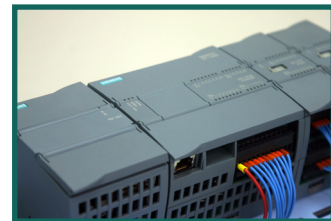
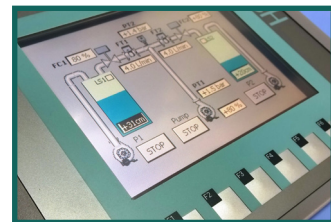


Integrated Teaching and Research Platform **ASTANK 2**



Systems Engineering

ASTANK 2 Integrated teaching and research platform for systems engineering

Reasons for choosing

ASTANK 2

Versatile platform for a broad range of hydraulic and pressure experiments: tank filling and drainage, coupled vessels or pipe pressure processes.

Tanks with different shapes that increase complexity in modelling and control.

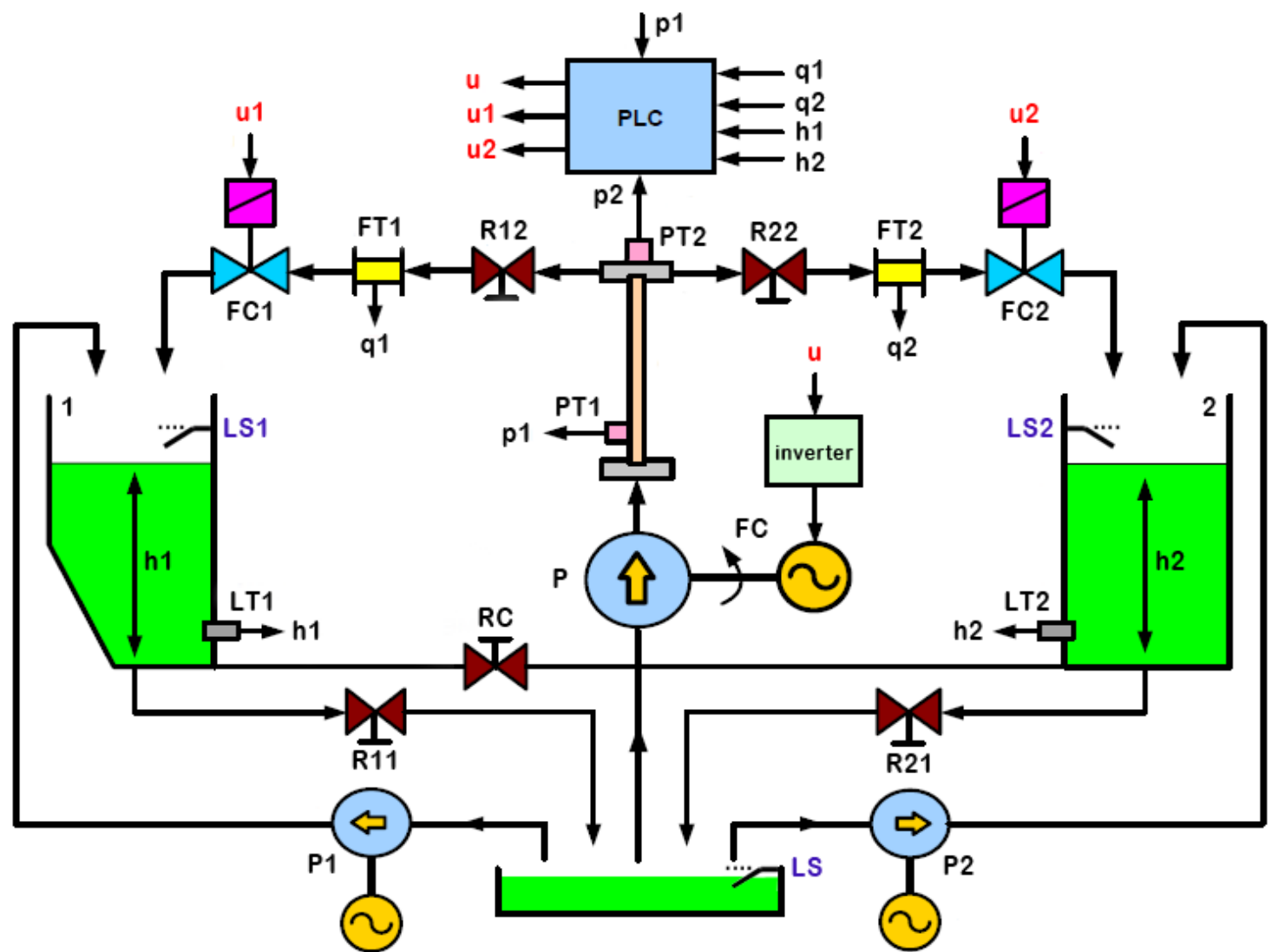
Equipment fitted with large number of sensors and actuators.

