ANOMALIES DETECTION WITH UNISIM DESIGN

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AGENDA

- Who we are
- Simulation: Historic perspective and the Digital Twin
- Process Plants break, physical laws don’t
- Inprocess Bad Actors application
- Conclusions
WHO WE ARE
Accompany our clients in their success in achieving safer, greener, more reliable and more profitable industrial operations.
Our services

**KNOWLEDGE TRANSFER**
- Process Simulation Training; Technology Courses; KIP - Knowledge Improvement Program; Operator Training
- 300+ training courses conducted

**ENGINEERING SIMULATION PROJECTS**
- Steady State Simulations: What-If studies; KPIs; APC gains and inferentials; Optimization; Refinery Reactor Modelling
- Dynamic Process Modelling: Compressors; Flare Systems; HIPPS; APC; Flow Assurance
- 130+ simulation studies

**OPERATOR TRAINING SYSTEMS**
- Commercial Simulation Software: HYSYS, UniSim, PetroSIM, VMGSim
- DCS independent.
- 50+ OTS commissioned
- Proprietary Instructor Station & communication layer

**PROPRIETARY APPLICATIONS**
- ITOP: generic OTS for unit operations
- IIS – Inprocess Instructor Station
- IPSV; H2 Network Tool; PSA Simulator; Iflow; Bad Actors
SIMULATION: HISTORIC PERSPECTIVE AND THE DIGITAL TWIN
This science has been there long time ago, but we are the first generation of people who has in our hands software tools and desktop computers capable to simulate dynamically entire plants. Most of their applications are still in the early stages. Our human brain is now the limiting factor
What is a Digital Twin?
It is the digital version of your running asset. It contains:

- all the process layout and streams conditions (Compositions, Pressure, Temperature, Flow, etc);
- all the equipment geometric data (dimensions, elevation, tray sizing, sensor location, etc);
- all equipment manufacturer performance data (pump curves, compressor curves, heat exchanger rating data, etc);
- all actuated valves (valve pressure drop, sizing, characteristic, etc);
- and all instrumentation (control loops, PID tuning, instrument ranges, selectors, etc).

All this information is consolidated in a UniSim Dynamic Process Model.
THE AUTOMATION PYRAMID WITH THE DIGITAL TWIN

The Process Plant

- Valves & Instruments
- Inferentials & Virtual Sensors
- Basic Controls
- ARC
- RTO, f(x), tables
- Advanced apps

The Operator

- Train operator on Start-up, Shutdown, Emergency & trip scenarios.
- Knowledge repository of plant incidents & best operation practices
- Equipment anomaly detection. Monitoring and look-ahead apps.
- SS model for RTO. Obtain simple optimization f(x) or lookup tables
- Develop & Test ARC. Deep Gain analysis and seed models for APC.
- Improve basic control layout (this is the most important layer!)
- Checkout new DCS code. Checkout automatic sequences.
- Develop rigorous inferentials. Train AI data driven models.
- Discover faulty instruments. Automatic fault detection application.
- Better understanding of plant behaviour (SteadyState & Dynamics)
- Reproduce and study any plant operation issue
- Develop and tune Operating Procedures. HAZOP assistant.
- Discover faulty instruments. Automatic fault detection application.
PROCESS PLANTS BREAK, PHYSICAL LAWS DON´T
GETTING INSPIRATION

Who did say this?

“Just a moment…Just a moment
I've just picked up a fault in the AE-35 unit.
It's going to go a hundred percent failure within 72 hours”

In that movie, HAL has the capability to predict failures of equipment based in their working variables and how the unit should *ideally* work.

Question is: Can we do the same for Process plants?

PD: Afterall, the AE-35 was not faulty, just the Hal’s mad plan to kill the crew!
WHAT I HAVE SEEN IN CONTROL ROOMS

• Process plants provide thousands of process values every second, most of them are shown in the ICSS Operator displays and can trigger one or more alarms.

