PRAGMATIC AI-DRIVEN PROCESS CONTROL

FOR INTELLIGENT MANUFACTURING

APC CONSULTING

3i - Intelligent - insight - Improvement

CURRENT INDUSTRY

- AI and analytics help manufacturers improve **efficiency**, **quality**, and **competitiveness**
- Key uses include **predictive maintenance**, **quality control**, **energy savings**, and **production planning**

AI ADOPTION

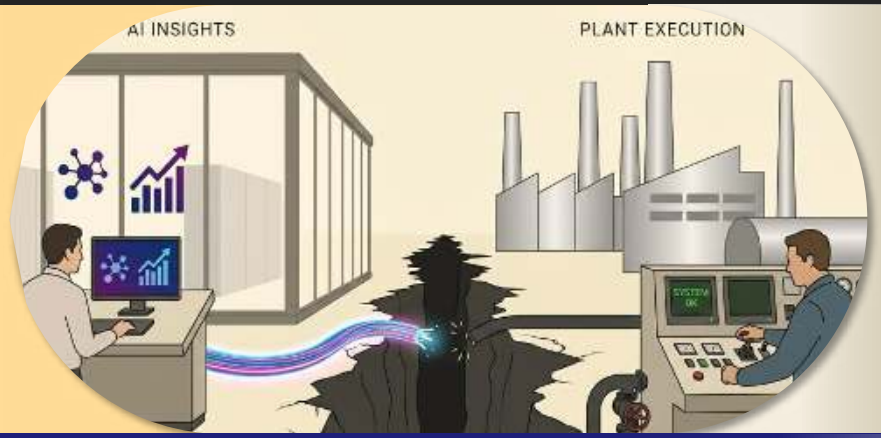
- Most AI solutions analyze historical data offline rather than control processes in real time
- AI is often used for recommendations, not direct real-time process control

LIMITED DIRECT IMPACT ON REAL-TIME OPERATIONS

- AI insights are often disconnected from control systems, limiting real-time action
- Safety and integration concerns can lead to delays, manual intervention, and lost value

KEY CHALLENGES

01



Gap between AI Insights & Plant Action

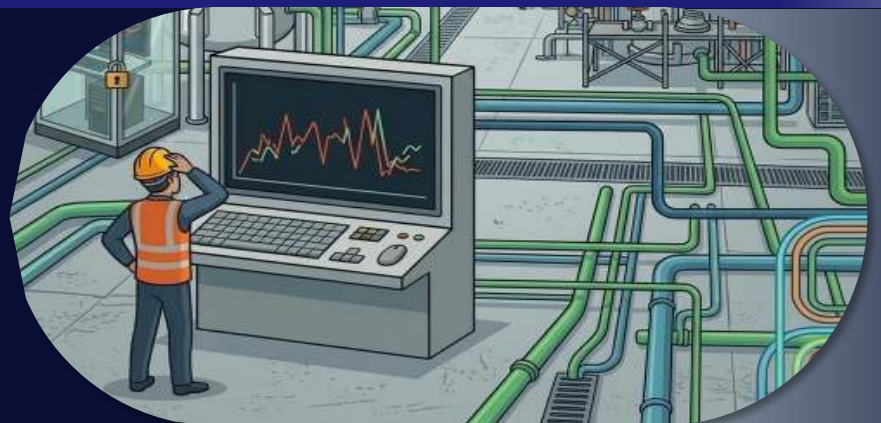
More plants are piloting AI every year — for predictive maintenance, quality checks, and scheduling optimization. The technology is no longer experimental.

Standalone AI Cannot Drive Real-Time Optimization

Current AI models generate dashboards and alerts, but a human operator still decides what to do. The AI watches — it does not act.

02

03



Even when AI has control, rigid rules fail in complex conditions

With rising variability, fixed rules fail. Without adaptation, AI still drives inefficiency and upsets.

The Missing Link:
AI Must Be Embedded within APC and Process Control

1
2
3

AI FOR SMARTER PROCESS CONTROL

AI as An Extension of APC

APC has been running plants for decades. The proposal is to enhance it with AI — not discard it. AI handles the complex, variable parts that traditional APC struggles with.

1

Enhancement Not Replacement

AI suggests adjustments to help operators optimize plant operation further among multiple units / sections . Operators keep their familiar control – AI adds capability on providing higher advisory level .

2

Integrated within Existing Control Layers

The AI models live within the APC/DCS infrastructure, so they can directly or advisory to adjust setpoints, respond to upsets and act without waiting for human intervention or follow smart alert with AI guidance

AI Embedded Mode

Advisory Mode

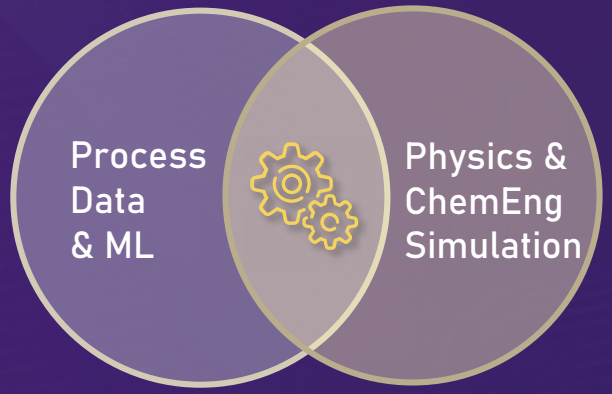
HOW AI ADD VALUES FOR SMARTER PROCESS CONTROL

Alert → Action Taken → Feedback

Multi-Role / Complex Logic / Case Specific

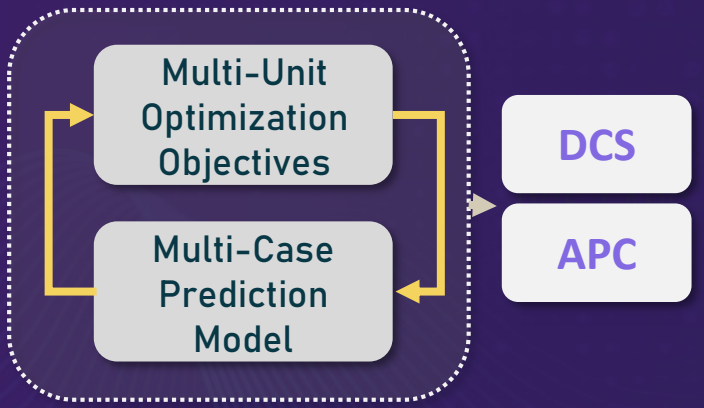
Advanced Multi-Unit Constraint Management

Optimizes multiple units within safety and process constraints, ensuring stable operation and maximum efficiency under dynamically changing conditions or costs.



