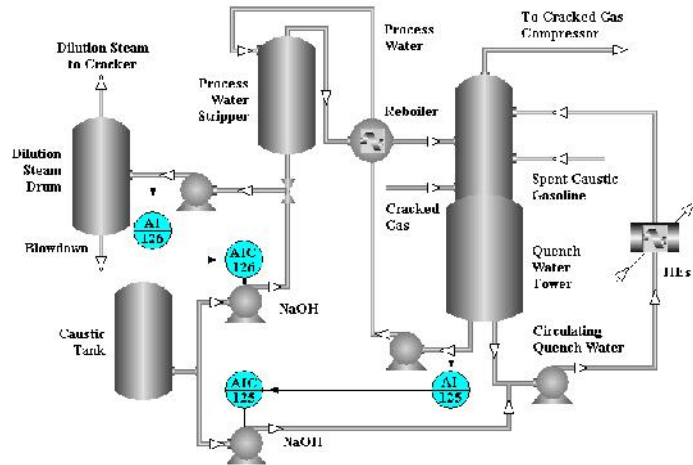
MFA control of steam dryness, temp, pressure, with optimal fuel-and-air ratio.

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



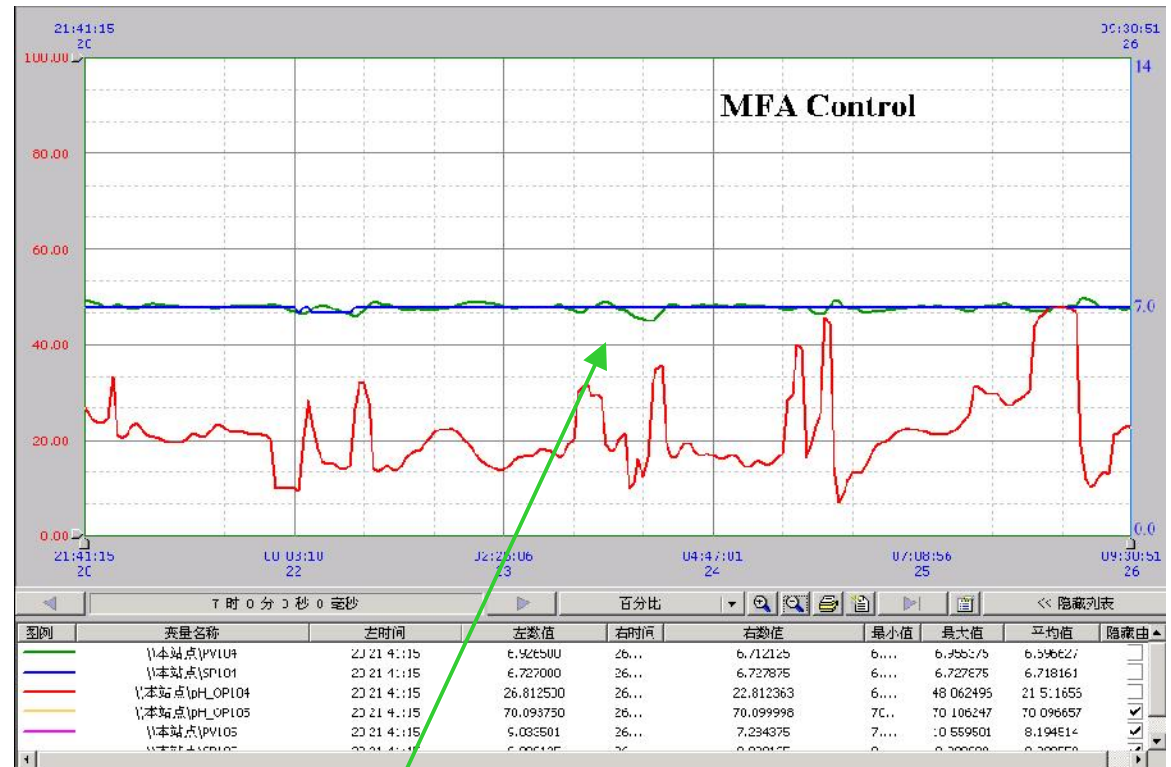
# MFA Quench Water pH Control

*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.