• Most of these alarms are a consequence of an anomaly in the process plant (warning: H/L Level, Temp, etc) and can evolve later to trip an equipment or entire unit (HH/LL Level, Temp, etc).

• When plant production is affected by process issues (either trips of units or reduced throughput), every operator and engineer start to build their own theory, sometimes obvious, sometimes not so obvious.

• Engineers start to trend historical process data and talk with operators to try to diagnose what has happened in the plant, understand the causes and think how to avoid it next time. Frequently the root cause is not found and the trip is repeated after few days.

Can simulation models help here?
WHAT ALARMS WOULD PRODUCE HAL?

With the help of simulation, could we generate more advanced alarms like these?

- “HeatExchanger HX-001 is violating the energy balance”

- “Flow valve FCV-001 is operating outside characteristic, most likely fail in flowmeter”

- “Compressor C-001 has a lower efficiency than usual”

- “Colum T-001 will enter to flooding in 15 min”

- “Product quality will go off-spec in 30 min and the phone will ring”

**Inprocess Bad Actor** is conceived to provide early warning of plant anomalies which could evolve to a trip and provide additional information to the Operator/Engineer to diagnose it.
# REAL PLANT VS. IDEAL PLANT (UNISIM)

<table>
<thead>
<tr>
<th>Equipment failure</th>
<th>Real Plant</th>
<th>Digital Twin (Unisim model)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump impeller eroded</td>
<td><img src="image1.png" alt="Image" /></td>
<td>According to their manufacturer test curves</td>
</tr>
<tr>
<td>Valve seat leakage</td>
<td><img src="image2.png" alt="Image" /></td>
<td>According to their manufacturer characteristic</td>
</tr>
<tr>
<td>Heat Exchanger tube leak Or tube rupture or fouling</td>
<td><img src="image3.png" alt="Image" /></td>
<td>According to their manufacturer datasheet</td>
</tr>
<tr>
<td>Instrument failure</td>
<td><img src="image4.png" alt="Image" /></td>
<td>Exact measurement</td>
</tr>
<tr>
<td>Analyzer failure</td>
<td><img src="image5.png" alt="Image" /></td>
<td>Exact measurement</td>
</tr>
</tbody>
</table>

Could a clever application exploit these differences to determine the fault?

That is Inprocess Bad Actor
INPROCESS BAD ACTOR FOR ANOMALIES DETECTION
Inprocess Bad Actors: functional blocks

Communication layer

Data validation

Data management and models execution

Detailed Equipment rating models

Steady-State models

Dynamic models

Anomaly Detector Engine

Equipment and process rules

Realtime Database (ICSS OPC server or historian)

INPUT

OUTPUT

Graphical User Interface

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The application is designed to identify two types of anomalies:

**Equipment anomalies:**
- Flow transmitters & Control valves (FLOW-VALVE)
- Vessels
- Pumps
- Heat Exchangers
- Online analyzers
- Compressors
- Distillation columns

**Process anomalies:** When the individual equipment composing the process doesn´t identify an anomaly but the overall process unit or subprocess behaves differently from their model. It requires to customize the rules based on the specific process.
In general, flow transmitters are the least reliable instruments in a plant. Most of them are orifice plates and the causes of the anomalies can be multiple. Coriolis, vortex, etc, can also provide wrong measurements when not working at design conditions (two phases presence).

Regardless of the type of flowmeter, the application is focused in finding anomalies in the operating point of control valves with or without installed flowmeter.

For every control valve the application uses the installed valve characteristic to monitor the actual operating point.

For valves with no flowmeter, the characteristic is inferred from historical data run over the dynamic model.

For every valve, the application allows to adjust certain parameters (tolerances, outside time, filter time, etc) to eliminate the false positives.

Once anomaly is detected, then it is analysed by the app.
When a FLOW-VALVE anomaly appears, there could be two reasons: flowmeter problem or valve problem.