Open architecture equipment designed for laboratory use.

A large number of experiment handbooks for systems engineering laboratories is available.

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■ Sensors and Actuators	6
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Process Configuration

ASTANK 2 is a versatile educational platform which makes a wide range of experiments possible. The two tanks can be used independently or coupled to exhibit more challenging dynamics. The left tank has been built with a sloped wall to enhance the nonlinearity.

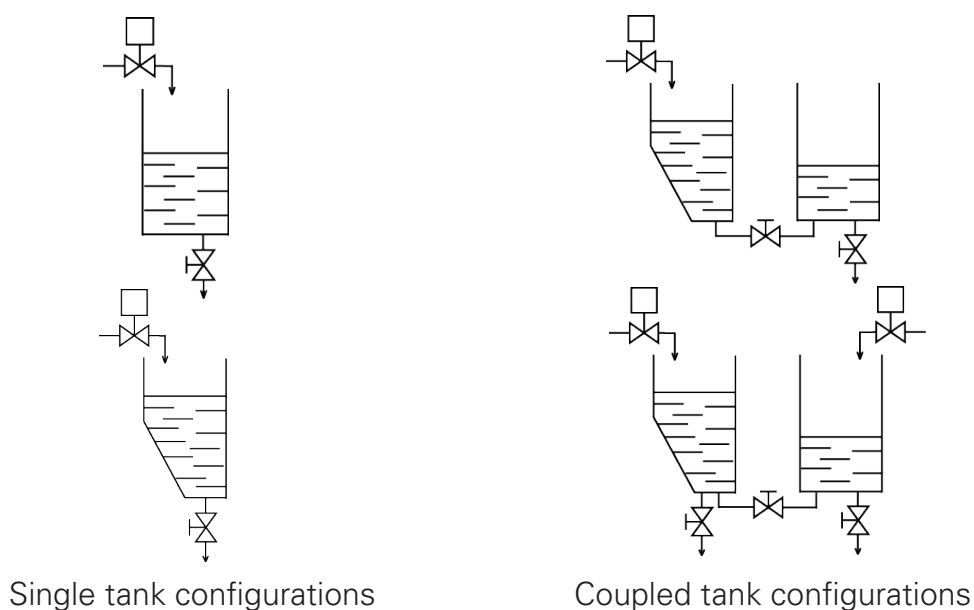
Dynamics

ASTANK 2 comprises of two water tanks placed at the same height. The tanks can be used as charge / discharge processes independently or coupled. Water drainage from the tanks is achieved using free flow. The flow rate is a function of water column height and discharge pipe geometry and can be affected by opening or closing taps. The more open these taps are, more water will flow and thus will result in a faster process. Similarly, a slower process can be achieved by suppressing flow. The relationship between water level and water flowing out of the tanks is nonlinear. To make this even more challenging, the left tank has been built with a sloped wall which adds to modelling complexity.