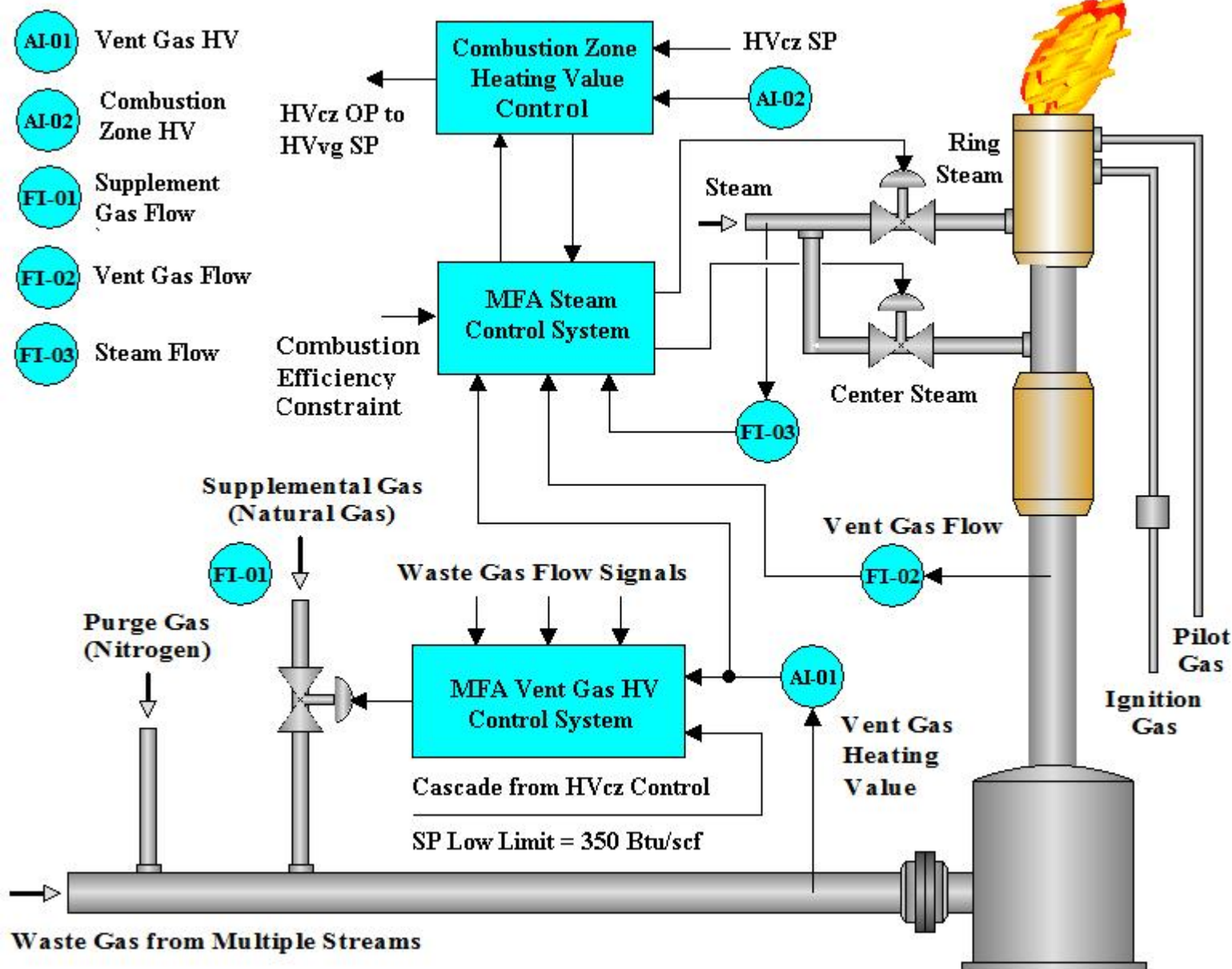


pH process has a 30 minute delay. Trend shows 12 hours of data. MFA produced control signals in the range of 7% to 50% to make significant adjustments to the caustic flow in order to keep the pH (green) under control with only 0.28 variation range.





