industrial systems and control

Get More from your Process using Modelling and Simulation

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Industrial Systems and Control Ltd.

ISC Background

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- Founded in 1987
- Control Engineering Consultancy
  - Marine, Metals, Process and Automotive Industries
  - Specific Problem Solving
  - What-If ? Analysis

  Through Dynamic Modelling and Simulation
- Applied Control Technology Consortium
  - Established 1990
  - Technology Transfer and Training

Presentation

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- What is Modelling and Simulation ?
- Examples:
  - Offshore Oil Platform Export Pump
  - pH Control in a Paper Mill
  - Water Pumping Station Modelling
  - Distillation Column Re-tuning

Dynamic Modelling

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What is a dynamic model?

"A parameterised set of algebraic and differential equations that together define the static and dynamic behaviour of a system"

Dynamic Modelling

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Why?

- de-risk the plant design process
- safe exploration of the plant operating envelope
- investigate the causes of problems
- evaluate control designs and process changes

Static v. Dynamic Modelling

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Static Modelling:

- Used in plant design
  - Component selection (to achieve plant spec^{n})
  - Energy balance calculations

Dynamic Modelling:

- Used to design/evaluate plant for dynamic behaviour
  - Induced by set point changes
  - Induced by disturbances
  - Start-up/shutdown

Physical Dynamic Modelling

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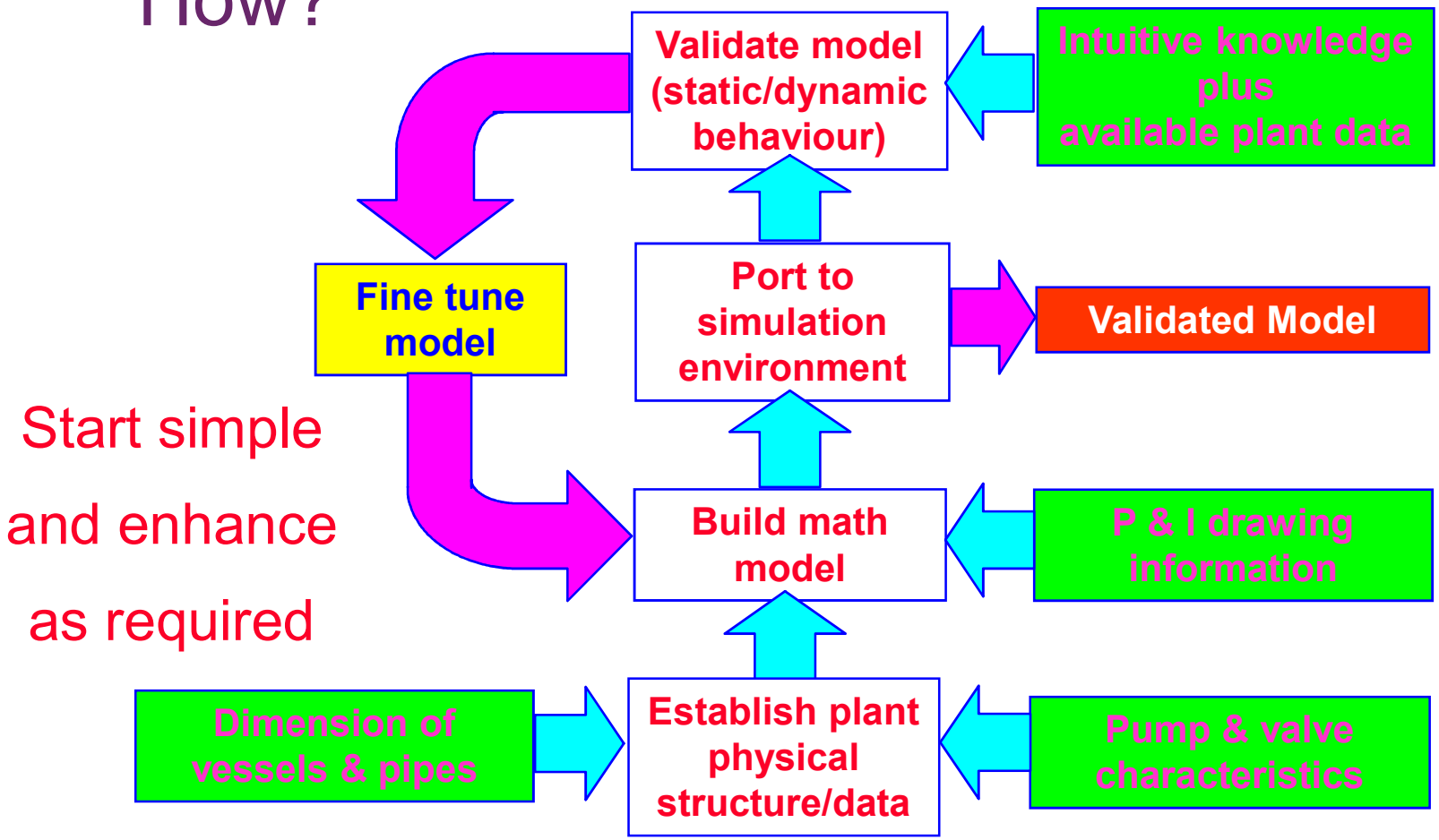
How?



Modelling – The Main Challenges

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- Define the objectives and level of detail
- Defining the model boundaries and assumptions
- Obtaining:
  - Plant component characteristics
  - Relationships between variables
  - Measured plant data
- Validation:
  - Matching the behaviour of the model to that of the plant

Linear Process Example

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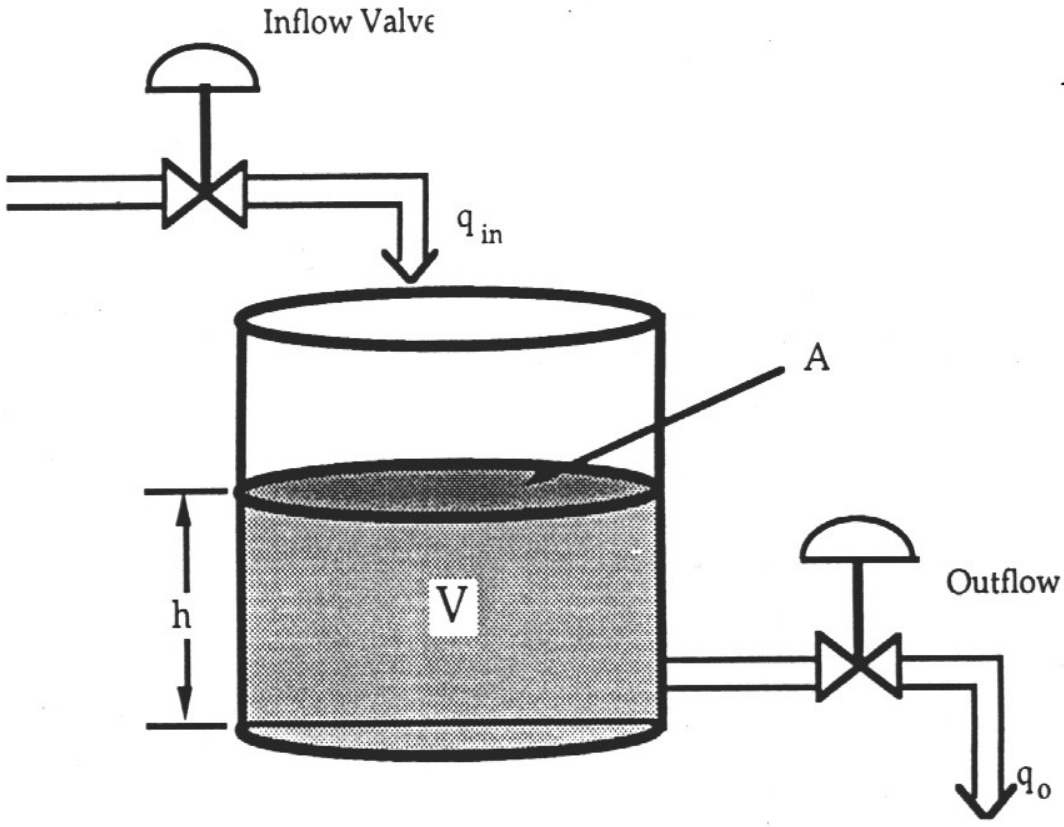
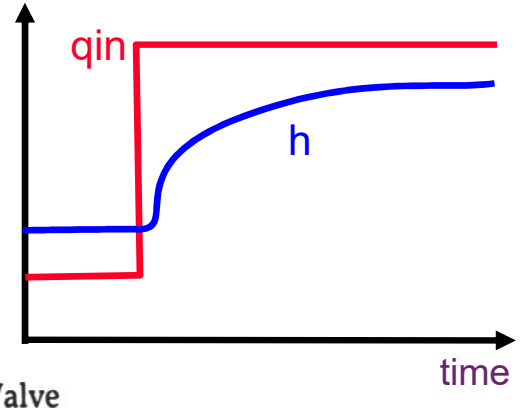
A Simple Tank:



Simple analysis gives relationship:

$$\frac{h}{q_{in}} = \frac{R_f}{AR_f s + 1}$$



Nonlinear Process Example

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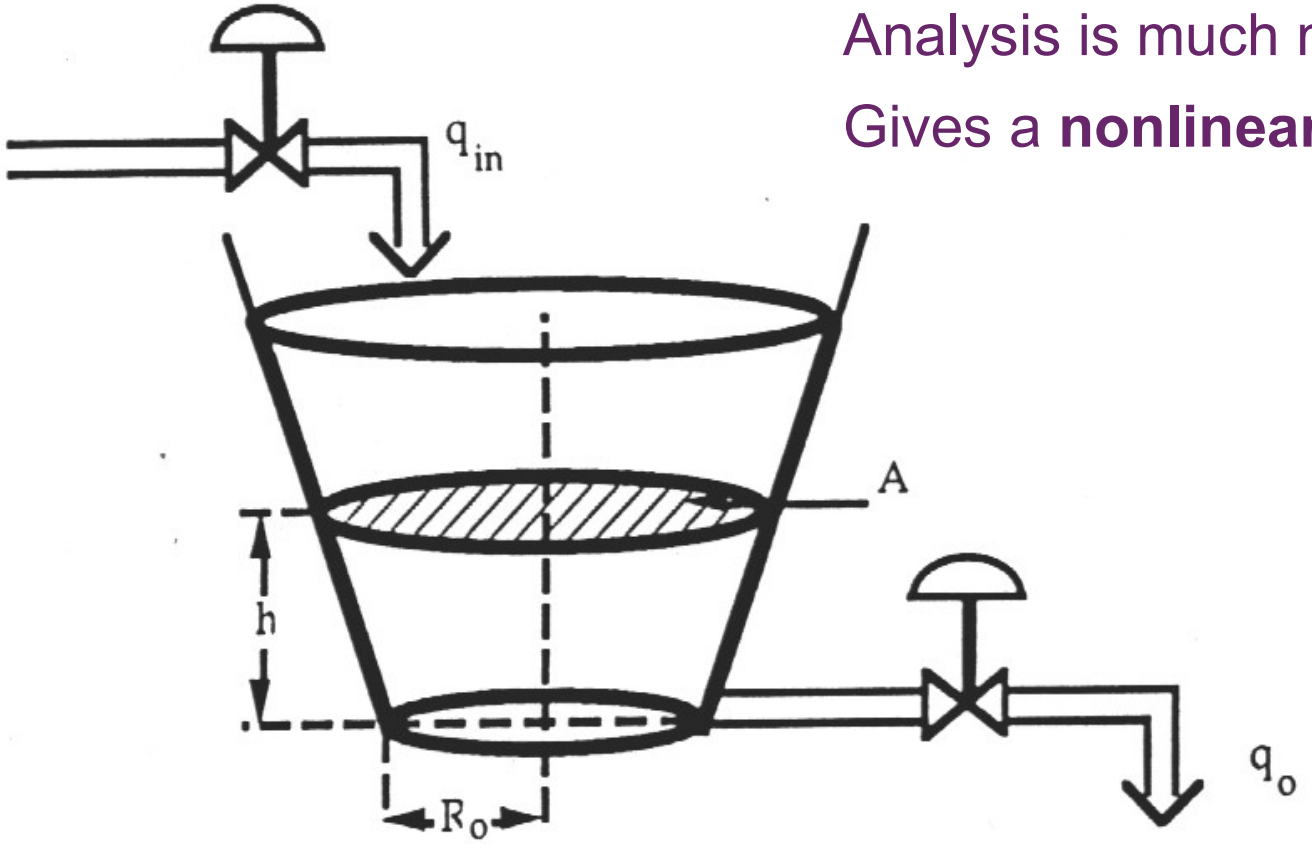
A Non-Simple Tank:



Analysis is much more complex

Gives a **nonlinear** relationship

Simulation

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What is Simulation?

“Simulation is the numerical solution of a mathematical system model by a computer”

Dynamic Simulation Tools

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- Provide
  - Integration algorithms (to solve nonlinear differential equations)
  - Static behaviour representation
- Simplify model building process:
  - Hide much of maths
  - GUI Function block programming interface
  - Hierarchical structure
  - Libraries of common components
  - System/control analysis tools

Dynamic Simulation Tools

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- Matlab/Simulink
- HYSYS Dynamics
- LabVIEW
- ACSL
- VisSim
- Easy5

Dynamic Simulation Tool Comparison

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Modelling Tool / Modelling Tool Features	VisSim	LabView	MATLAB	MATRIX$_x$	Easy5	HYSYS Dynamic	ACSL
Block Structure Programming	√	√	√	√	√	√	√
Hierarchical Structure	√	√	√	√	√	√/×	√
Industrial Component Libraries	×		√	√	√	√	×
Continuous & Discrete Events	√	√	√	√	√	√	√
Basic Level Programming	√	√/×	√	√	√	√/×	√
Precision Validation Capability	√	√/×	√	√	√	√	√
Model Compiler	√	√	√	√	√	?	√
System/Control Analysis	√	√	√	√	√	×	√
Hydrocarbon phase tables	×	×	×	×	√	√	×
Widely Applied	√	√	√	√?	×	√	×
Price Indicator	Low	Low	Med.	N/A	High	High	High

Example 1: Offshore Oil Platform

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Problem

- MOL export pump speed oscillations
- High maintenance - costs and time
- … which Impact on oil production
- Repeated attempts to tune controllers – none really solved problem

Consultancy Approach

- Represent process behaviour using Hysys Dynamics
- Use to understand problem
- Evaluate (change) solution options

Hysys Dynamic model environment

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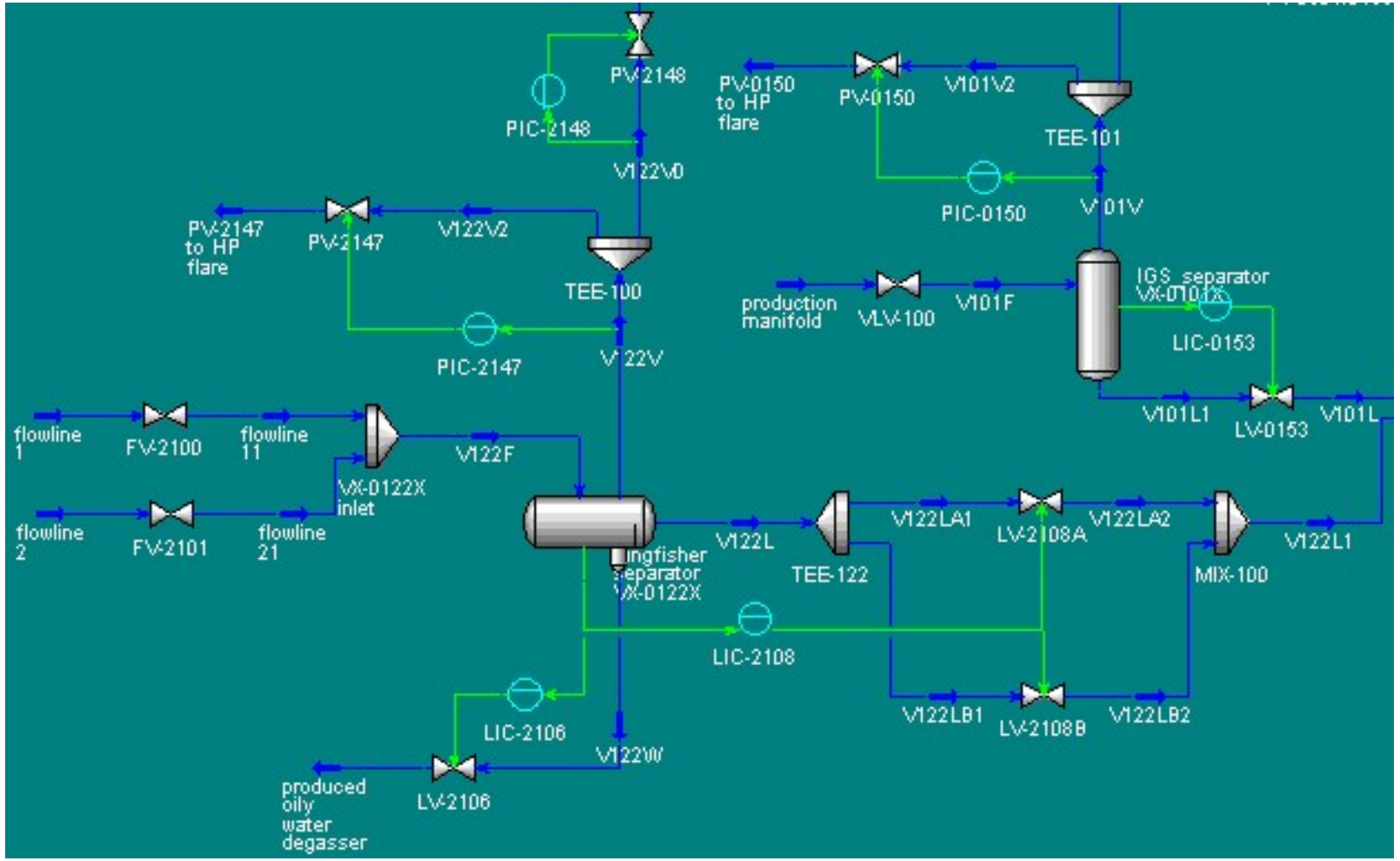