Engineering Knowledge Embedded in Intelligence

Combines process expertise, engineering principles, process knowledge, and plant operational practices to deliver reliable and trusted decisions.



AI for Complex Process Dynamic Model

Extends traditional process models by learning complex nonlinear behavior from plant data, enabling more accurate prediction and adaptive optimization.

DEMONSTRATED BENEFITS

Improved Operational Stability

Reduction of
Control Performance Variation

Optimized Raw Materials

Reduction of Raw Material
e.g. Catalyst Consumption

Energy Efficiency Improvement

Reduction of Steam Usage

Increased Throughput

Increasing in Production Yield
Reduction of Batch Time
Run higher Partial Pressure or Feed against constraints

Enhanced Product Quality

React to the Quality Disturbance faster e.g. accumulated impurity overtime, catalyst or product specific mode

AI APPLICATION ENHANCEMENT FOR PROCESS INDUSTRIES

01 ADAPTIVE APC

- Upstream variability impacts downstream units
- Challenges: cracking temperature, conversion, impurities vs product output
- AI-APCs are improved by multi-unit optimization strategy for dynamic load change stability, product quality, and energy efficiency
- Petrochemicals - olefins and vinyl chain

02 NON-LINEAR APC

- Polymer processes are highly nonlinear and grade-dependent
- Challenges: melt index control, grade changes, catalyst shifts
- AI-APC suggested further optimization target for product yield and quality, raw material consumption, and energy efficiency for specific reactor vs catalyst conditions including downstream condition
- Polymers, PE and PP Production

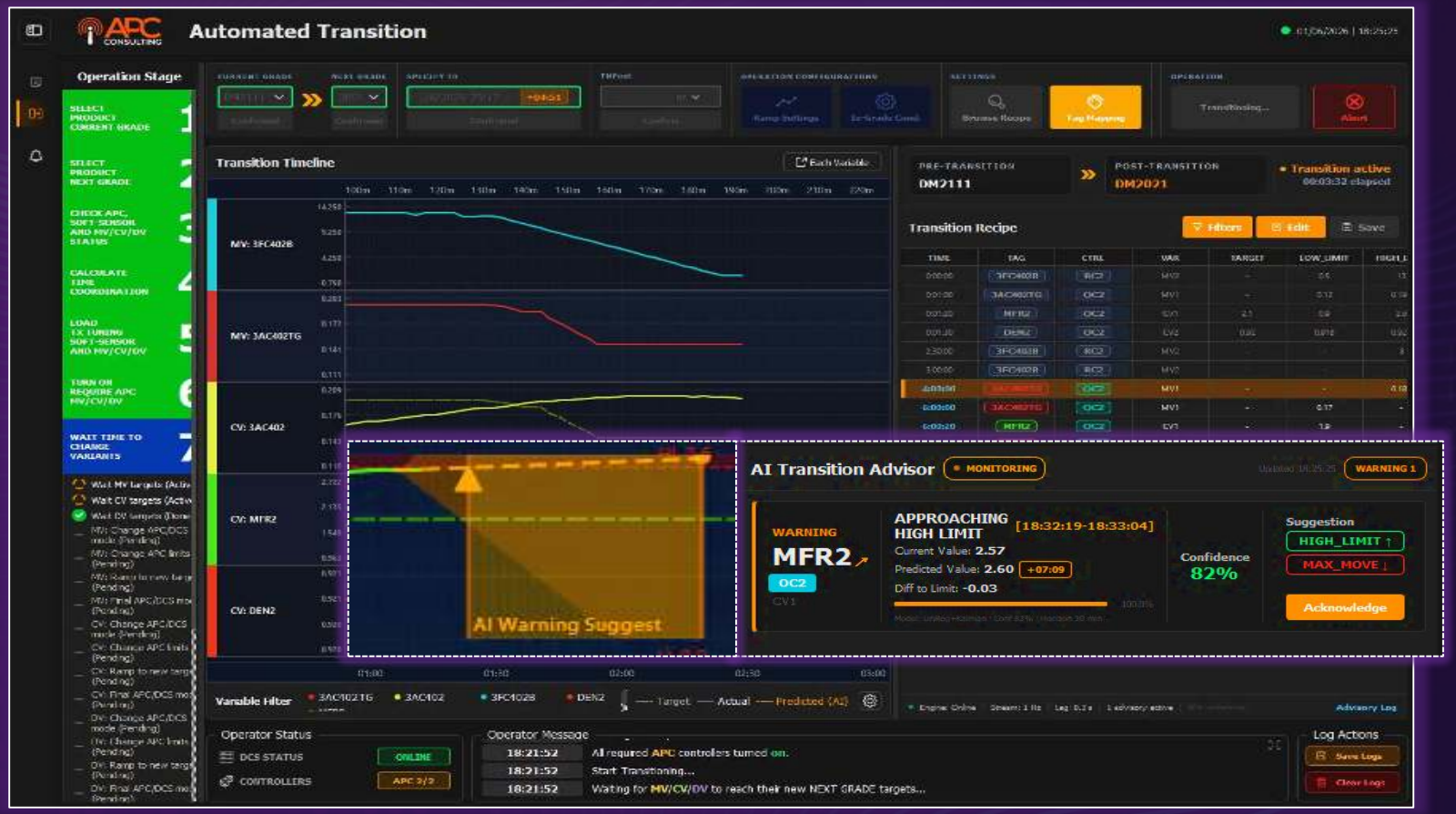
03 BATCH OPTIMAL CTRL

- Batch variability from recipes, materials, and scale-up
- Traditional APC cannot handle fast and model change across batch production steps / recipes
- AI-Batch Analyzer continue to suggest temp profiles / condenser / jacket temp in batch step to further reduces time, improves yield, and minimizes idle time
- PVC, Latex, ABS, Specialty Polymer Production, Catalyst Production

Example of AI-Enables Process Application

AI Transition Advisor for Automated Transition

Real-time prediction analysis that detecting limit breaches and target deviations, guiding operators with parameter suggestions before process issues occur



Real-Time Prediction

Uses historical data and trends to predict process variables and forecast future behavior in real time