# MFA Control for Steam Assisted Flares





## 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.

### 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.

**SIEMENS**



APOGEE  
BAS

**MFA**  
IN CONTROL



## 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 2017, about 800 systems are in operation.





## 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.



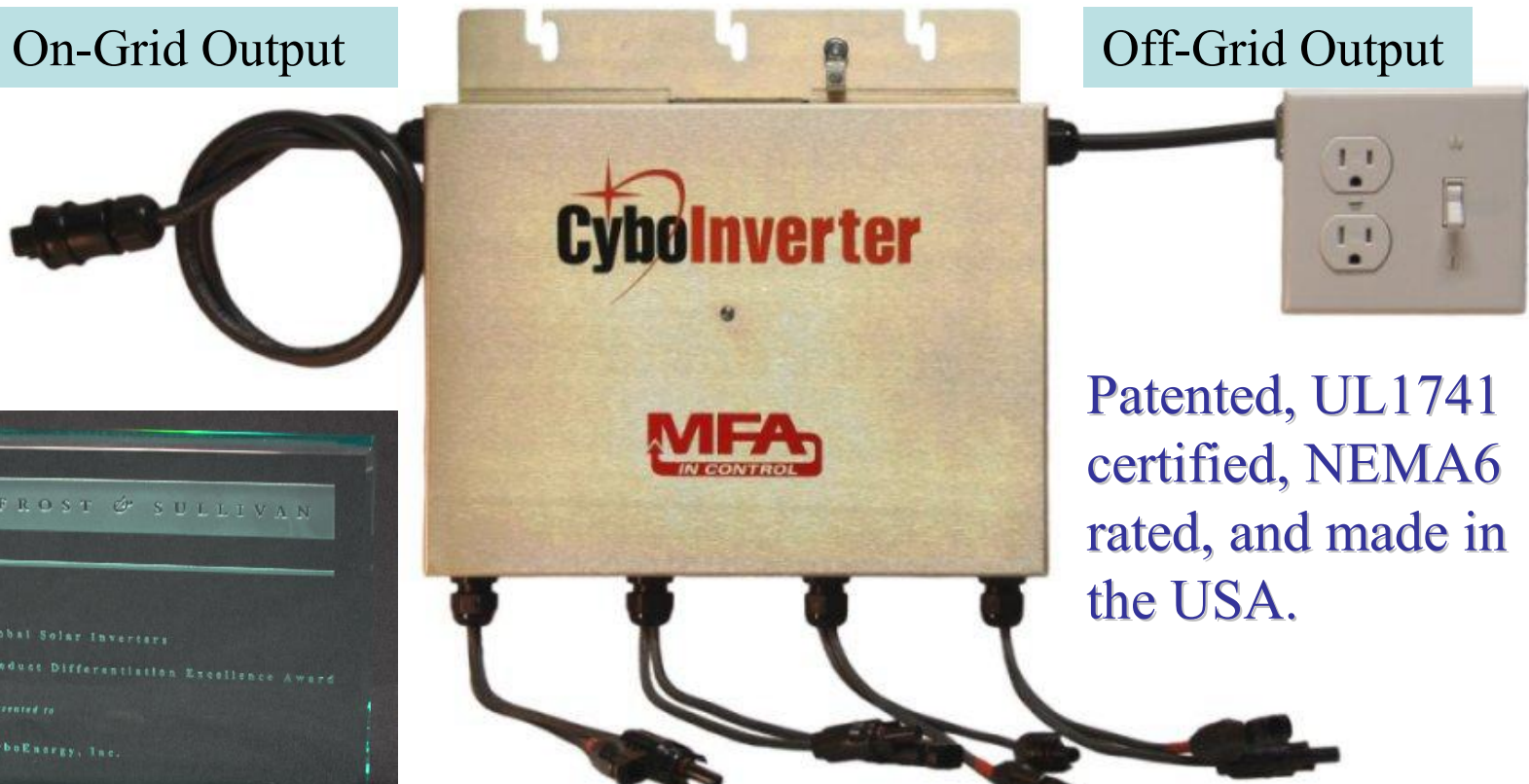


## MFA in On/Off-Grid CyboInverter

A 4-channel CyboInverter is a 4-input-1-output high-speed nonlinear system with varying