Front–end of oil/gas/water separation process

Identifying the Source of the Problem

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- Level controllers on surge vessels
  - two controllers had been “altered” to error-squared
  - DCS constraints gave pure integral action → **instability !!**
  - inappropriate controller gains
- Solution:
  - Re-tune and reconfigure controllers
  - Possible improvements through DCS upgrade

Simulated Results

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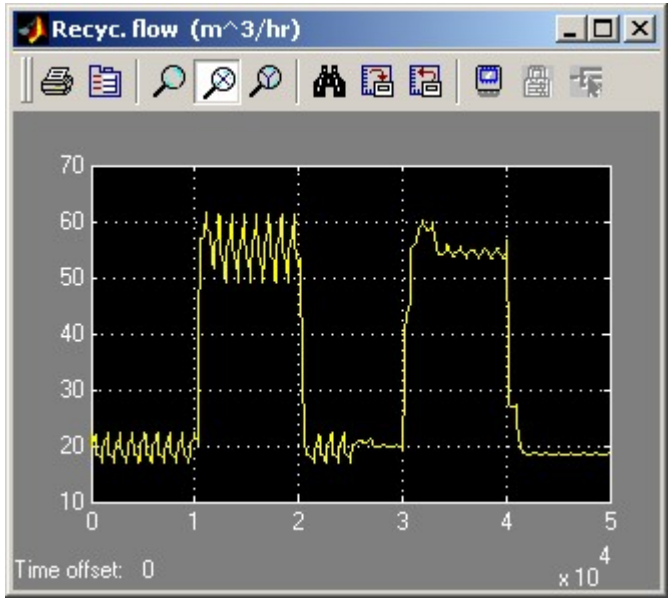
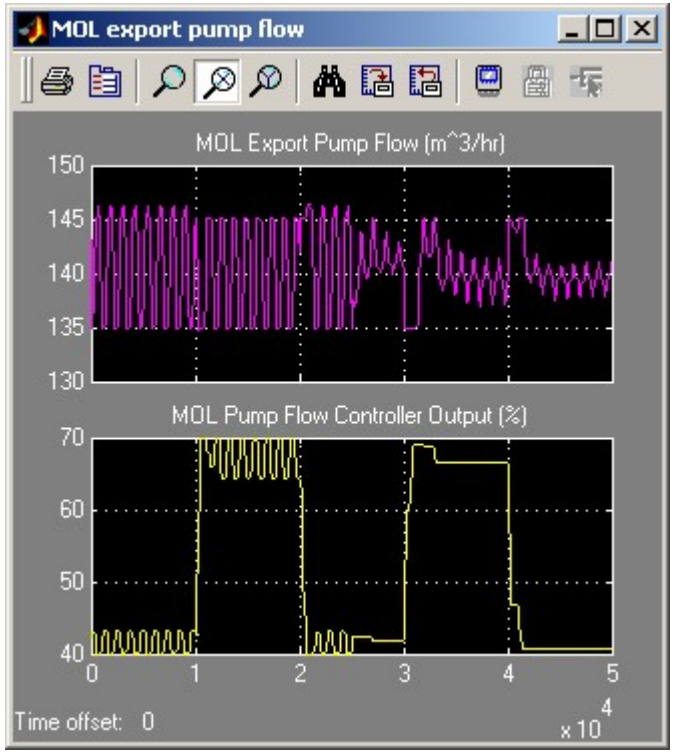
MOL Pump Dynamic Flow Behaviour



- MOL pump recycle flow
  - First 7 hrs. - current control
  - Last 7 hrs. – re-designed control



- MOL pump flow control
  - First 7 hrs. - current control
  - Last 7 hrs. – re-designed control

Simulated Results

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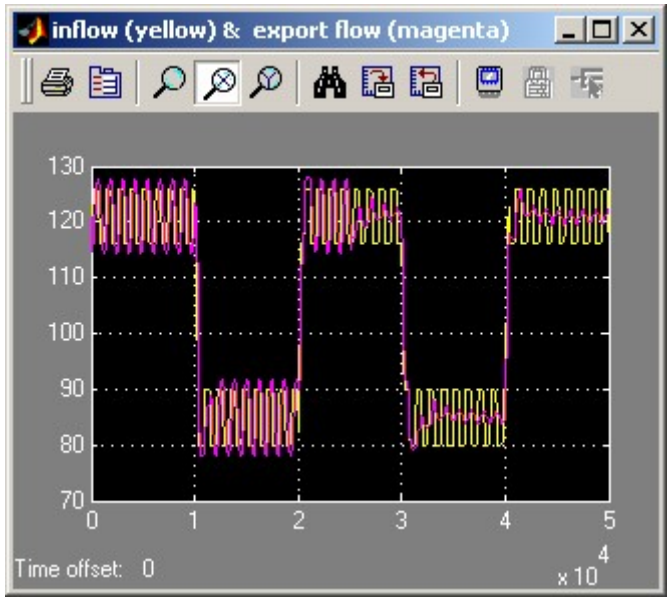
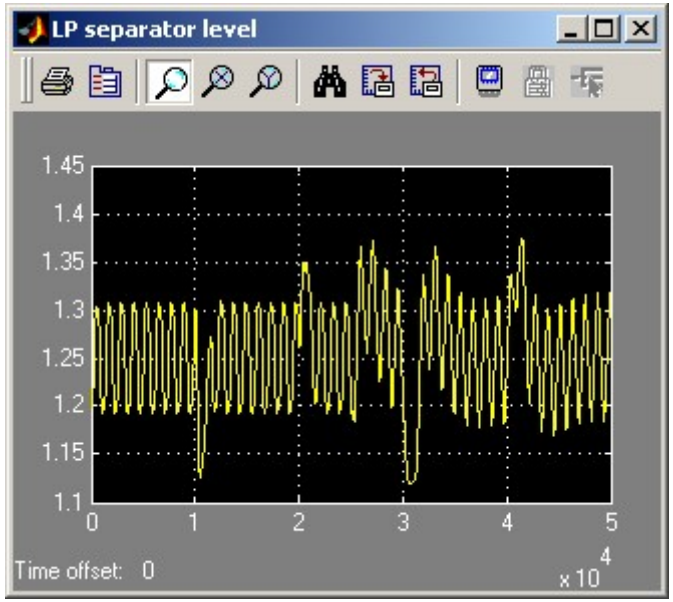
LP Vessel Dynamic Behaviour





- LP separator inflow & outflow
  - First 7 hrs. - current control
  - Last 7 hrs. – re-designed control

- LP separator level
  - First 7 hrs. - current control
  - Last 7 hrs. – re-designed control

Currently being implemented offshore

Example 2: pH control in a Paper Mill

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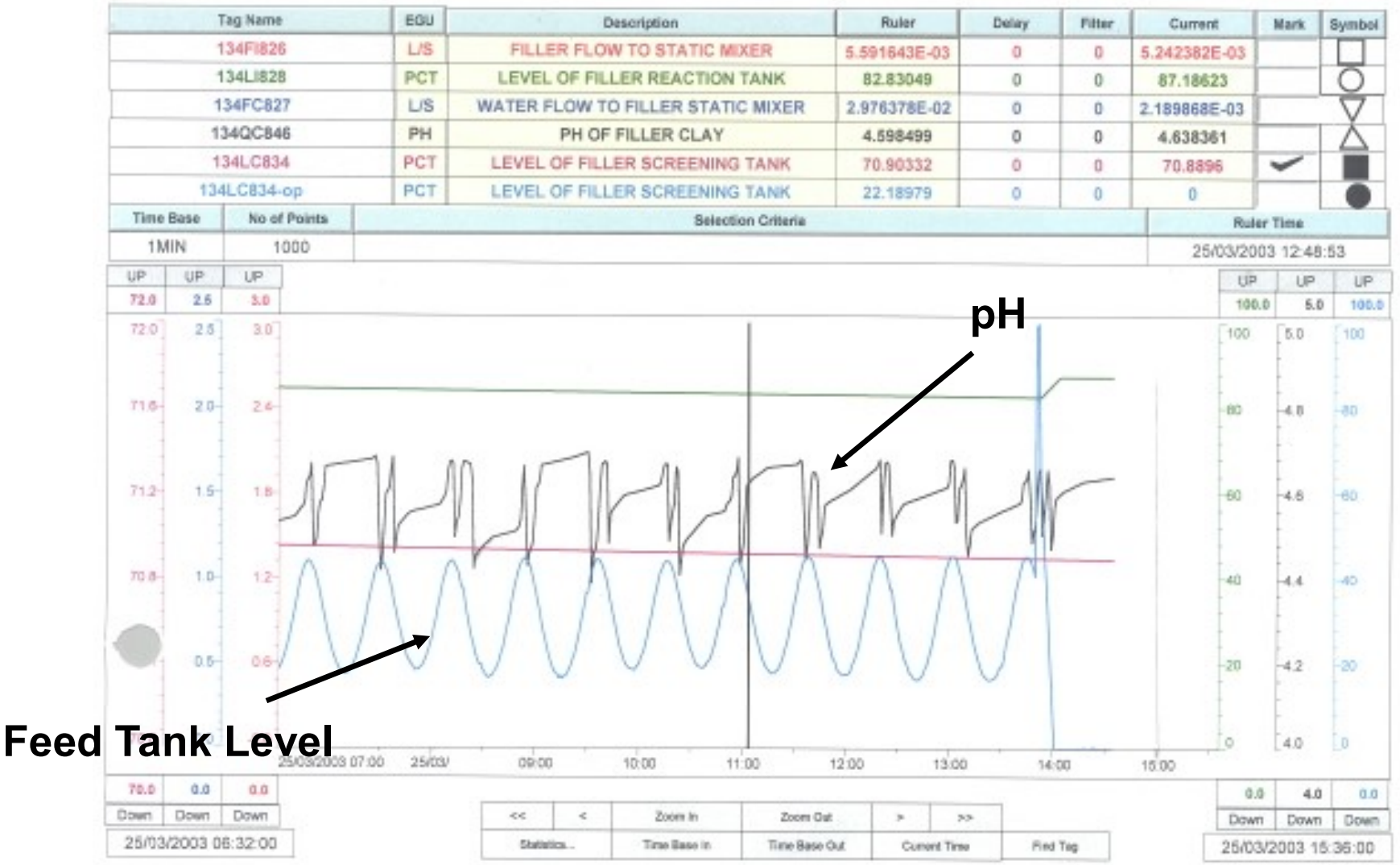