Abnormality Detection

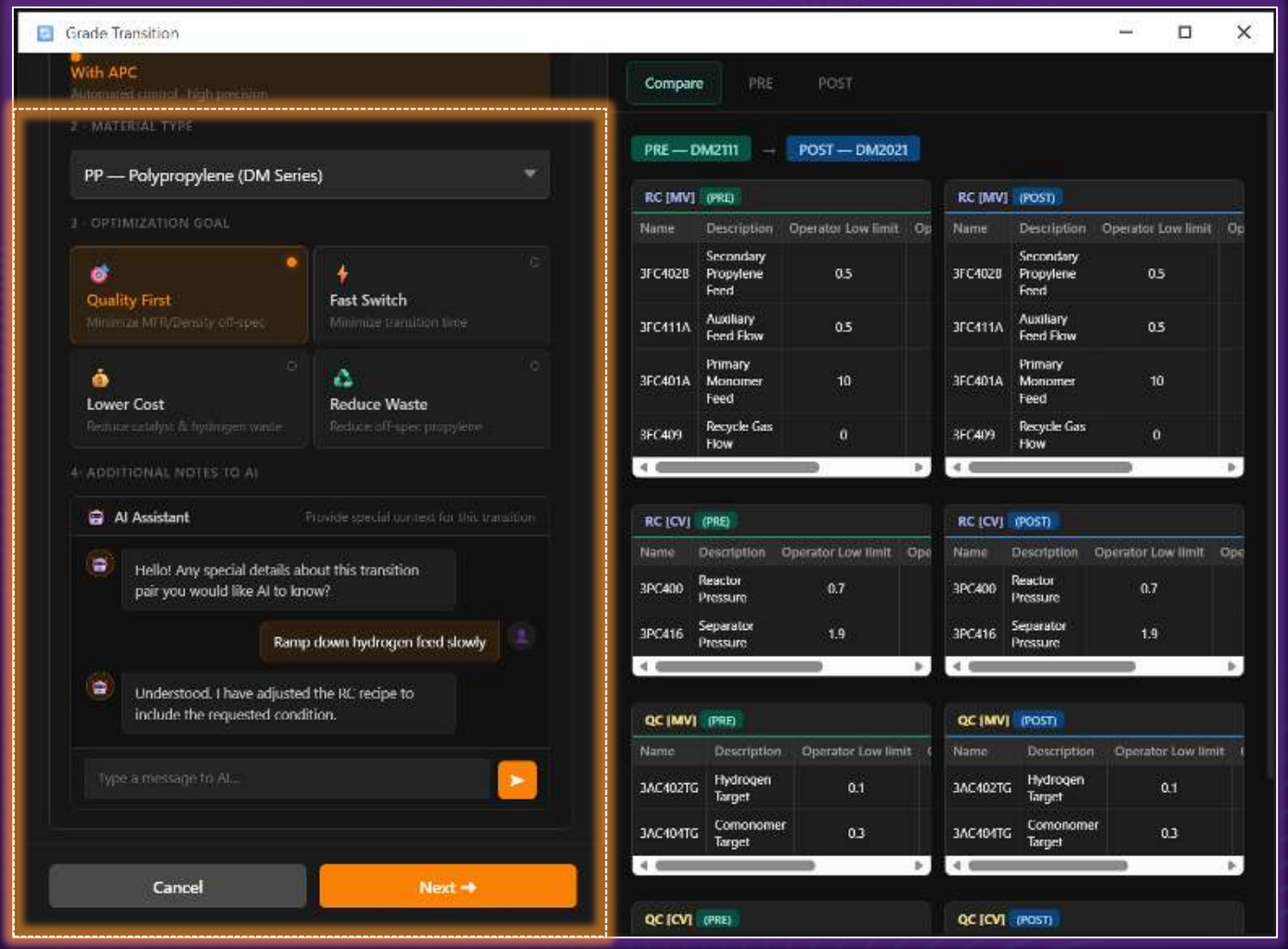
Detects limit breaches and setpoint deviations, providing real-time alerts and dashboard highlights

AI Transition Advisor

Detects optimal transition patterns and suggests operator actions to minimize deviation from optimal pattern

Example of AI-Enables Process Application

AI Transition Advisor for Automated Transition



AI-Driven Template Generation

Uses our core analytics model to evaluate historical data, automatically identifying the "Golden Transition" pattern to generate optimized recipe templates

Context-Aware AI Assistant

Allows engineers to input specific operational contexts, constraints, or custom adjustments to refine the template before generation

Example of AI-Enables Process Application

AI Operator Assistant Panel for Process MPC

Real-time AI insights that detect disturbances, highlight key issues, and recommend actions—enabling faster decisions and stable, optimized operations.

Process Disturbance Detection

Continuously monitors process variables to detect disturbances, abnormal conditions, and performance degradation in real time

Real-time Operational Insights

Provides AI-generated insights into current process behavior, highlighting potential causes and operational impacts

Key Process Observations

Automatically identifies critical process events, trends, and deviations that require operator attention