To discern that, the application is always running two digital twins in the background, one governed with Flow SP (DTSP) and one governed with valve OP (DTOP).

The one which is following better the plant when appears a FLOW-VALVE anomaly will determine the guilty.

If DTOP follows better the plant: it is a flowmeter problem.

If DTSP follows better the plant: it is a valve issue (bypass open, broken seat, etc)

The picture shows an real issue with the flowmeter of the steam. 
The DTOP fits better with the plant data (Pressure & Level)
The application verifies that the mass balance is respected taken into account the level variation, pressure variation and the geometry of the vessel including level taps. This early detection can identify issues before Low or High level alarms and prevent pumps or unit trips.

Every vessels will define a subset dynamic model and will run three digital twins of that model:

- **DTIL**: Governed by Input flows and Level
- **DTOL**: Governed by Output flows and Level
- **DTIO**: Governed by Input and Output Flow

### Vessels anomalies

- **Level transmitter anomaly**: When real level transmitter is not following the DTIO.
- **Vessel leakage**: When DTIO and DTOL are not following the plant data.
- **Valve bypass open**: When the outlet flows determine by DTIL trigger a VALVE-FLOW anomaly.
The application verifies that the manufacturer performance curves are respected in terms of hydraulic and efficiency performance. Depending on the available instrumentation (pressure, flows, temps) the kind of anomalies that can be detected will vary. If amperemeter is available the electric motor can be also included in the scope.

Every pump will define a subset dynamic model and will run two digital twins of that model:

- **DTC**: Governed by pump curves
- **DTPT**: Governed by pressure and temperatures

**Hydraulic performance**: When the DTC is not delivering the pump outlet pressure. This can be caused by pump cavitating.

**Efficiency performance**: When DTC is not following the outlet temperatures. DTPT will provide actual performance.

**NPSH alert**: When the DTC or DTPT approaches NPSH limits.
The application verifies that the heat and material balances are respected taken into account the pressure variation and the geometry of the exchanger or aircooler.

Every exchanger is modelled individually with a rating modelling tool (Unisim Heat Exchangers) using the design geometry, process plant data from instrumentation and process data from the Digital Twin model of the unit as needed.

The detection of anomalies is very dependent of the instrumentation available around the exchanger.

**Sudden change in performance**: when there is a sudden change in the calculated heat transfer coefficient. This could reveal a tube rupture, stream clogging, etc.

**Fouling factor alarms**: Fouling factors are calculated based in current performance and the system can be configured to advise when it is needed to do a cleaning.
Inprocess Bad Actors: Setting Unisim models

- Allows for multiple Steady-State or Dynamic Unisim cases
- Windows services to manage Unisim models
- OPC Data source or custom interface
Something is going wrong

This equipment has a problem
How is the fouling factor calculated?

- An objective function is defined
- The function takes into account some key parameters as: In/Out tubes temperature, In/Out shell temperature, Flows
- Unsim Optimizer uses the fouling factor as the degree of freedom.

Challenges & Solutions:

- Exchanger energy balance:
  - The balance didn’t match, the tubes required more energy than given by shell.
  - Solution: Flow meter on shell side was bad calibrated. The asset recalibrated the sensor

- Fouling Calculation has too much noise:
  - The plant data is noisy so It’s necessary to do some treatment
  - Solution: Data reconciliation using UniSim to recheck all plant values
Customer case: Heat Exchangers
• The value of the Inprocess Bad Actors application is **increasing the plant uptime and avoiding equipment damages** by early identification of anomalies not currently detected by ICSS alarms.

• Inprocess is currently testing some modules of the application with customers who already own dynamic process models of their plants, from previous DSS and/or OTS.

• The goal is to install 3-4 applications in different businesses (Oil&Gas, Refining, Chemical) and to collect all the key requirements and anomaly casuistic.

• There are other areas of value of online Digital Twin that could be further explored to configure other application modules (look-ahead, what-if, incident tracking)