Life Cycle Simulation using Bayesian Calculation

by Ferdinand Heru Utomo
Project Description

Initiatiate the Life Cycle simulation using the Bayesian Calculation

- Building Bayesian network model for a chemical process
- Modeling a database for the process
- Implement the simulation application
- Building a user interface for the application
- Add knowledge-rules for the decision advices
Area of Application

Hybrid Distillation and Vapor Permeation Process

• Separation Process
• At a laboratory scale
• Pilot at Laboratory of Process Equipment, Delft University of Technology
Distillation Process

- Column
- Condenser
- Reboiler
- Container, water-rich
- Container, IPA-rich
Vapor Permeation
What is Life Cycle?

- Engineering
- Commissioning
- Production

Maintenance

Revamp?
- +Q
- +flexibility
- downtime
- -$ (+$)

Cause?
- +Q
- +flexibility
- downtime
- -$ (+$)

Production

Production
The Process Life Cycle

1. Process Design (using ASPEN)
2. Process Monitoring (using Honeywell, ERP, etc)
3. Costs, Maintenance and Effectiveness (using SAP)
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Modeling Uncertainty

- Fuzzy Logic
- Statistical Probabilities (Bayesian Technique)
Why not Fuzzy Logic?

- Misunderstood the term ‘uncertain reasoning’
- No further facts examination
- Not wholly consistent
Bayesian Technique

in contrast…….

• Represents Conditional independence information naturally
• Represents joint probability distribution
• Use a well-known statistical formula, based on the formula:

\[ P(E|H) = \frac{P(H,E)}{P(H)} \]
The Bayes’ Rule

\[ P(E \mid H) = \frac{P(H \mid E) \cdot P(H)}{P(E)} \]

Finding the probability of the evidence based on the facts on the hypothesis when the conditional probabilities between the hypothesis and evidence is known.
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Simulation Application

- simula database
- Bayesian model
- rules
- data handling
- Bayes network
- rule-based advice
- USER
Data Handling

ASPIEN
SAP
TestPoint

translator

simula
database
### Coversion Example

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- Column.Top.Temp = 111

Data from ASPEN
Simula Database

- Integration
- Standardization
- Uniformity
- Selected technique: Object-Oriented model
Database Model
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SmileX

- ActiveX component implementing Bayesian network
- Work with application GeNIe
- Basic Bayesian network operations
Enhancing SmileX(1)

- Restructuring the network into object classes
- Adding a conversion function
Enhancing SmileX(2)

Adding a conversion function

Temp = 100°C → conversion → Temp is OK

Reference:

if (Temp > 95) and (Temp < 105) then *Temp is OK*
if (Temp > 105) then *Temp is High*
if (Temp < 95) then *Temp is Low*
Applying
The Bayesian Network Model

Design steps:

• Understanding the process principles
• Finding the variables
• Constructing the network
• Validate the model
• Fine tuning
Distillation Process

Reboiler:
• degrades → bottom temperature lower
• lower temperature → less vapor
• less vapor → lower vapor flowrate

Condenser:
• degrades → more vapor exiting the process
• more vapor → less reflux
• less reflux → less/more purity
Vapor Permeation

Membrane Unit:

• Low permeate pressure $\rightarrow$ high quality
• Low distillate flowrate $\rightarrow$ high quality
Bayesian Network Variables

Inputs:
- Bottom Temperature
- Bottom Water Concentration
- Distillate Flowrate
- Retentate Concentration
- Permeate Pressure

Outputs:
- Reboiler Degradation
- Condenser Degradation
- Membrane Degradation
- Performance
Bayesian Network Model for the Process
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Simulation User Interface (1)

Main window
Simulation User Interface (2)

Data tabs

![Data sheet interface with temperature and pressure values]
Simulation User Interface (3)

Analysis Results
Simulation User Interface (4)

Action window

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Degrad. (%)</th>
<th>Maintenance ($)</th>
<th>Replacement ($)</th>
<th>Action</th>
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<td>120</td>
<td>750</td>
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<td>HE02</td>
<td>1</td>
<td>50</td>
<td>200</td>
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</table>
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Simulation Testing

Assumptions:
• All in good condition
• Stable state
• Quality as reported
• No process control
Test Results

Equipment Degradation

Data Set

Prob(OK)

0830mem.dat  1130mem.dat  1210mem.dat  1445mem.dat  1530mem.dat  1545mem.dat  1630mem.dat  1700mem.dat  1830mem.dat

Reboiler
Membrane Unit
Condenser
Reboiler Degrades?

- Against the assumption
- Analysing the data file:
  - very large record file
  - may includes start-up and shut-down data
Conclusions

• It was possible to apply Bayesian techniques to the Life Cycle simulation
• The tested model lacks of accuracy because of limited measurement
• Although measurements are few, preliminary result seems to be meaningfull
Further Research

• How to increase the accuracy for larger processes
• Supporting the Bayesian network with statistical correlation analysis (instead of expert review)
• Simulation based on online process data
• More compatible with commercial software packages