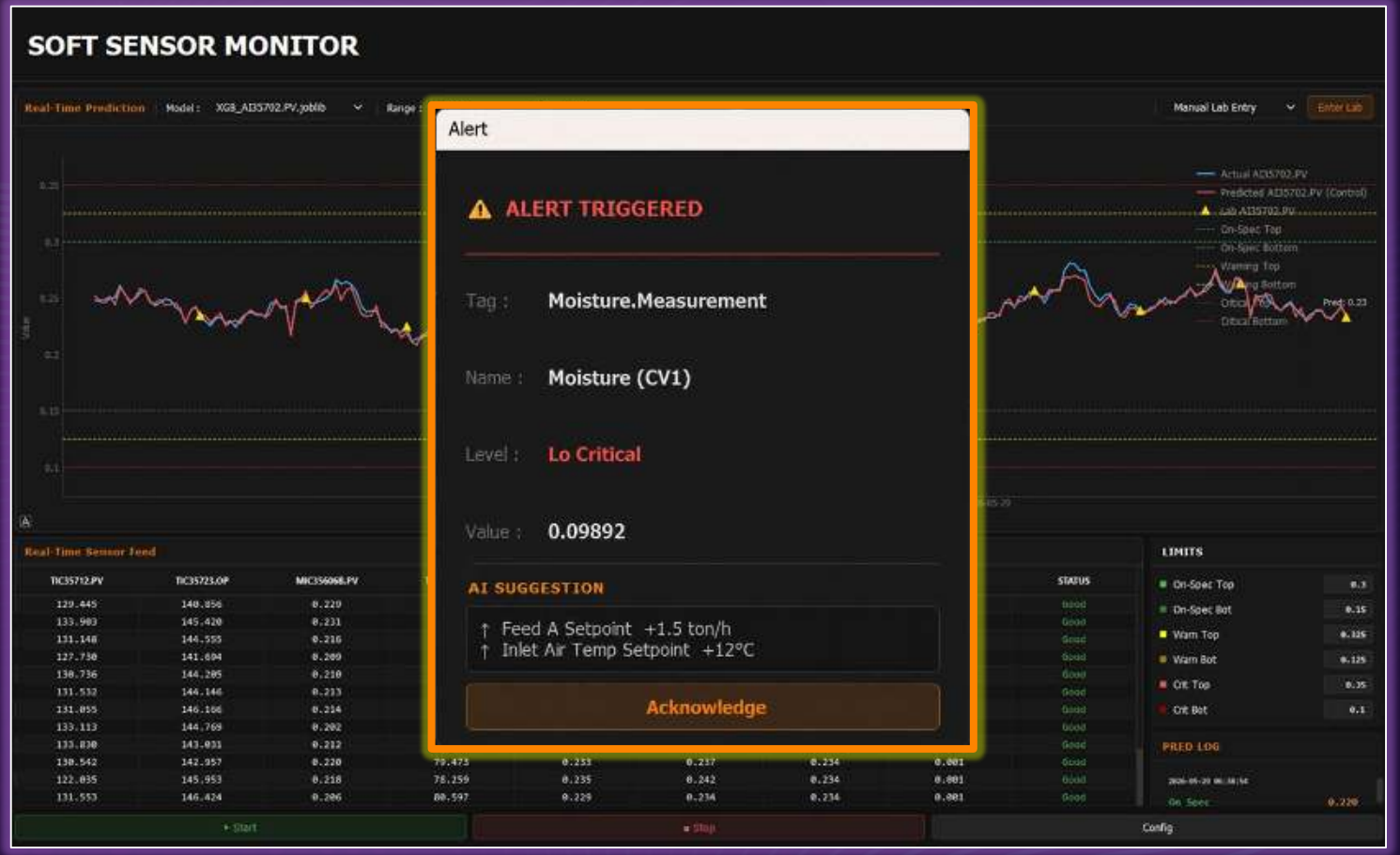
Operator Suggested Actions

Recommends corrective actions and parameter adjustments to help operators maintain stable and optimal operation

Example of AI-Enables Process Application

AI Alert for AI/ML Soft Sensor

Deliver smart alerts with built-in root-cause analysis and AI-driven operator guidance for faster and effective responses



Real-Time Alert Detection

Detects abnormal conditions, limit violations, and process upsets in real time

Root Cause Analysis

Identifies the most likely causes of alerts using process relationships and historical data

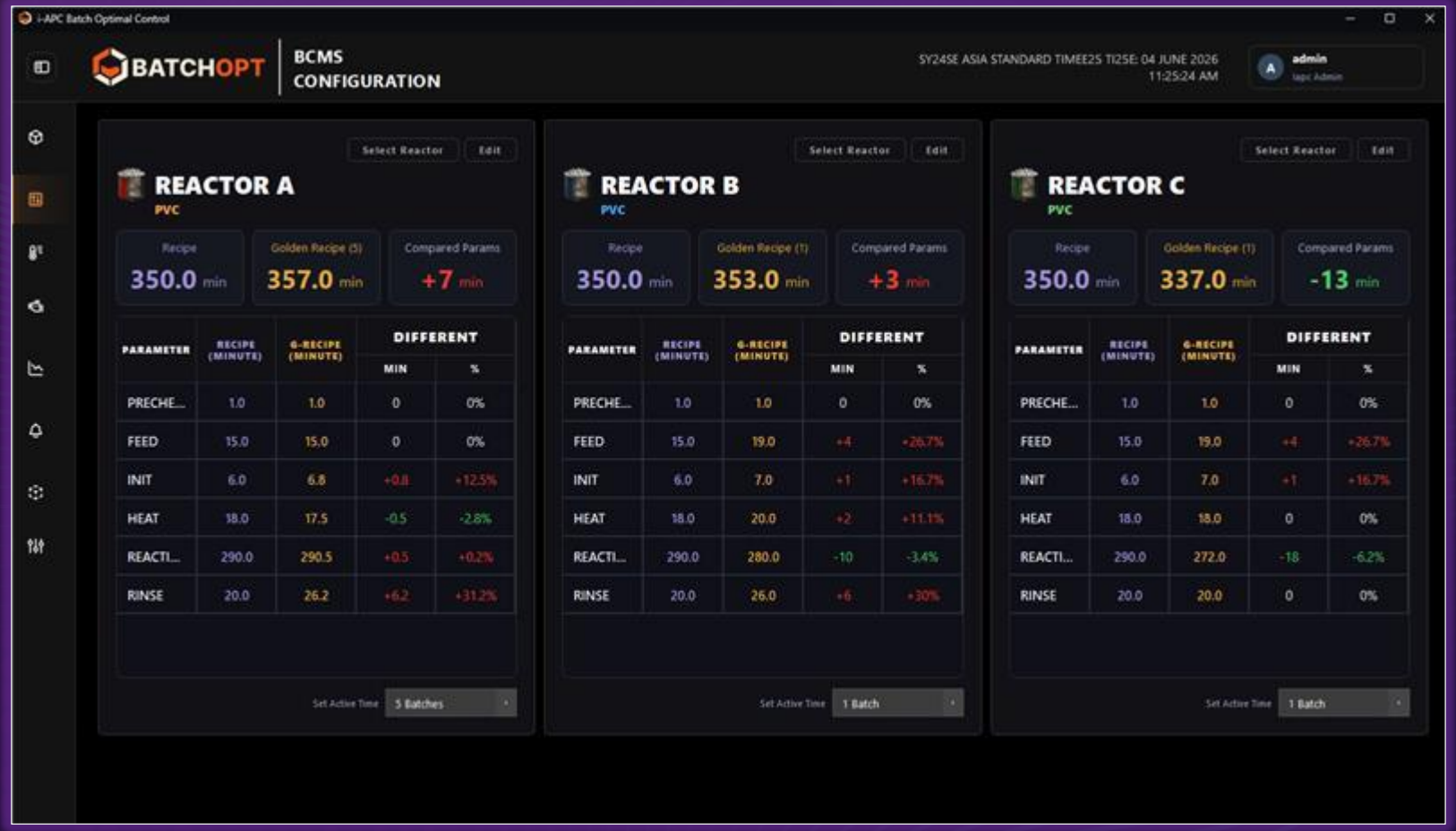
AI-Guided Recommendations

Provides actionable suggestions to help operators respond faster and maintain process stability

Example of AI-Enables Process Application

Smart Batch Analyzer

AI learns from historical operating plant data to return the most time-efficient recipe for the current month with actual best-performing batch in similar conditions.