Tag Name	EGU	Description	Ruler	Delay	Filter	Current	Mark	Symbol
134FI826	L/S	FILLER FLOW TO STATIC MIXER	5.591643E-03	0	0	5.242382E-03		
134LI828	PCT	LEVEL OF FILLER REACTION TANK	82.83049	0	0	87.18623		
134FC827	L/S	WATER FLOW TO FILLER STATIC MIXER	2.976378E-02	0	0	2.189868E-03		
134QC846	PH	PH OF FILLER CLAY	4.598499	0	0	4.638361		
134LC834	PCT	LEVEL OF FILLER SCREENING TANK	70.90332	0	0	70.8896	✓	
134LC834-op	PCT	LEVEL OF FILLER SCREENING TANK	22.18979	0	0	0		

Time Base	No of Points	Selection Criteria	Ruler Time
1MIN	1000		25/03/2003 12:48:53

pH Control Evaluation

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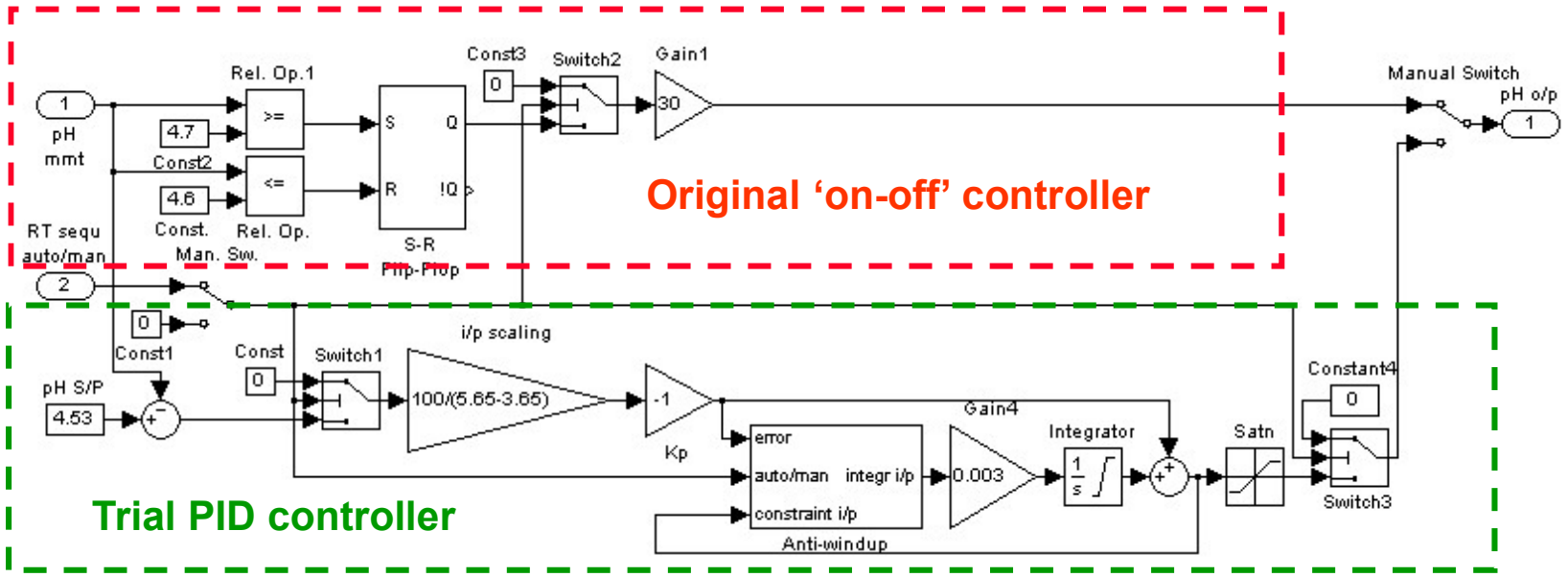

Modelled Controller Features

- Ideal PID Controller Structure
- Anti-windup
- Logic to inhibit controller during RT empty cycle
- Logic to switch between PID & 'bang-bang' controllers

Validation of Model pH Dynamic Data

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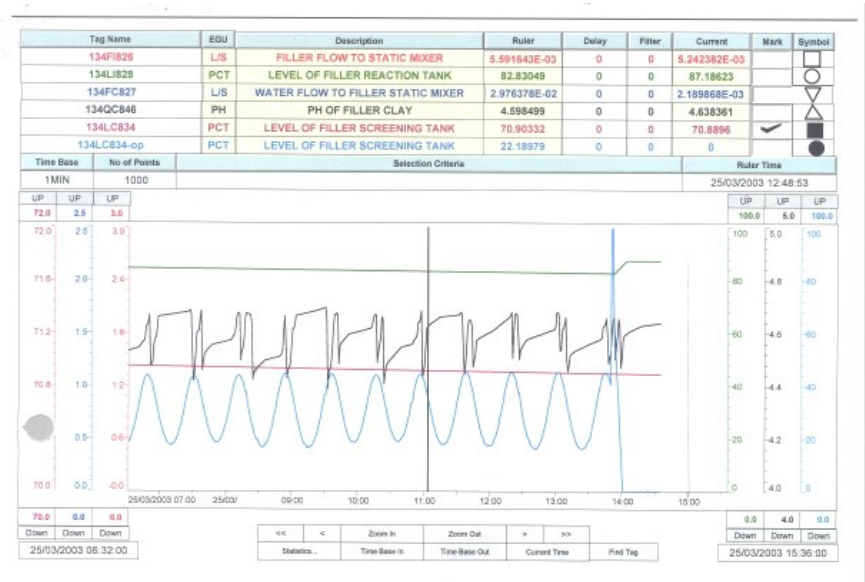
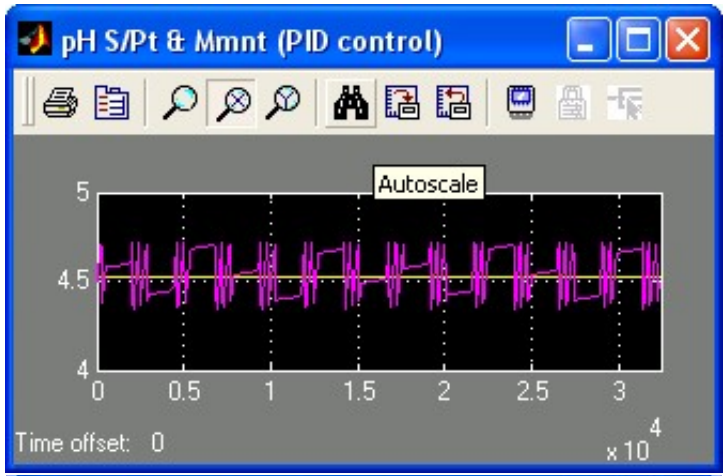
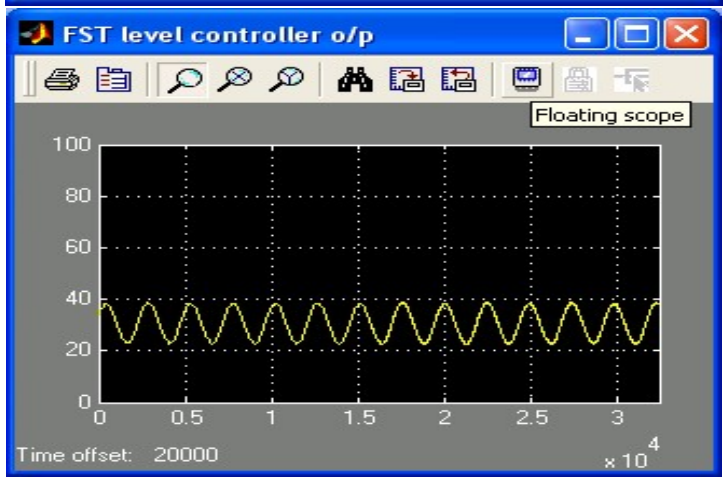
Plant data over a 9 hour period