Versatility

ASTANK 2 can be configured in independent or coupled tank setup. Experiments can be designed that range in complexity from single input / single output level and flow control, cascade level-flow control to multivariable control scenarios.

Water is pumped in the process using a main pump or auxiliary pumps. The main pump is inverter-driven and can achieve a variable flow-pressure characteristic by changing supply frequency. This adds an extra degree of flexibility in controlling flow and pressure in the system. The auxiliary pumps offer constant flow and have been designed to act as disturbances to the charge / discharge process.





Sensors and Actuators

Measurements play an important role in understanding process behaviour. Besides the level sensors, ASTANK 2 has been fitted with pressure and flow sensors on the hydraulic circuit.



Level switches and sensors

Water level is measured with pressure sensors fitted on the floor of the tanks. The SITRANS P210 sensor with a range of 0–0.1 bar has been chosen for accuracy and reliability. The pressure reading can be translated into water column height with straightforward processing. Each tank is provided with level switches to prevent water overflow or pump dry running. The safety logic is hardware implemented.



Pressure sensors

SITRANS series static pressure sensor with a range of 0–1.6 bar are fitted at the pump discharge outlet and on the common feed line. They can be used to identify the pump flow-pressure curve and optimize energy use.



Flow transducers and control valves

A flow transducer and continuous control valve is provided on each of the two branches feeding the tanks with water. The flow transducer GHM Messtechnik is capable of accurately measuring low flow rates and has a range of 1–15 L/min. The control valve is a solenoid actuated proportional valve manufactured by Burkert with a range of 0–0.7 bar. With this setup, flow or cascade flow-level control loops can be implemented.



Inverter driven pump

The main pump displaces water from the reservoir to the two tanks. It has a magnetic-coupling to accommodate frequent starting and stopping cycles in laboratory operation. The motor is driven with a SIEMENS Sinamics inverter to enable experiments in which the pump mechanical power input is variable.



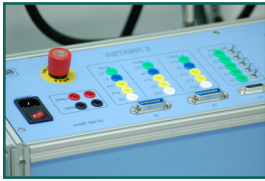
Auxiliary pumps

Each tank has been provided with a constant flow pump to act as disturbances in feedback control experiments.



Connectivity

ASTANK 2 offers an open architecture and can be easily integrated with PLCs and HMIs.



Open architecture

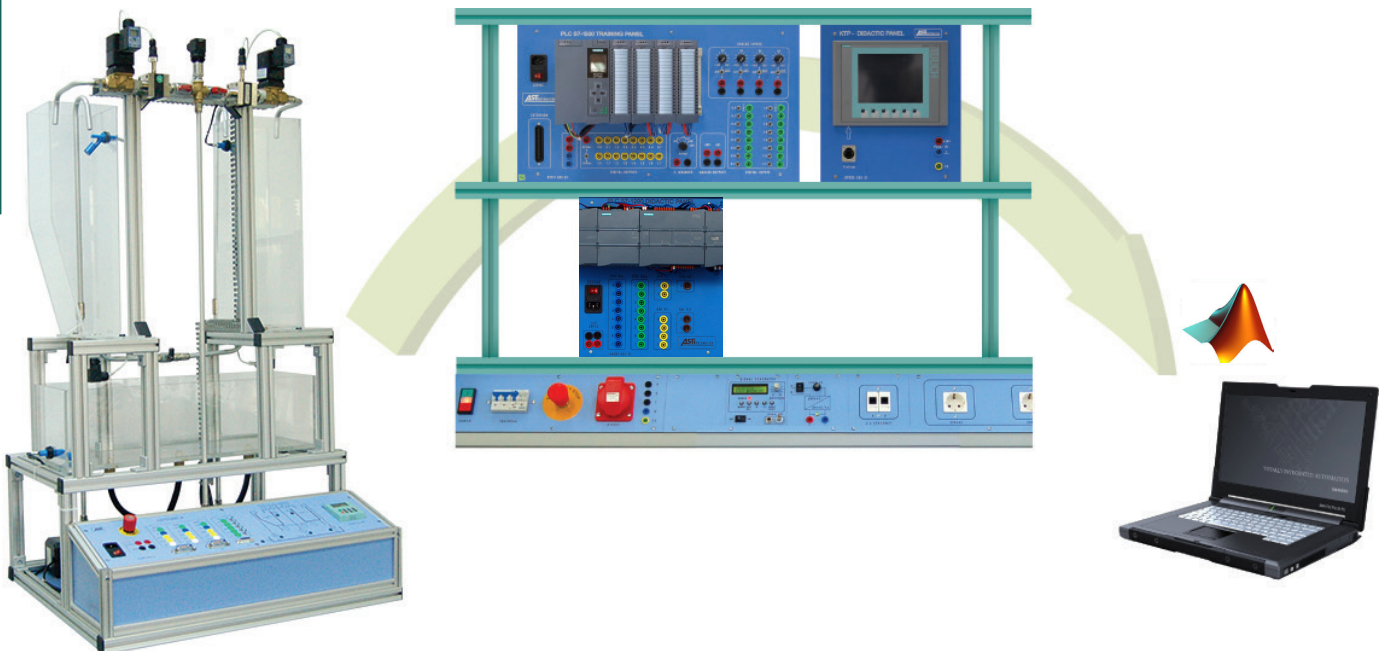
ASTANK 2 has an open architecture. Signals from the sensors and actuators are available through 4mm connectors on the main panel. This allows for easy integration with laboratory equipment.