Seasonal Pattern Recognition

Finds batches from the same season across years, not just the same calendar month

Percentile-based Golden Transition Selection

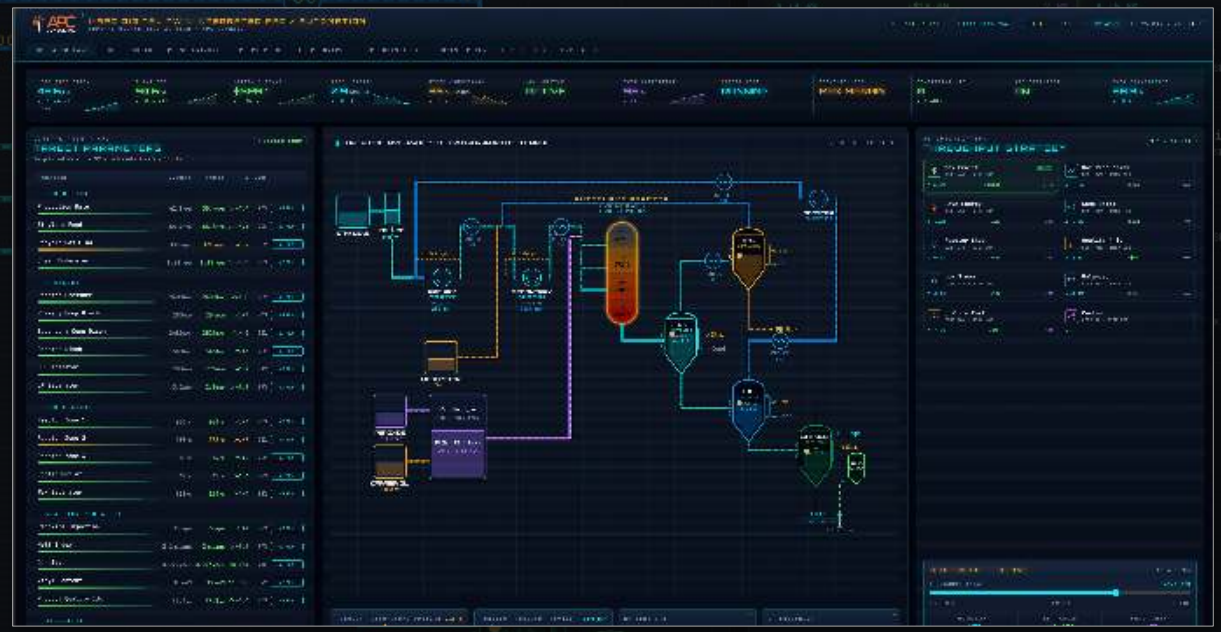
Matched batches by total duration consistently efficient, not a fluke outlier

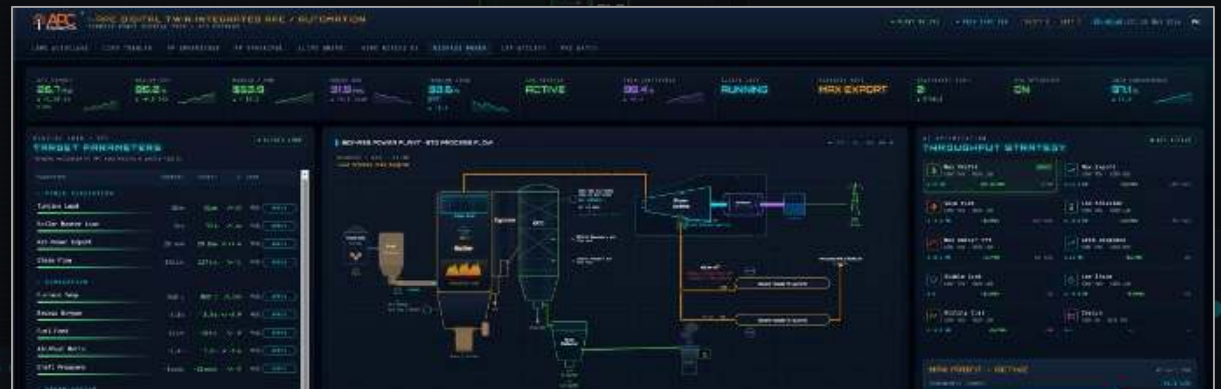
Zero Disruption to Live Operations

No automatic changes are applied to the running system

Pragmatic Use Cases

- PP Spheripol
- HDPE Mitsui / Nissan / Excene Slurry
- LDPE LyondellBasell Lupotech
- LDPE Autoclave ICI Exxon
- PP Spherizone
- LLDPE/HDPE Unipol Gasphase
- Biomass Utility / Power Plant
- EDC Production / VCM Production