Model data over a 9 hour period





pH Control Comparison

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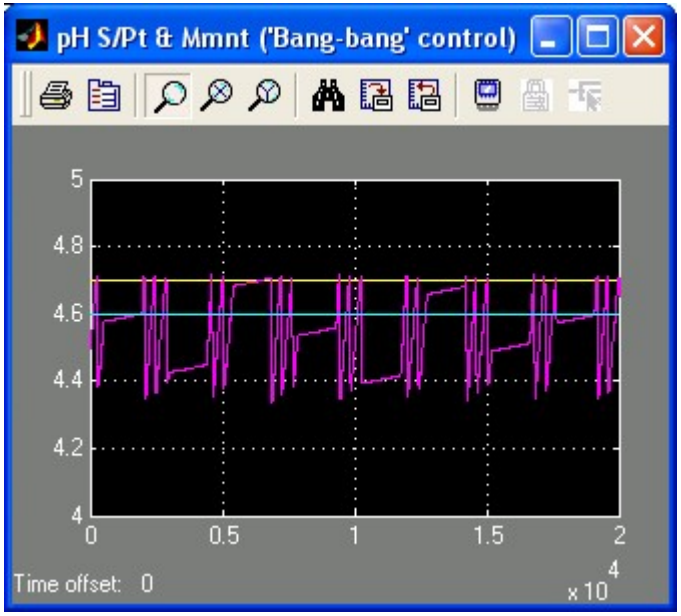

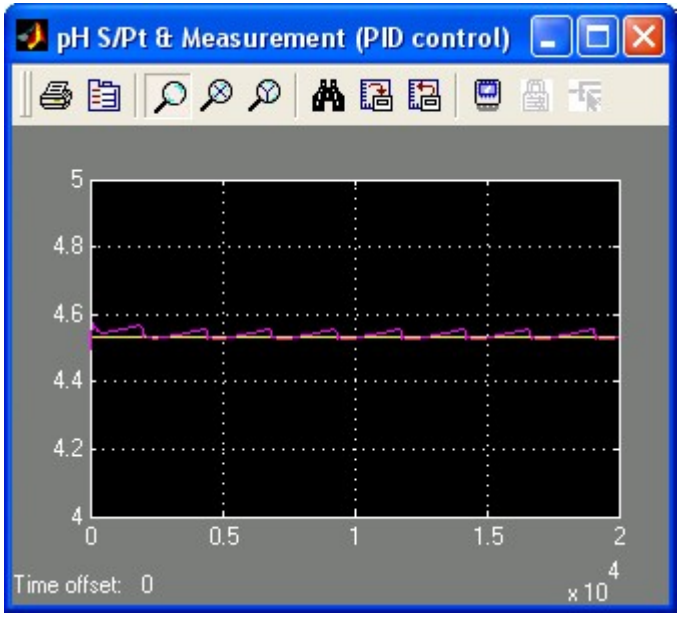

Current 'On-Off' Control

pH 'Trigger' points at
- 4.7 (H_2SO_4 on)
- 4.6 (H_2SO_4 off)

Peak to peak pH amplitude
0.38 pH units

Reduced by >90% →

PID Control Alternative

pH set point at
- 4.53

Peak to peak pH amplitude
0.03 pH units

pH response following recommendations 28/09/04

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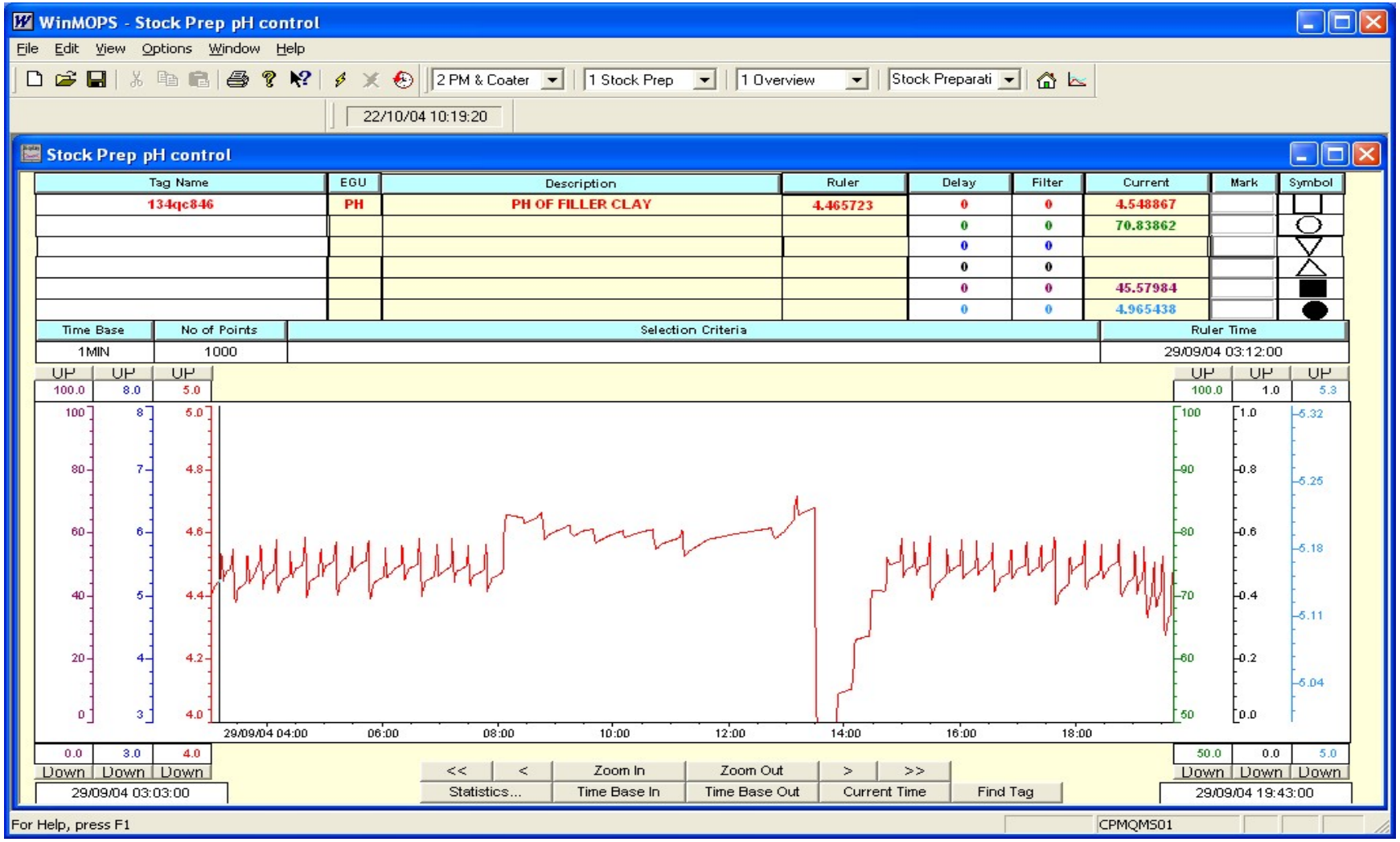

Example 3: Water Pumping Station

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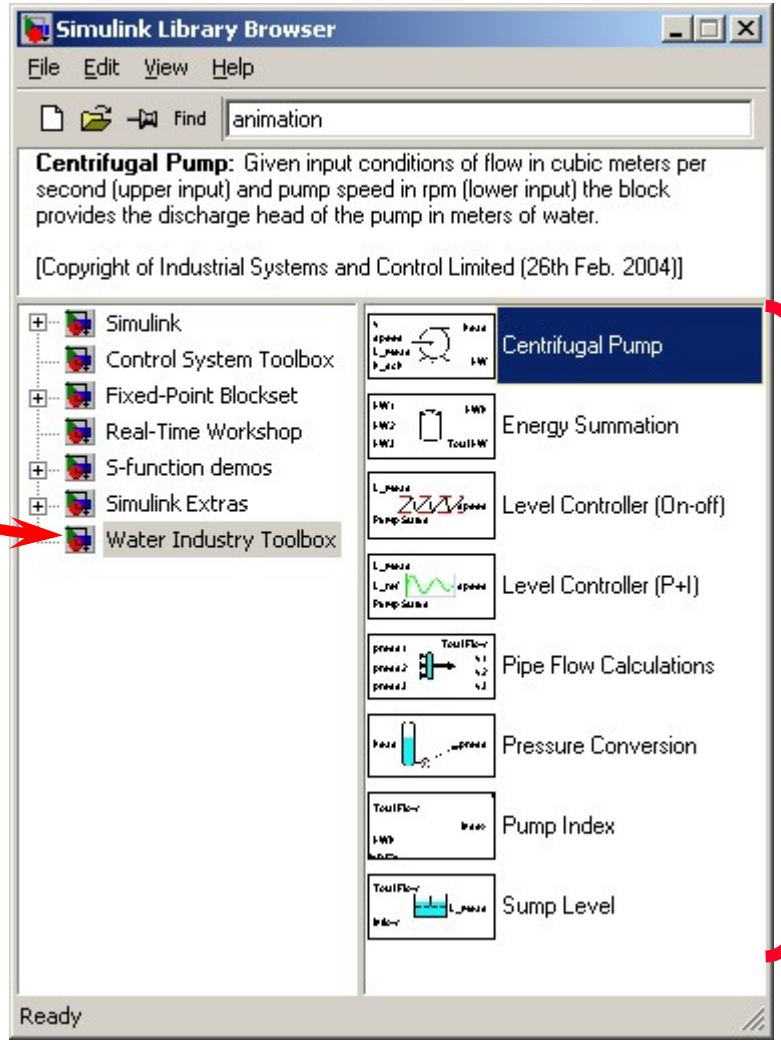
Simulink Browser