Complete Package

We offer a tailored package for **ASTANK 2** consisting of SIEMENS PLCs and HMIs. The PLC performs monitoring and control functions whereas the HMI touchpanel offers convenient visualisation and user input.

MATLAB and Simulink can be integrated with **ASTANK 2** for data acquisition and real time control using the PLC and an OPC server or the Modbus TCP protocol.



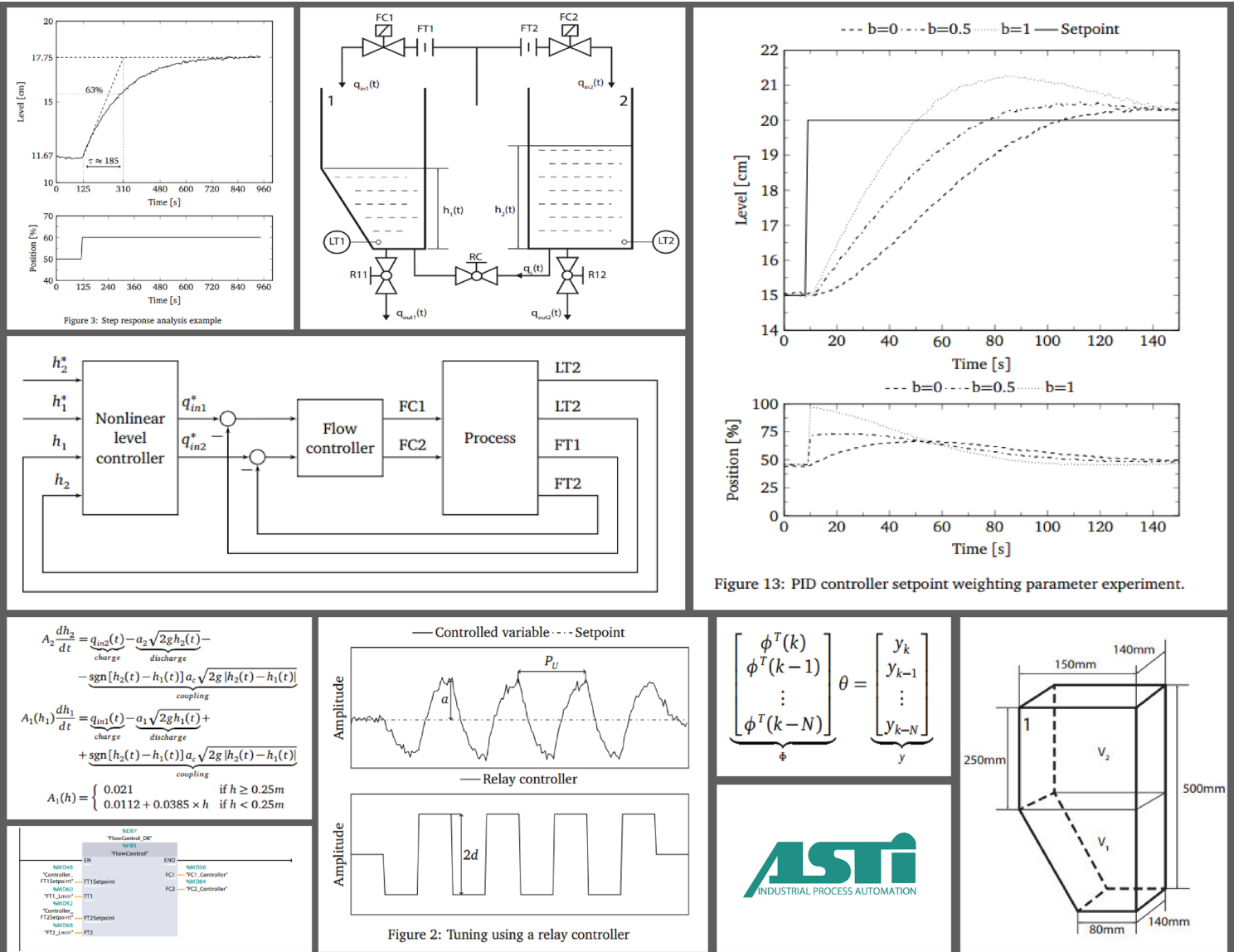
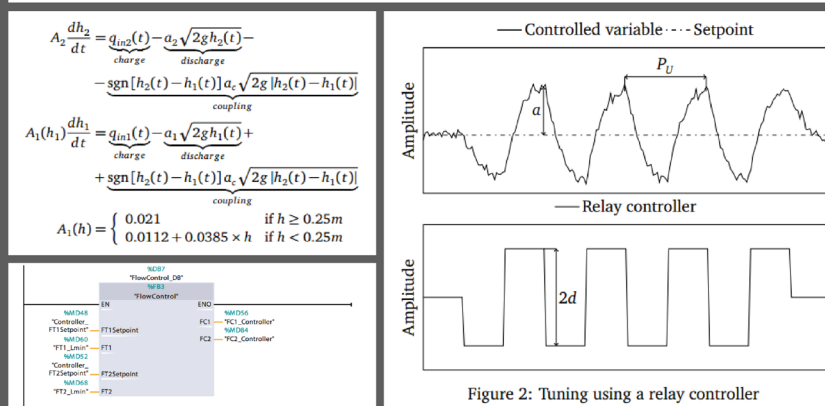
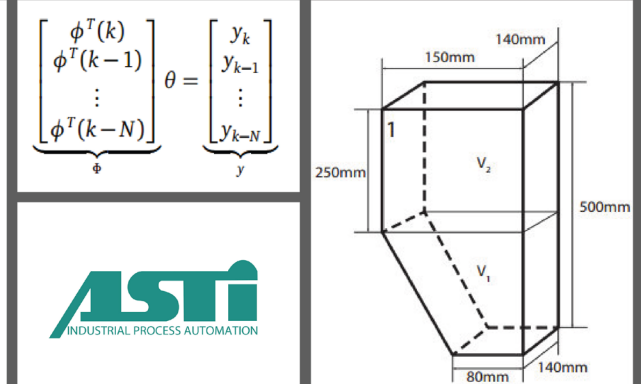
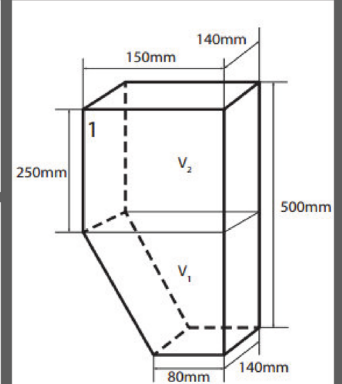