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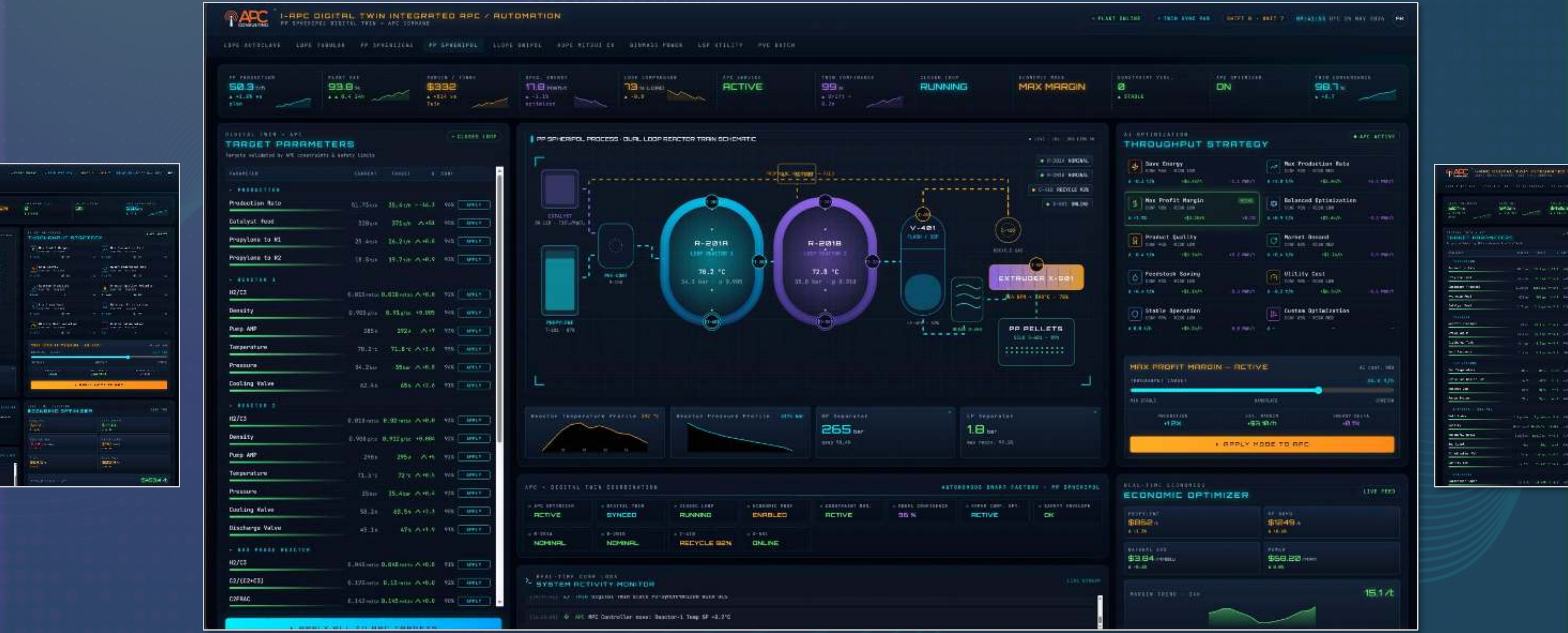
I-APC DIGITAL TWIN INTEGRATED APC / AUTOMATION
LDPE AUTOCLAVE
LDPE TUBULAR
PP SPHERIZONE
PP SPHERIPOL
LLDPE UNIPOL
HDPE HOSTALEN CX
BIOMASS POWER
LSP UTILITY
PVC HATCH
45.8 t/h
94.5 %
$330.8
0.9
83 % LDPE
ACTIVE
96 %
RUNNING
MAX MARGIN
0
ON
98.4 %
TARGET PARAMETERS
CLOSED LOOP
Production Rate
Ethylene Feed
Recycle Gas Flow
Chain Moderator
Reactor Pressure
Primary Comp Disch
Secondary Comp Disch
Booster Disch
HP Separator
LP Separator
Reactor Zone 1
Reactor Zone 2
Reactor Zone 3
Cooler Outlet
Wax Separator
Peroxide Injection
Melt Index
Density
Vinyl Content
Product Quality Idx
LDPE AUTOCLAVE - PROCESS FLOW DIAGRAM (P&ID SCHEMATIC)
AUTOCLAVE REACTOR
ETHYLENE
CHAIN
BOOSTER
PRIMARY
SECONDARY
MODERATOR
WAX
HP
LP
PE Wax
INITIATOR
PEROXIDE
CARRIER OIL
EXTRUDER
PELLETIZER
AI OPTIMIZATION
THROUGHPUT STRATEGY
APC ACTIVE
Max Profit
Max Production
Save Energy
Comp Ratio
Reactor Stab
Quality Prio
Low Steam
Balanced
Utility Cost
Custom
MAX PROFIT — ACTIVE
APPLY MODE TO APC
REAL-TIME SCENARIO
ECONOMIC OPTIMIZER
LIVE FEED
$1176
$1714
$13
$113
$21.3
$2507
$8411
$1819


APC
I-APC DIGITAL TWIN INTEGRATED APC / AUTOMATION
50.4
94.1
$325.8
0.7
18.4
ACTIVE
96
RUNNING
MAX MARGIN
0.56
ON
98.5
TARGET PARAMETERS
Production Rate
Ethylene Feed
Comonomer Feed
Hydrogen Feed
Catalyst Feed
Diluent Flow
Reactor Pressure
Loop Velocity
Slurry Density
Solids Concentration
Reactor Temp.
Reactor ΔT
Settling Leg Level
Flash Sep. Pressure
Recovery Comp. Load
Diluent Recovery
Monomer Recovery
Melt Index (MI)
Density
Hexene Ratio
HDPE MITSUI CX · SLURRY LOOP REACTOR SCHEMATIC
R-101
R-102
265
1.8
THROUGHPUT STRATEGY
Max Margin
Max Production
Save Energy
Reactor Stab
Quality Prio
Comp Optim
Diluent Recov
Utility Cost
MAX MARGIN — ACTIVE
APPLY MODE TO APC
ECONOMIC OPTIMIZER
$337.0 /t
SYSTEM ACTIVITY MONITOR

