Building the Virtual Plant for DeltaV

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Introduction

- The Business Climate and need for a Virtual Plant
- Virtual Plant System Architecture
- Component Selection – DeltaV Simulate and MiMiC
- Virtual Plant Planning Concerns
- Process Model Development
- Operator Training Scenarios
- Instructor Stations / Graphics / Controls
- Additional Virtual Plant Features - Snapshots, Speedup / Slowdown, Playback
Business Climate - Operations Challenges

- Increased demand for skilled operators
- Retirement of experienced operators
- Increased government oversight
- Fiduciary liability of operations management
- Global competitive pressure
Demographic Time Bomb

- Average age of energy industry worker over 50
- Half of the current work force will retire (more than 500,000 workers) in 5 to 10 years
- Irreplaceable knowledge loss
- Newer generation of workers with less mechanical inclination

- Petrochemical / energy plants in danger of closing due to lack of qualified operators
- Delayed retirement plans will be accelerated as equity markets recover
The Automation Paradox

- Highly automated plants have less operational errors.
- Automation can handle simple and some complex operational tasks quicker, safer, and at a lower cost than a human operator.
- Automation and new process technology allows plants to operate longer without downtime.
- Operator role is different - more pressure to monitor the automated control system.
- Operators lose skills to deal with plant upsets or abnormal conditions.

![Bar Chart]

**Operator Error is the highest cause of loss**
(average dollar loss in millions of dollars)
Risks in Automation

- Hidden errors and issues in the automation system application software
- Operator actions that are inappropriate or insufficient
- Operating procedures that are incomplete or in error
- Documentation demands from OSHA National Emphasis Program

- Finding issues on site can delay startups
- Not finding issues until too late can endanger the process and operations staff
- Lack of diligence can result in fines or worse
Simulation – Wrong Approach

- Using process design models
  - Process design models do not have the real-time performance or range of operations conditions

- Using an emulated automation system
  - Operator HMI graphics, alarms, controls should be identical to real system
  - Control strategies should be identical

- Adding simulation to the control system configuration
  - Adds error and risk to automation system

- Starting too late
  - Last minute training systems provide less value
Simulation – Right Approach

- Virtual Control System – exact replica of the plant system
  - Training on identical HMI graphics, alarms, controls
  - Testing on identical control strategies

- Virtual Process – dynamic simulation
  - Selective application of simulation fidelity
  - Easy-to-use, easy-to-change

- Integrated approach for testing and training
  - Integrated to automation project schedule
  - Available as operations resource for control system life cycle
Effective Knowledge Transfer

- **Explicit** – what the operating procedure says
  - Virtual Plant / Control system used to test operating procedure and control system

- **Implicit** – how it really works
  - Virtual Plant / Control System used to allow new operators to use the operator controls

- **Tacit** – how the decision effects the whole plant
  - Virtual Plant / Control System Training Scenarios show the new operator how to work with the real plant / control system

**Effective Knowledge Transfer Must Include Hands On Operations of the Plant**

*Source: NTL Institute for Applied Behavioral Science*
Virtual Plant for Testing and Training

- Value to Process Plant Operations

Project Timeline
- Software Testing Begins
- Hazop Review
- Reduce Capex Costs
- Increase Opex Benefits
- Training Value
- Other Solutions

Value to Plant Operations

Phase:
- Software FAT
- Commissioning and Startup
- Controls Upgrade

Benefits:
- Testing Value
- Training Value
Simulation Delivers Results

- Time to Market - reduce startup time – $100-500K / day
- Product Quality - reduce off-spec product – $50K-$1MM / run
- Operating Cost - reduce unscheduled downtime – $5-50K / hour
- Reduce Risk – reduce unknown failures and incidents - $50K - $1MM / incident
  - Automation System Application Software
  - Operator Actions and Responses
  - Operating Procedures
**DeltaV Virtual Plant / Control System**

**MiMiC Simulation Software**

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**Engaging Minds. Amazing Results.**