inputs. Very difficult to control using PID or model based control methods. MFA is the enabling tech for this.

On-Grid Output

Off-Grid Output



Patented, UL1741 certified, NEMA6 rated, and made in the USA.



Received "Global Product Differentiation Excellence Award" for Solar Inverters from Frost & Sullivan.

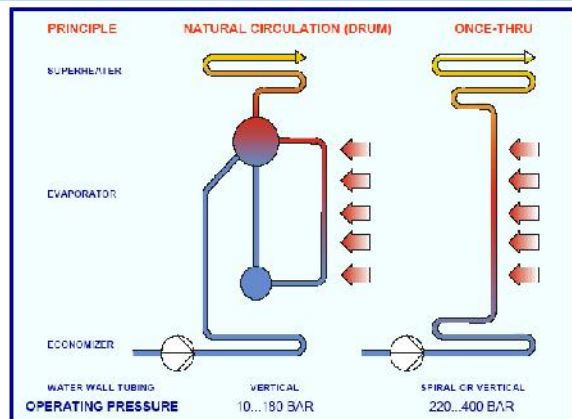


## CyboSoft's DOE Grants

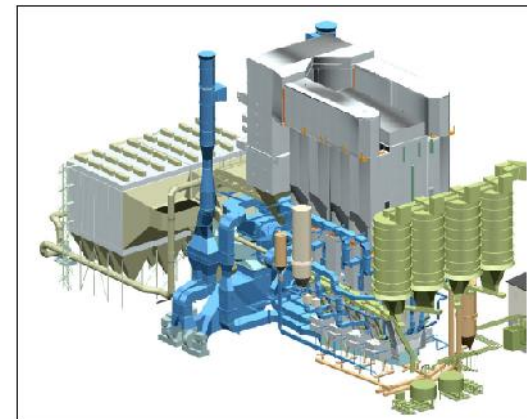


- 1. SBIR Phase II Grant: Intelligent Control of Advanced Power Generation Systems Using Model-Free Adaptive Control Tech.