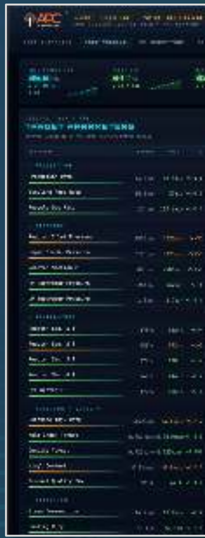

APC CONSULTING
I-APC DIGITAL TWIN INTEGRATED APC / AUTOMATION
LLDPE AUTOCLAVE
LDPE TUBULAR
PP SPHERIZONE
PP SPHERIPOL
LLDPE UNIPOL
HDPE MITSUI CX
BIOMASS POWER
LDP UTILITY
PVC BATCH
PLANT ONLINE
TWIN SYNC 96%
SHIFT B · UNIT 7
50.1 t/h
94.9 %
$426.6
0.6
12.3
ACTIVE
96 %
RUNNING
MAX PROFIT
0
ON
98.3 %
DIGITAL TWIN · APC
TARGET PARAMETERS
CLOSED LOOP
Targets calculated by APC constraints & safety limits
PARAMETER
CURRENT
TARGET
Δ CORR
PRODUCTION
Production Rate
Ethylene Feed
Comonomer (Hexene)
Hydrogen Feed
Catalyst Feed
PRESSURE
Reactor Pressure
Cycle Gas P
Discharge Tank
Vent Recovery
TEMPERATURE
Bed Temperature
Cycle Gas Cooler Out
Recycle Gas
Purge System
REACTION / QUALITY
Melt Index
Density
Hexene/C2 Ratio
Bed Level
Fluidization Vel
Quality Idx
UTILITIES
Compressor Power
LLDPE UNIPOL GAS-PHASE FLUIDIZED BED REACTOR SCHEMATIC
FLUIDIZED BED REACTOR R-301
FEED PURIFICATION
C2H4 PURIF
COMONOMER
H2 FEED
N2 PURIFY
FEED DRYING
CATALYST
DISENGAGEMENT
CYCLE GAS COMPRESSOR
COOLER
FINISHING
ADDITIVES
EXTRUDER
PELLETIZER
SILO
PRODUCT
RECOVERY & PURGING
RESIN PURGE
DEGASSING
VENT REC
RECYCLE GAS
MONOMERS
REACTOR DATA
GAS COMPOSITION
Reactor Temperature Profile
Reactor Pressure Profile
AI OPTIMIZATION
THROUGHPUT STRATEGY
APC ACTIVE
Max Profit
Max Production
Save Energy
Reactor Stab
Quality Prio
Low Comp Load
Balanced
Utility Cost
Low H2
Custom
MAX PROFIT — ACTIVE
THROUGHPUT TARGET
PRODUCTION
EST. MARGIN
ENERGY DELTA
APPLY MODE TO APC
REAL-TIME ECONOMICS
ECONOMIC OPTIMIZER
LIVE FEED
Ethylene
$1182/t
Hexene
$1842/t
Hydrogen
$3.8/kg
Liquid Nitrogen
$1654/t
Electricity
$111/MWh
Cooling Water
$0.42/m³
Comp Power
$1434/t
Catalyst
$184/kg



APC
I-APC DIGITAL TWIN INTEGRATED APC / AUTOMATION
ACTIVE
RUNNING
MAX MARGIN
ON
TARGET PARAMETERS
Production Rate
Catalyst feed
Propylene to R1
Propylene to R2
Density
Pump AMP
Temperature
Pressure
Cooling Valve
Discharge Valve
PP SPHERIPOL PROCESS - DUAL LOOP REACTOR TRAIN SCHEMATIC
R-201A
R-201B
V-401
EXTRUDER X-501
PP PELLETS
265
THROUGHPUT STRATEGY
Save Energy
Max Production Rate
Max Profit Margin
Balanced Optimization
Product Quality
Market Demand
Feedstock Saving
Utility Cost
Stable Operation
Custom Optimization
MAX PROFIT MARGIN - ACTIVE
APPLY MODE TO APC
ACTIVE
SYNCED
RUNNING
ENABLED
NOMINAL
RECYCLE 92%
ONLINE
SYSTEM ACTIVITY MONITOR
ECONOMIC OPTIMIZER
$852
$1249
$3.84
$58.20
15.1 /t


I-APC DIGITAL TWIN INTEGRATED APC / AUTOMATION
TARGET PARAMETERS
LDPE TUBULAR · HIGH-PRESSURE TUBULAR REACTOR
THROUGHPUT STRATEGY
MAX PROFIT MARGIN — ACTIVE
APPLY MODE TO APC
SYSTEM ACTIVITY MONITOR
ECONOMIC OPTIMIZER
$459.4 /t


I-APC DIGITAL TWIN INTEGRATED APC / AUTOMATION
TARGET PARAMETERS
Turbine Load
Boiler Master Load
Net Power Export
Steam Flow
Furnace Temp
Excess Oxygen
Fuel Feed
Air/Fuel Ratio
Draft Pressure
Main Steam P
Main Steam T
Reheat Temp
Condenser Vac
Stack O2
NOx
CO
Dust
Feedwater Flow
Cooling Water
ID Fan Speed
BIOMASS POWER PLANT · BTG PROCESS FLOW
Boiler
Cyclone
ECO
THROUGHPUT STRATEGY
Max Profit
Max Export
Save Fuel
Low Emission
Max Boiler Eff
Grid Response
Stable Comb
Low Steam
Utility Cost
Custom
MAX PROFIT – ACTIVE
APPLY MODE TO APC
ECONOMIC OPTIMIZER
SYSTEM ACTIVITY MONITOR
ACTIVE
RUNNING
MAX EXPORT
ON
SYNCED
ENABLED
92
-0.92



DIGITAL TWIN INTEGRATED APC/DCS/AUTOMATION

MODEL DEPLOYMENT APPROACH

Legacy First-Principal Approach

- Complex commercial ChemEng Simulation software — high cost
- Extensive molecular structure data required (MWD, Mn, Mw, PDI)
- Complicated kinetic parameter fitting methodology
- Prone to model-plant mismatch from unmeasured disturbances
- Difficult to deploy and maintain for online DT applications
- Better than data modeling approach only

Practical New Digital Twin Approach

- Simplified polymerization kinetics embedded in DT framework
- No molecular structure data needed — focus on production rate & consumption
- AI-assisted kinetic parameter fitting and autotuning feature
- Hybrid AI/ML corrects prediction - plant bias in real-time
- No dedicated software licensing — deployable across many processes

HDPE Slurry / Loop

Mitsui CX / Hostalen / INEOS Innovene S / CP Chem MarTech / Borstar

Gas-Phase PE

Unipol / Univation / INEOS Innovene G / Borstar

PP Slurry / Loop

Spheripol / Hypol / Innovene PP / Borstar

Gas-Phase PP

Unipol / Grace PP / Novolen / Spherizone / Borstar

LDPE Autoclave

Exxon / LYB / ICI

LDPE Tubular

LYB / Exxon / STM /

> 12+
Process Types

AI/ML
Hybrid Model

Model Auto
Tuning

INTEGRATED AI SOLUTION PLATFORM

Automated Recipe /Sequencer Workflow

Grade Transition / Utilities / Heating / Cooling / Equipment Mode Switching / Startup / Shutdown

- Equipped with AI Analytics for Performance Monitoring
- Model Deviation
- Uncertainties handling to adjust recipe
- sequence automation workflow
- Golden batch
- Transition analyzer

Digital Twin

OptAssist Dashboard

- 1st Principal Model
- Simplified Reaction Kinetics
- Mass-Energy Balance
- Hybrid with AI/ML Model correcting model vs prediction bias
- multi-unit optimization recommendation via AI/ML/LLM through real-time process specific dashboard