Figure 13: PID controller setpoint weighting parameter experiment.



$$\begin{bmatrix} \phi^T(k) \\ \phi^T(k-1) \\ \vdots \\ \phi^T(k-N) \end{bmatrix} \theta = \begin{bmatrix} y_k \\ y_{k-1} \\ \vdots \\ y_{k-N} \end{bmatrix}$$

ϕ y



Experiments

The large array of sensors and actuators ASTANK 2 is equipped with, offer great flexibility in developing experiments for teaching and research.



Pressure-flow curve plotting

Target group: BSc students/ MSc students/ Engineers/ Researchers

- Familiarize with the operating principles of pumps, hydraulic circuits, flow and pressure sensors.
- Acquire data for pump operating points by varying the inverter frequency.
- Plot and interpret the characteristic pressure-flow curve of the hydraulic system.



Mathematical modelling of the hydraulic circuit

Target group: BSc students/ MSc students/ Engineers/ Researchers

- Fit polynomials on the static curves identified in the previous experiment.
- Find the optimal pump operating point in terms of power consumption for a given flow or pressure.



System identification

Target group: MSc students/ Engineers/ Researchers

- Design a PRBS sequence.
- Excite the the coupled tanks with PRBS signal and acquire experimental data.
- Fit ARX models to the data.
- Compare model performance in terms of prediction error, correlation, parameter relevance.
- Compare the data driven models with first principle models.



Flow control using the inverter driven pump

Target group: BSc students/ MSc students/ Engineers/ Researchers

- Experimental dynamical model identification by using step changes on the inverter output frequency and observing changes in flow rate.
- Fit and validate ARX or transfer function models on the data.
- Design P/PI controllers for tracking a flow rate setpoint using pole placement.
- Implement controllers in PLC. Apply disturbances and observe performance.



Flow control using the valve

Target group: BSc students/ MSc students/ Engineers/ Researchers

- Experimental dynamical model identification by applying a step command to the control valve and observing changes in flow rate.
- Fit and validate ARX or transfer function models on the data.
- Design P/PI controllers for tracking a flow rate setpoint using pole placement.
- Implement controllers in PLC. Apply disturbances and observe performance.



Pressure control using the pump and inverter

Target group: BSc students/ MSc students/ Engineers/ Researchers

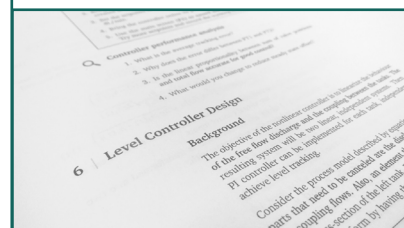
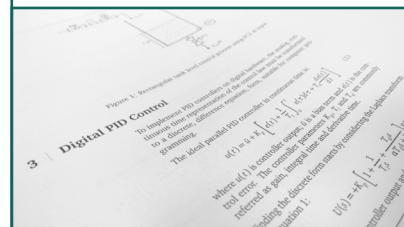
- Experimental dynamical model identification by applying a step command to the inverter and observing pressure changes in the hydraulic circuit.
- Fit and validate ARX or transfer function models on the data.
- Design P/PI controllers for tracking a pressure setpoint using pole placement.
- Implement controllers in PLC. Apply disturbances and observe performance.



Level control

Target group: BSc students/ MSc students/ Engineers/ Researchers

- Develop a first principle mathematic model based on the geometry of the tank.
- Experimentally identify tank discharge flow coefficient.
- Compare the first principle model to the experimental model.
- Design P/PI controllers for level tracking.
- Implement the controller in PLC. Apply disturbances using the auxiliary pumps.