### OT Supercritical Boiler



### Circulating Fluidized-bed Boiler



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

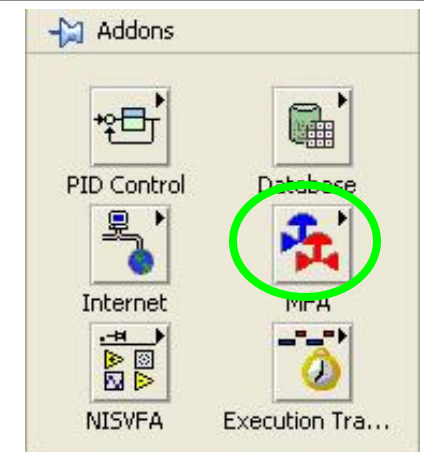
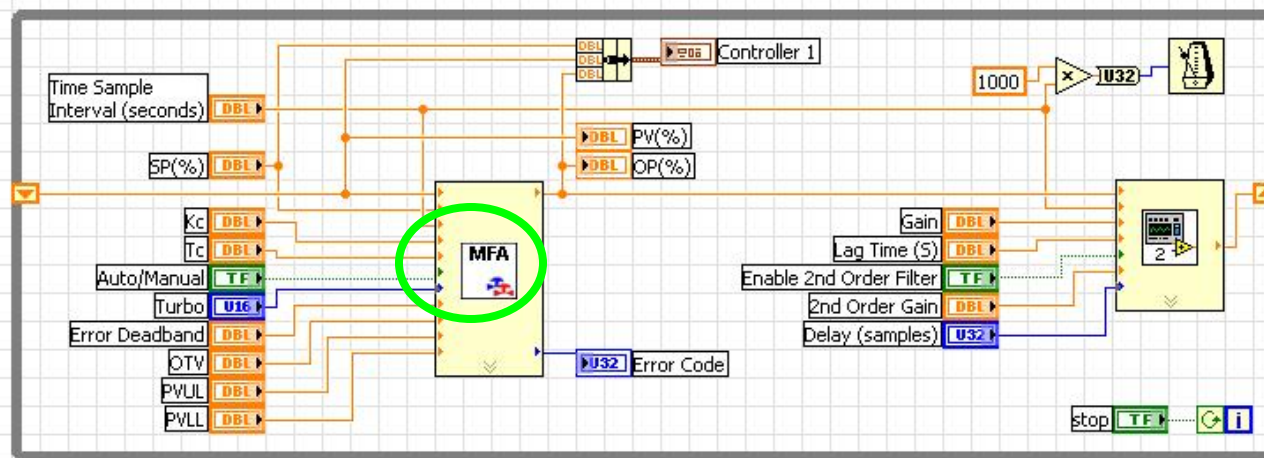
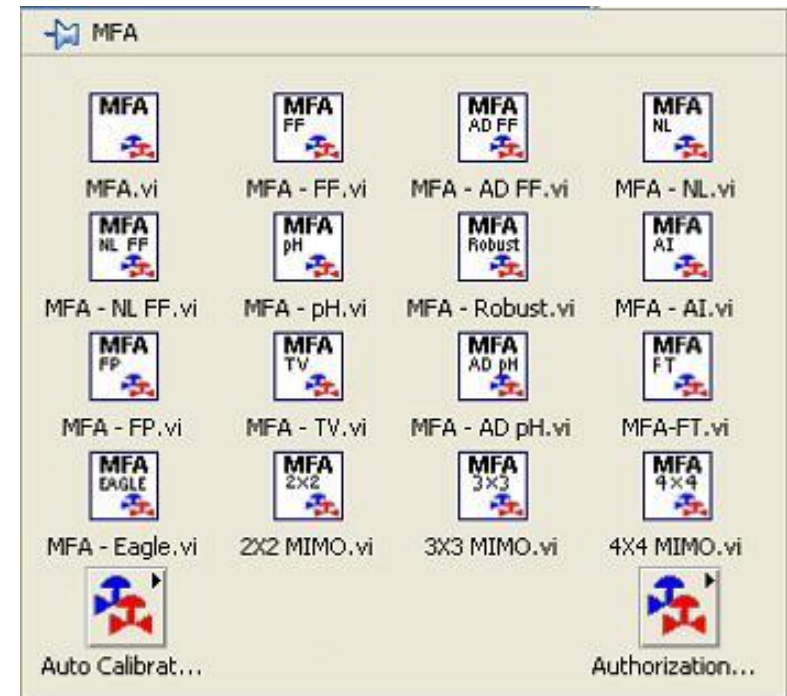
- 2. SBIR Phase II Grant: Intelligent Actuation Control Using Model-Free Adaptive Control Technology.
- 3. SBIR Phase I Grant: Intelligent Industrial Furnace Control Using Model-Free Adaptive Control Technology.