AI / ML Soft Sensor Batch OPT

Batch process/ temperature control/ batch time optimization/ feed or utility constraints

- Comparable Bias Adjustment
- Real-time quality estimation
- Process Condition Optimization Guidelines

APC / DCS / Automation

Reaction / Purification / Recovery / Downstream

- Linear and Non-linear Dynamic Model
- Step response model, State Space model, Non-linear model
- Economic & Energy Optimization

DIGITAL TWIN INTEGRATED APC/DCS/AUTOMATION

BENEFITS

Digital twin combines physics and AI for real-time corrections

Optimizes cross-unit constraints to improve efficiency

AI analytics monitors performance and corrects bias

Flexible, scalable AI deployment across all units

Closes gaps across multiple APC operations

Adjusts APC/DCS settings to optimize performance

Targets optimized using specified hist data, models, and feedback

Advanced APC expertise boosts productivity and energy efficiency

DEPLOYMENT CONSIDERATIONS

Data Readiness and Coverage

Many plants find that historical data contains gaps, inconsistent tags, or limited operating-range coverage. Modern AI Smart Process Control approaches can often start with available data and progressively improve model performance as additional operational knowledge and plant data are incorporated. Otherwise, data generation from trusted 1st principal model to be considered.

Operator Engagement and Adoption

Successful AI deployment depends on operator confidence and acceptance. Providing transparent recommendations, involving operations teams throughout development, and demonstrating measurable early benefits help accelerate adoption and sustainable performance improvements.

System Connectivity and Integration

Connecting AI models to legacy DCS systems — many of which are 10–20 years old and not designed for external software — requires careful engineering, testing, and often custom middleware.

Cybersecurity and Deployment Architecture

Depending on site requirements, AI solutions can be deployed fully on-premise, within private networks, or through hybrid architectures. Proper cybersecurity design ensures secure, reliable, and scalable operation while meeting plant IT and OT governance requirements.

LIFECYCLE MANAGEMENT

Deploying AI is only the beginning. Long-term value requires continuous model governance and performance management

MODEL MAINTENANCE AND RETRAINING

As processes change over months and years — new equipment, new grades, catalyst changes — models must be retrained on updated data to stay accurate and relevant. 1st Principle model with autotune help to minimize the model deviation overtime.

SUSTAINABLE LONG-TERM OPERATION

A governance plan — including scheduled reviews, retraining triggers, and assigned ownership — ensures the system stays effective for years, not just during the honeymoon period after launch.

PERFORMANCE MONITORING

Continuous tracking of model prediction error and controller performance flags degradation early — before quality or efficiency problems become visible on the plant floor

2017

COMPANY FOUNDED

i-APC Consulting Co., Ltd. officially established in Bangkok, Thailand together with Insight Advanced Process Control LLC in Houston, Texas

2018

APC & DIGITALIZATION EXPANSION

- Linear and Non-linear Advanced Process Control (APC)
- Process Control Optimization
- Industrial Analytics
- Digital Transformation Consulting

2021

INDUSTRY 4.0 & AI/ML DIRECTION

- AI/ML Soft Sensor
- Big Data Analytics
- Predictive Analytics
- Online Property Prediction
- Non-Petro Process Industries

2022

SOLUTION DEV GROWTH

- Batch Optimal Control
- Loop Performance MS (LPMS)
- Batch Constraint MS (BCMS)
- Process MPC for Downstream Unit
- New Plant Stabilization
- Rapid APC Deployment

2025

INTELLIGENT MANUFACTURING

- AI-Assisted Automated Sequencer
- Digital Twin-Supported APC/DCS
- Automated Sequencer / Transition
- Simplified Recipe Initialization
- New plant APC

2026

PRAMATIC AI

i-APC Consulting Co., Ltd. has officially registered middle east branch in **Oman** and secured projects in gulf countries.

INTEGRATED AI SOLUTION PLATFORM

CORE DEPLOYMENT PRINCIPLES

AI must be embedded, not isolated

Integrate AI directly into control systems and daily workflows to enable real-time insights, faster decisions, and continuous optimization

Leverage proven APC foundation

Build on existing APC infrastructure to ensure stable performance, scalability, and smoother AI adoption

Focus on measurable plant value

Prioritize use cases that deliver clear impact higher throughput, improved quality, reduced variability, and lower off-spec production

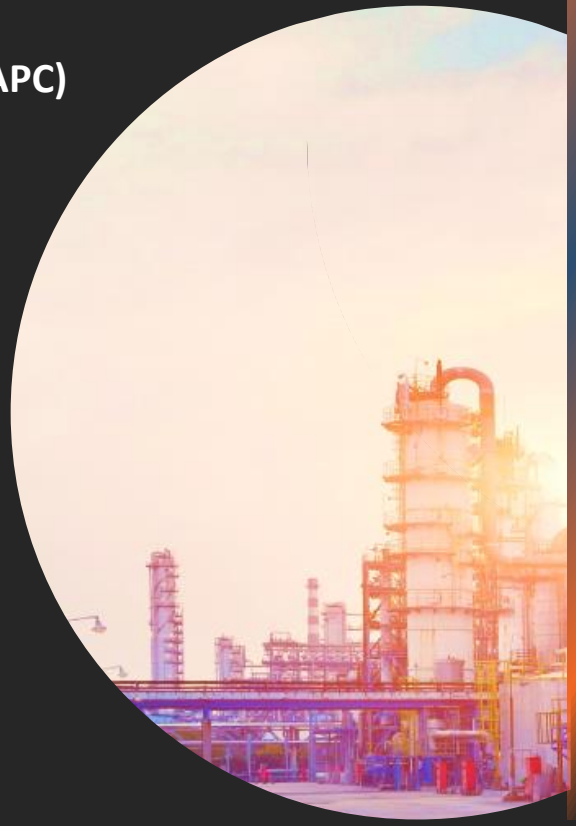
Secure AI, On Your Terms

Run AI within your own infrastructure to maintain cybersecurity, protect operational data, and ensure uninterrupted operation.

APC CONSULTING
3i - Intelligent - insight - Improvement

ENABLE A SUSTAINED
COMPETITIVE ADVANTAGE

Visit us at
Booth E6 (i-APC)



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i-APC

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i-APC is uniquely positioned with flexible supporting teams and experienced experts to deliver innovative solutions.