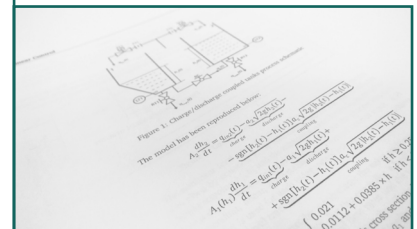




Cascade level control

Target group: MSc students/ Engineers/ Researchers

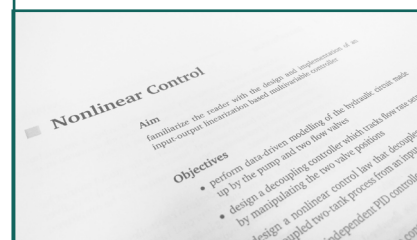
- Experimentally identify mathematical models for flow subsystem (from valve position to flow rate) and the level subsystem (from flow rate to tank level).
- Design a proportional controller for the flow subsystem and a PI controller for the level subsystem using the pole placement method.
- Tune cascade controllers using experimental methods.
- Implement the cascade control system in a PLC.
- Compare the performance of the two controllers with the single loop setup from the previous experiment.



Multivariable state space control

Target group: MSc students/ Engineers/ Researchers

- Configure the process as a multiple input multiple output coupled system (two measured levels, two manipulated flow rates).
- Identify ARX models for the coupled tank process.
- Design state space controllers for setpoint tracking
- Implement state space controllers in PLC.
- Compare linear and nonlinear controllers based on the Hammerstein-Wiener models.



Nonlinear control

Target group: MSc students/ Engineers/ Researchers

- Develop first principle mathematical models of the coupled tanks configuration.
- Design nonlinear controllers (input-output linearization, backstepping, dynamics inversion) for the process.



Nonlinear identification

Target group: MSc students/ Engineers/ Researchers

- Develop Hammerstein-Wiener nonlinear models on the coupled tanks configuration.
- Design input sequences that best identify the nonlinearities.
- Design control laws based on the nonlinear models.
- Compare linear and nonlinear controllers based on the Hammerstein-Wiener models.



Model predictive control

Target group: MSc students/ Engineers/ Researchers

- Develop multivariable ARX or state space models for prediction.
- Tune cost function weights to observe the trade-off between tracking performance and control usage.
- Tune prediction and control horizons.

Technical specifications*

ASTANK 2		
	Dimensions (W × L × H)	700mm×580mm ×1270mm
	Rectangular tank volume	9.5L
	Sloped tank volume	8.2L
	Reservoir volume	19L
	Power input	230V/50 Hz
	DC Supply	24V 3A
Pressure sensors		
	Type	SIEMENS Sitrans
	Description	diaphragm with ceramic cell
	Measurement range	0–1.6 bar
	Accuracy	±0.25%
	Linearity	±1%
	Output signal	2–10V

Level sensors		
	Type	SIEMENS Sitrans
	Description	diaphragm with ceramic cell
	Measurement range	0–0.1 bar
	Accuracy	±0.25%
	Linearity	±1 %
	Output signal	2–10V
Flow sensors		
	Type	GHM Messtechnik
	Description	dynamic diaphragm
	Range	1–15 L/min
	Output signal	4..20 mA
Control valves		
	Type	Burkert
	Description	proportional solenoid valve
	Range	0–0.7 bar
	Input signal	0–10V
Main pump		
	Type	March May MMP
	Description	centrifugal with magnetic coupling
	Head pressure	1.4 bar
	Peak flow rate	20 L/min
Auxiliary pumps		
	Type	EHEIM
	Description	centrifugal
	Head pressure	0.12 bar
	Peak flow rate	5 L/min
Inverter		
	Type	SIEMENS Sinamics
	Output	0–230V 0–650Hz
	Input signal	0–10V
	Maximum motor rating	0.25kW



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