"Water Industry Toolbox" icon added to Simulink Library Browser



"Water Industry Toolbox" Blocks

Building a Pumping Station Model

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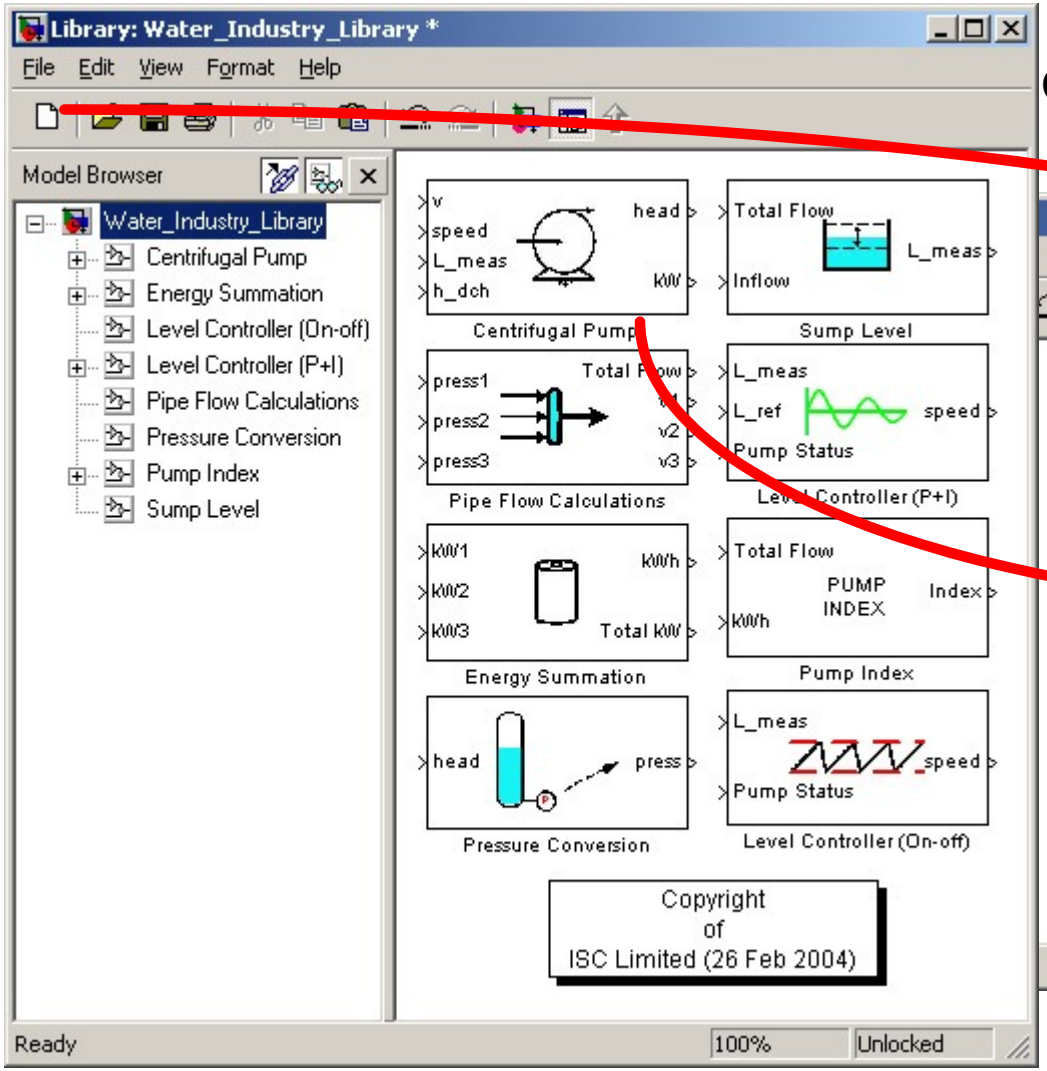
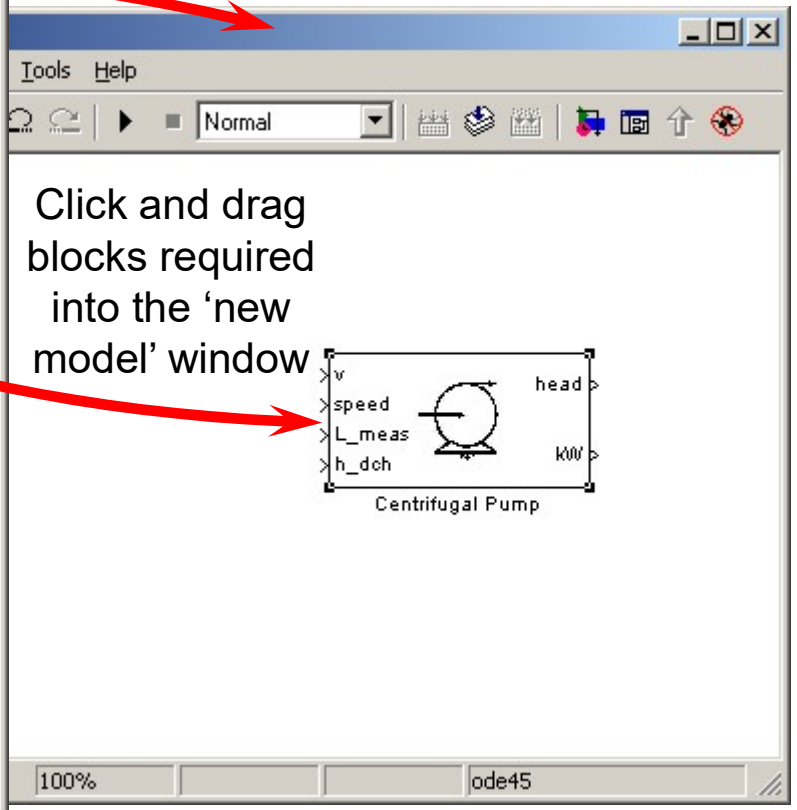


Create 'new model' by clicking on 'new model' icon

Click and drag blocks required into the 'new model' window



Constructed Model

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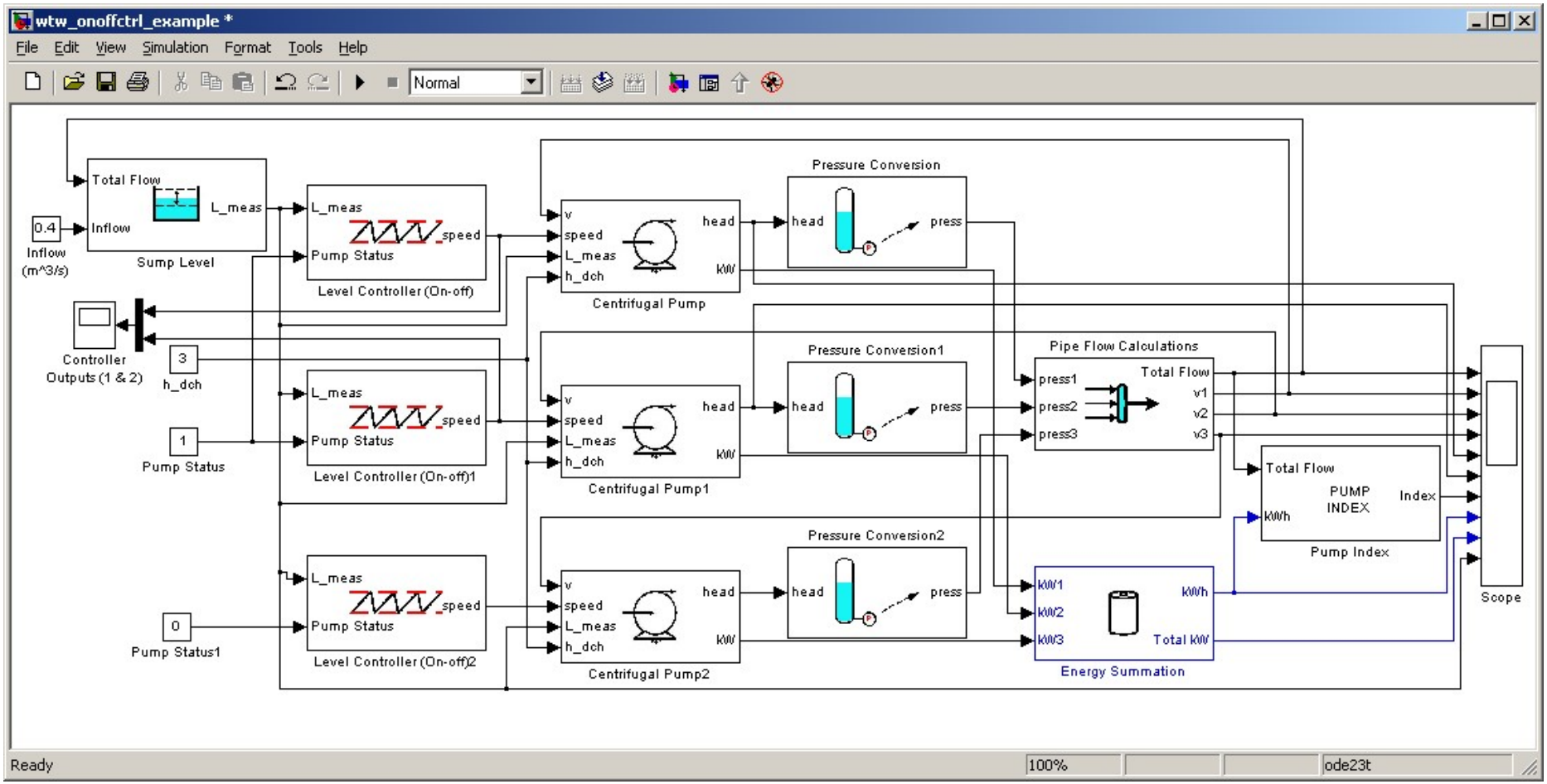