# Embedded MFA in NI LabVIEW

## MFA Control Toolset 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.

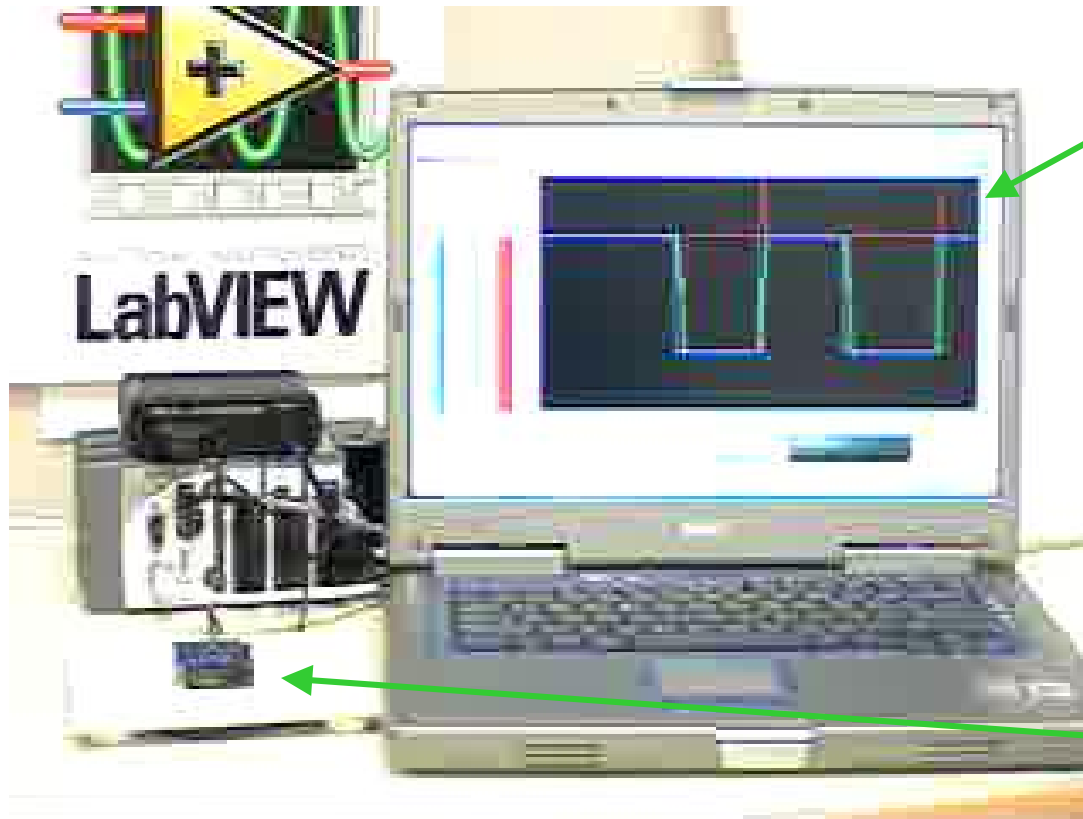




# MFA Motion Control on Piezo Motor

## 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)

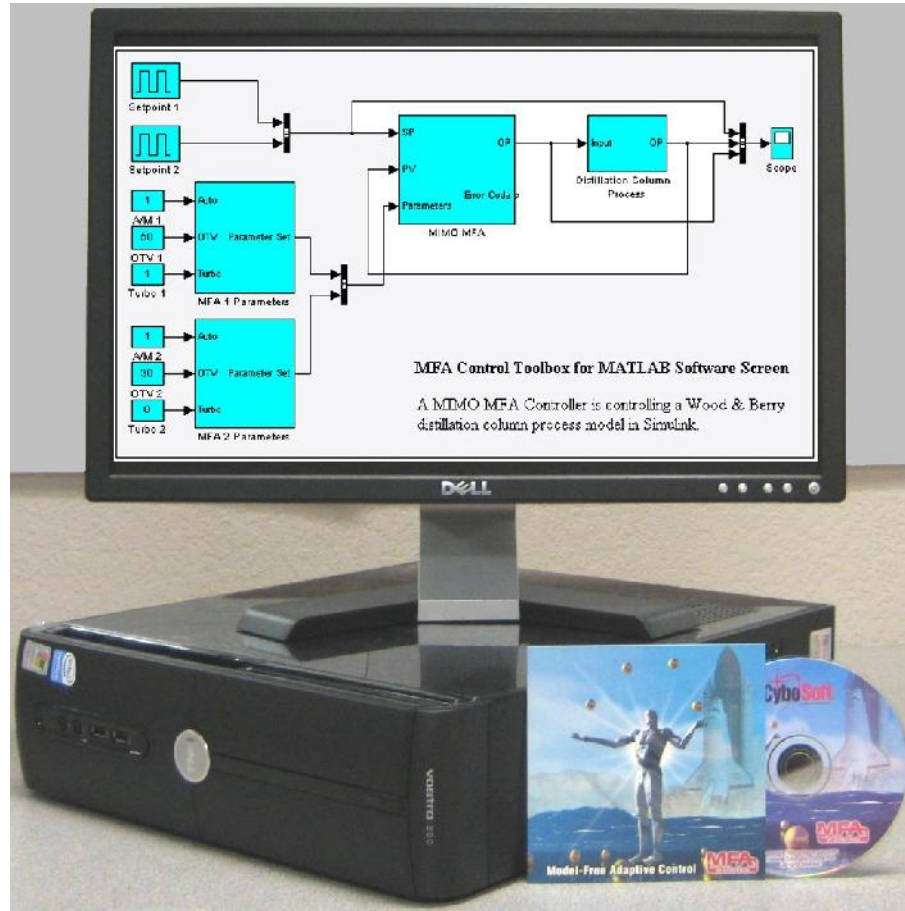
Red – Controller Output (OP)