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Software Acceptance Testing Systems
- Non-intrusive IO simulation (FF, Digital Bus IO, Serial IO)
- Validated systems (GAMP4 guidelines)
Architectures – Team Training

- Operator Training Systems – Team Environment
  - Module parameter simulation (simulate value)
Architectures – Individual Training

- Operator Training Systems – Individual Environment
  - Module parameter simulation (simulate value)

Simulation Network

DeltaV Simulate Standalone Workstations

MiMiC

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Architectures - DeltaV SIS

- DeltaV Simulate SIS OPC SIO Driver
  - Software Acceptance Testing and Operator Training
  - IO channel simulation

![Diagram showing DeltaV Simulate configurations](image-url)
Architectures – DeltaV and PLC/ESD

- SAT and OTS – Integrated System Environment
  - MiMiC SIO Driver specific for device

DeltaV Simulate Workstations

DeltaV – PLC/ESD Integration
  - Industrial Ethernet
  - OPC
  - MiMiC SIO Tags

MD Controllers w Virtual IO Module

Simulation Network

PLC /ESD Simulator

PLC /ESD

DeltaV Simulate Workstations

DeltaV – PLC/ESD Integration

MiMiC

Simulation Network

MiMiC

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Components – DeltaV Simulate

- **DeltaV Simulate** - DeltaV licensing scheme for “off-line” simulation systems
- Exact same graphics, alarms, faceplates, detail display as the operating plant
- Control modules run in Assigned Modules of workstation running same functions as controller
- Full DeltaV Batch and APC functionality supported

Simulate Convert – makes controller configuration Simulate workstation friendly
- FF Function Blocks converted to standard DeltaV blocks
- External IO references to Digital Bus, Serial IO modified to OPC read/write parameters
- DST references removed
Components – DeltaV Simulate

The DeltaV Simulate Experience
Components – DeltaV Simulate

- **DeltaV Simulate** - DeltaV licensing scheme for “off-line” simulation systems
- Standalone – no DeltaV Networking
- MultiNode – DeltaV networking, controllers
  - PPN, Professional Plus Networked
  - PSN, Professional Station Networked
  - OSN, Operator Station Networked
  - ASN, Application Station Networked
- SimulatePro option for Standalone or MultiNode
  - Increase module execution memory from 16 MB to 96 MB
  - Supports freeze/snapshot/restore, speedup/slowdown
- SIS SimulatePro – v10.3, allows 32 logic solvers per workstation
Components – MiMiC Simulation Software

- Built for SAT and OTS
  - Non-intrusive simulation interfaces
  - Integrated Operator Training Management
  - Protects control system integrity

- Easy to use
  - Designed for use by the end-user or integrator
  - Automatic integration with control system
  - Auto-generation of simulation database

- Flexible, Powerful, Dynamic
  - Scalable from small to large applications
  - Selective application of simulation models
  - Dynamic, accurate modeling functions

MiMiC is Built for DeltaV!
Components – MiMiC Simulation Software

- The MiMiC Experience
Components – MiMiC Simulation Software

- **MiMiC Simulation Software** – dynamic process and IO simulation for SAT and OTS
- Simulation Engine License – 1000 to 30,000 Simulated IO (SIO) Tags
- SIO Drivers for DeltaV Simulate, SIS, DeltaV IO Bus
- Operator Training Manager – structured training scenarios with integral session scoring and reporting, process snapshot, speedup/slowdown controls
- MiMiC Server – allows 10 Remote Terminal Services session to one MiMiC Simulation Engine (MS Server 2003 OS)
- Advanced Modeling Functions and Objects – dynamic, accurate, high-performance models
Planning the Virtual Plant

- **Simulation Systems for Software / System Testing**
  - How many users (test engineers or users)
  - Span of testing – process unit or train, unit operation
  - Level of testing – control modules, equipment modules, batch, advanced control, MES, EBR, ERP
  - IO systems, 3\textsuperscript{rd}-party devices (ESD, PLC)