Actual Validation Results

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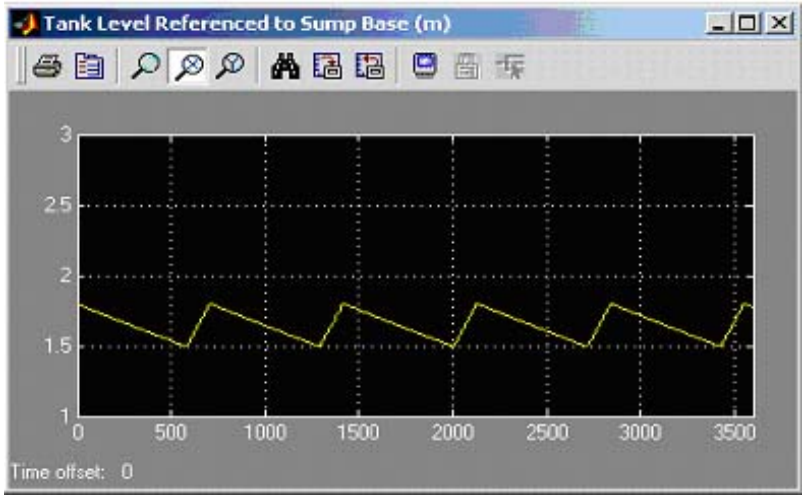
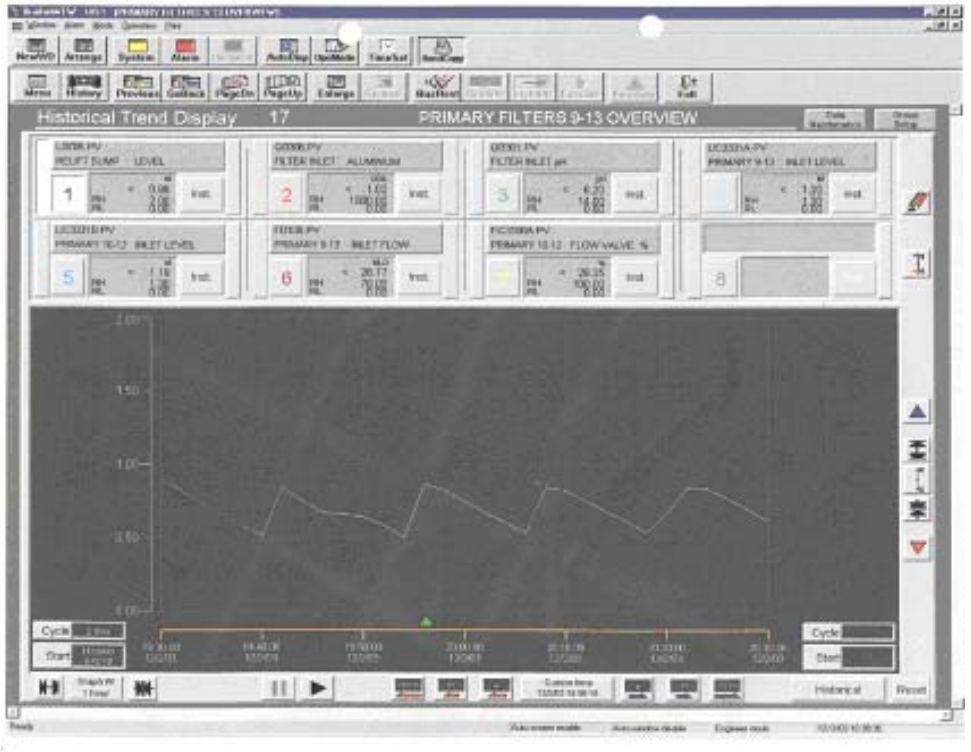


Model Tank Level Trend



Actual Tank Level Trend

Modelling Exercise Findings

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- Predicted Lift Efficiency:
  - Original on-off strategy – 24.7%
  - Single VSD pump – 33.3%
  - Dual VSD pumps – 69.4%
- Moving to Dual VSD pump would reduce energy consumption by 64.5% !!
  - due to lower pumping speeds
- Now implemented. Actual energy savings 65.1%

Example 4: Level Analysis & Tuning

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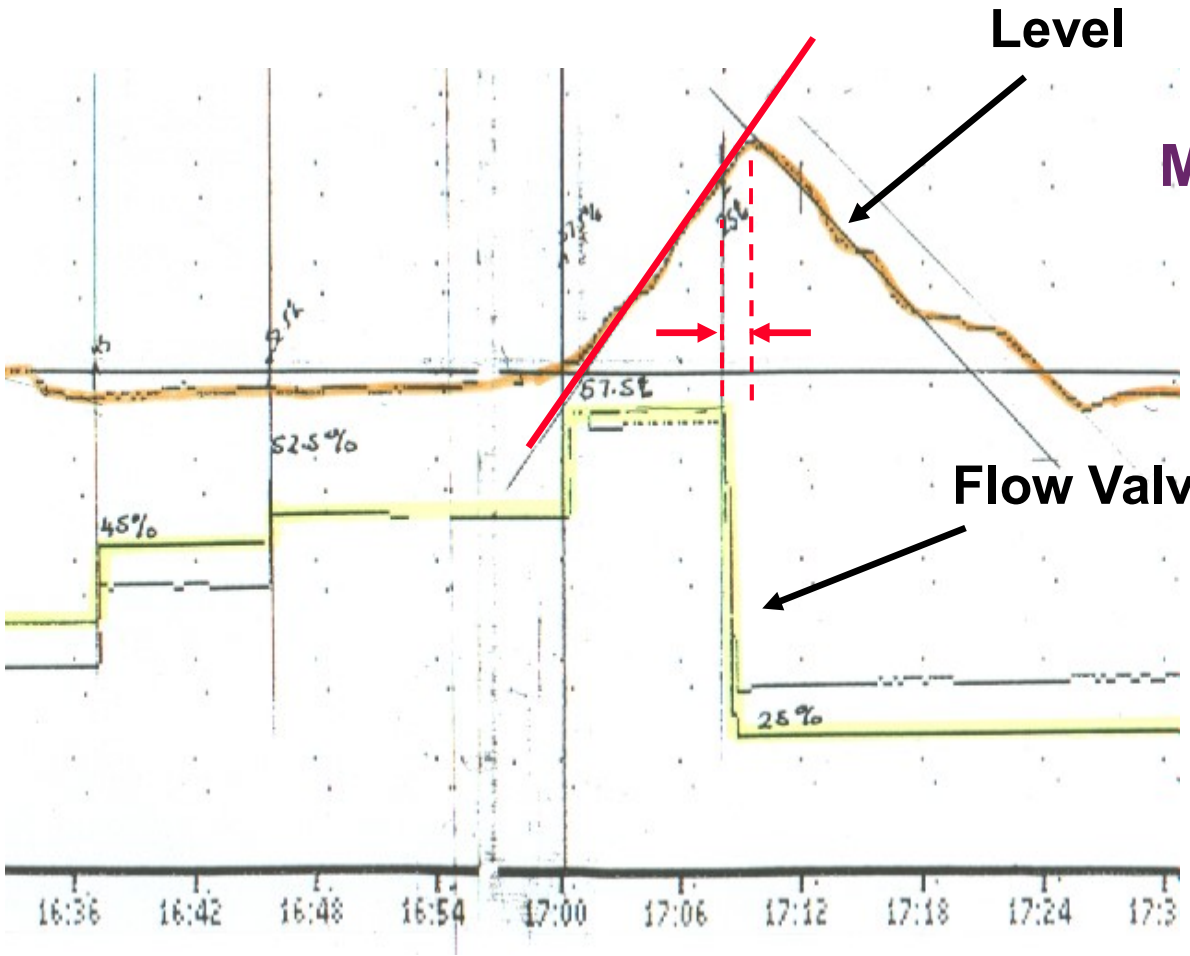
Step tests for level response:



Modelled using:

- ❒ integrator
- ❒ deadtime

Cascaded Level/Flow Loops

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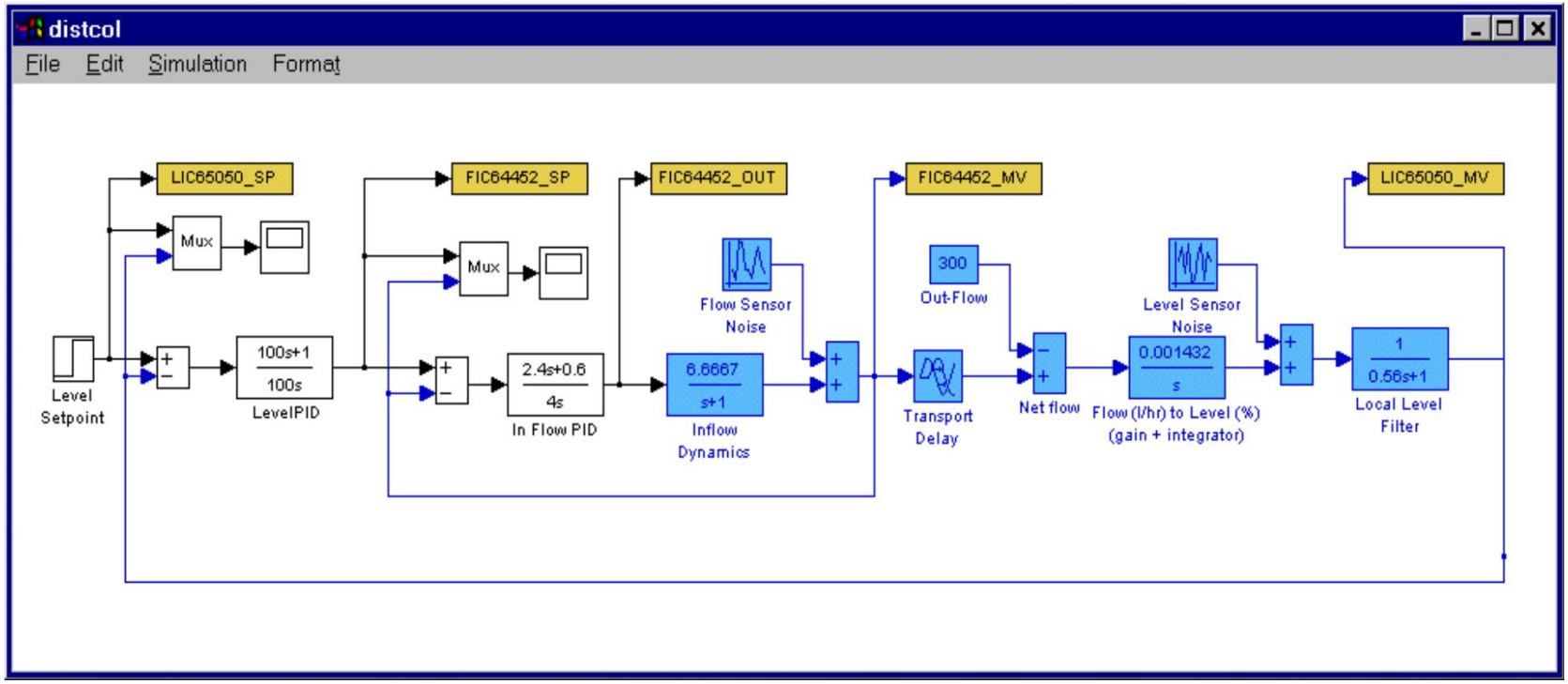
Simulink Model:



Cascaded Level/Flow Analysis & Tuning

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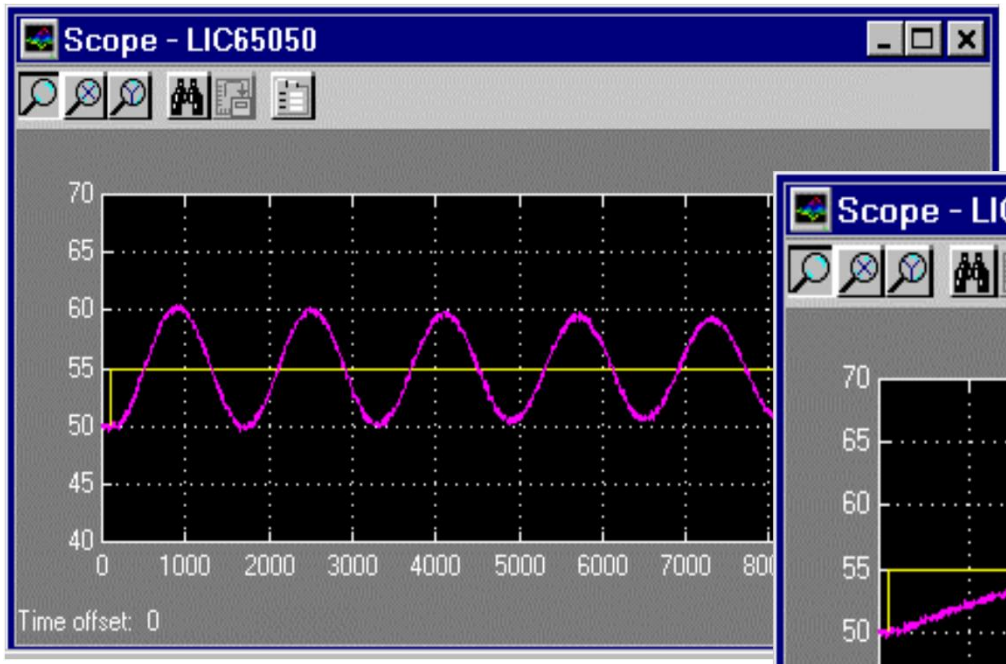
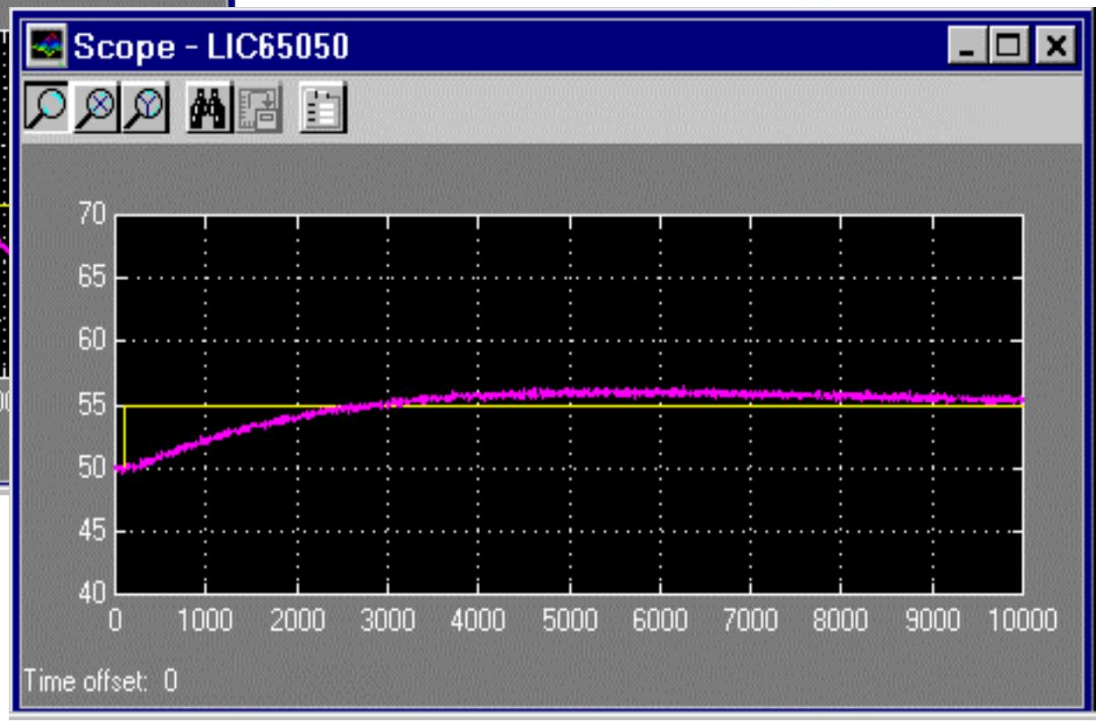
Level Controller Response:



Re-tuned gains:



Matched plant response !!

Summary

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- Hopefully demonstrated benefits of modelling
- It can be difficult – but tools can make it easier

Thanks for listening, any questions ?

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