Demo: a piezo-motor by Physik Instrumente





# MFA Control ToolBOX for MATLAB



## MFA Control ToolBox for MATLAB Software

### CyboCon CE – MFA Loop Controller

A low cost, all-in-one MFA control box that fits the wastewater treatment and China market





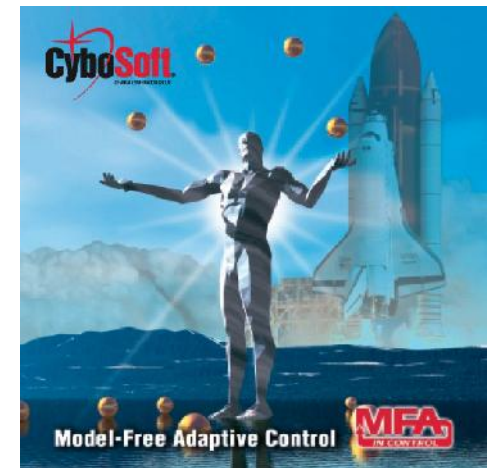
# CyboSoft Offerings

## Virtual Plant Software Family

- Real-time process modeling and control simulation software as a learning & training tool for various complex process. Help design your control system or see how the MFA control solution works.

## MFA Control Products and Solutions

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



## Control Consulting and On-Site Commissioning

- Consulting for building an effective control systems. Design, parts selection, on-site commissioning, and services.

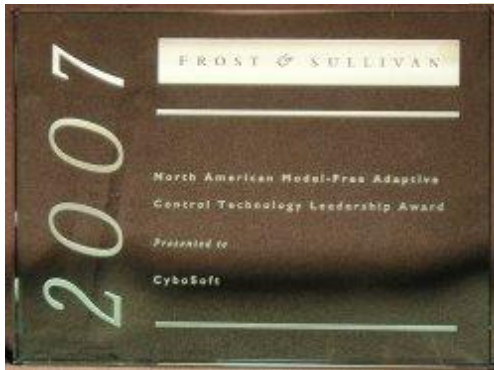


## Value = Competitive Advantage

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.**



## CyboSoft and CyboEnergy

- Founded in April 1994.
- A technology company offering specialty software.
- Core tech: MFA control, power inverters, etc. total 30 US patents.
- The leader in control technology serving the worldwide process control, building control, and equipment control markets.
- CyboEnergy developed and patented CyboInverter, the world's first solar power Mini-Inverter.

### Our vision and mission

- Make MFA control successful in key market segments.
- Provide control tech to address urgent needs to deal with the threats.



*Rancho Cordova, Calif.*