- **Simulation Systems for Training - OTS**
  - How many operators, availability
  - Span of training – process unit or train, unit operation
  - Team or individual training
  - Model performance requirements – accuracy, dynamics, operating conditions, shutdowns/startups
  - Record keeping requirements
Choosing Model Complexity

- **Modeling Techniques**
  - **First Principles** Modeling – based upon laws of conservation of mass, energy using properties
  - **Empirical** Modeling - realistic limits to the model using actual or assumed process correlations or data

- **Types of Process Models**
  - **Steady State** models - plant and process design. No transitions between process states, time delays or lags
  - **Dynamic** models – SAT and OTS. Time delays, lags, transport effects are modeled.

- Model design and math required for Steady State and Dynamic are much different

- SAT and OTS – we assume the process is designed, models reflect the design dynamically!
Choosing Model Complexity

- **Fidelity** – Rigorousness or Complexity of the Model
  - **Low Fidelity** – simple IO signal modeling, device tiebacks, value initialization. Model requires user intervention to respond to automation system actions.
  - **Medium Fidelity** – mass balance model, heat balance model, streams are single component. Model runs automatically and responds to automation system actions and process changes.
  - **High Fidelity** – complete mass balance, rigorous heat balance, reaction kinetics, streams model individual component thermodynamic properties. Model runs automatically and responds to automation system actions and process changes in a very similar manner to the designed process.

- ANSI/ISA - 77.20 - 1993 (R2005) Section 6, 7
Choosing Model Complexity

- Select Model Complexity for the **Task**
  - Control Modules – Tieback Simulation, Automated Test Scripts
  - Equipment Modules – Tieback Simulation, Limited Dynamics
  - Sequence, Batch – Mass Balance, Temperature & Pressure Dynamics
  - MES, Advanced Control Applications – Mass Balance, Heat Balance
- Select Model Complexity for the **Process**
  - Tank farm, material movements – lower complexity
  - Distillation, complex reactions, integrated, continuous processes – higher complexity
- **Balance Dynamic performance with steady-state accuracy**
Protecting Control System Integrity

- Minimize or eliminate additions, deletions to the off-line simulation system
- Simulate all modules and IO signals
- Use MiMiC OTM to drive scenario linkages, session scoring
- Use MiMiC for 3rd-party device integration and emulation
- Avoid Emulated Simulation Solutions!
- Avoid simulation in DeltaV modules!
Protecting Control System Integrity

- **High Integrity Off-line Systems**
  - Exact representation of:
    - Operator graphics, faceplates, detail display, help screens
    - Alarm strategies, priorities, timing, and operator acknowledgement and action response
    - Control strategies including control module, equipment module, sequence and batch, and advanced control loops response

- Support use and emulation of –
  - Physical system management tools - DeltaV Explorer and diagnostics, 3rd party configuration tools
  - Digital bus IO based systems - Foundation Fieldbus
Process Model Development

- MiMiC DeltaV Database Generator
  - SIO definition for DeltaV Railbus (VIM), DeltaV Simulate, DeltaV SIS SimulatePro
  - Base level IO, Analog, Discrete Tieback Models
  - MiMiC Modeling Node for each DeltaV device (controller, workstation)
Process Model Development

- Simulated IO Definition
  - DeltaV Railbus (VIM) – SIO Tag to physical IO address
  - DeltaV Simulate – OPC module parameter path
  - DeltaV SIS Simulate – OPC physical IO address

![MIMIC Explorer - Session ID 0 - SIM-DB_32](image-url)

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Process Model Development

- Models grouped by Simulation Nodes
  - Easy startup with user selected SIO definition
Process Model Development

- Mass Balance, Heat Balance Medium Fidelity
  - Auto-generated Simulation Database
  - IEC Modeling Blocks with Wires

Engineering Unit Conversions from Block to Block are calculated by MiMiC Simulation Engine
Process Model Development

- Dynamic, Accurate Simulations “High Fidelity”
- Advanced IEC Objects and Functions with Streams
- Thermo / Flash / Stream Property Functions
- Advanced Modeling Core Objects
  - Vessel, Valve, Pump, PRV, HX, DHX, Stream T
  - PF Solver
- Energy Management Objects
  - Boiler with Furnace, Steam Header, Desuperheater, Fuel, Turbine
- Distillation Objects
  - Column, Reboiler, Stripper
- Separator Objects
  - 2-phase, 3-phase Separator, Physical Absorber

Complex Dynamic Modeling

Process Model Development
**Operator Training Scenarios**

- **Training Scenarios**
  - Structured set of malfunctions or process events introduced into running dynamic simulation
  - Process models should be designed to support Scenarios
  - Scenarios can be easily added or changed without altering process models

- **MiMiC Operator Training Manager Scenarios**
  - Malfunctions can be set in MiMiC or DeltaV Simulate
  - MiMiC Simulation functions have malfunction actions built-in
  - Scoring conditions can be defined for each malfunction
  - "Ad Hoc" Instructor driven scenarios with reporting
  - Training sessions use a Scenario definition
  - Training Session report results in HTML, PDF, or RTF

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**ENGAGING MINDS. AMAZING RESULTS.**

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Instructor Stations / Graphics / Controls

- DeltaV
  - Familiar user interface
  - DeltaV-centric approach
  - Greater engineering effort

- MiMiC Component Studio
  - New user interface to learn
  - Simulator-centric approach
  - Lower engineering effort
Snapshots, Speedup/Slowdown

- **Process Snapshots**
  - Requires DeltaV SimulatePro, MiMiC OTM
  - Integrated Snapshot control of DeltaV modules, MiMiC simulation
  - Does not support Batch Executive Operations

- **Speedup / Slowdown**
  - Requires DeltaV SimulatePro, MiMiC OTM

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Operator Entry Playback

- DeltaV SimulatePro feature
  - No external controls so must use SimulatePro interface to control
  - Restore Integrated Snapshot in MiMiC Explorer
  - Event Journal entries can be changed or skipped

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**Operator Entry Playback**

- Control Network
  - GX110CR7

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**Real-Time Execution Multiplier**

- 0 / 30 / 20 / 10 / 10 / 20 / 30
- Stop

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**Playback Operator Changes**

- Playback From: 11/2/2006 3:20:54 PM

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Getting the Return on Investment

- Plan Simulation for SAT and OTS into the Automation Project Cycle up front
- Begin Testing and Training Early
- Test, test, test…Train, train, train…
  - Database, graphics, interlocks …
  - Batch, advanced control, reports, MES
  - Device failure, shutdown scenarios
  - Anything that you can’t test or train on the live system
- Use simulator for documentation and test records
- Keep the simulation system current with the on-line process automation system
- Simulators are Plant Operations Assets!
Summary

- Proven CapEx, Opex Benefits to using Simulation for SAT and OTS
- Time to Market - reduce startup time – $100-500K / day
- Product Quality - reduce off-spec product – $50K-$1MM / run
- Operating Cost - reduce unscheduled downtime – $5-50K / hour
- Reduce Risk – reduce unknown failures and incidents - $50K - $1MM / incident

Questions?
Where To Get More Information

- MYNAH Website – www.mynah.com
  - DeltaV Operator Training Systems with MiMiC
  - DeltaV Software Acceptance Testing with MiMiC
  - Pre-recorded E-Seminars
  - Understanding Simulation Fidelity Paper and Podcast
  - Simulation System Integrity Paper and Podcast
  - Delivering the Virtual Plant Paper and Podcast
  - Simulation Objections Answered Paper and Podcast
  - Using Simulation to Optimize the Results of Automation Projects, Dr. Tom Fiske, ARC
  - MYNAH YouTube Series

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