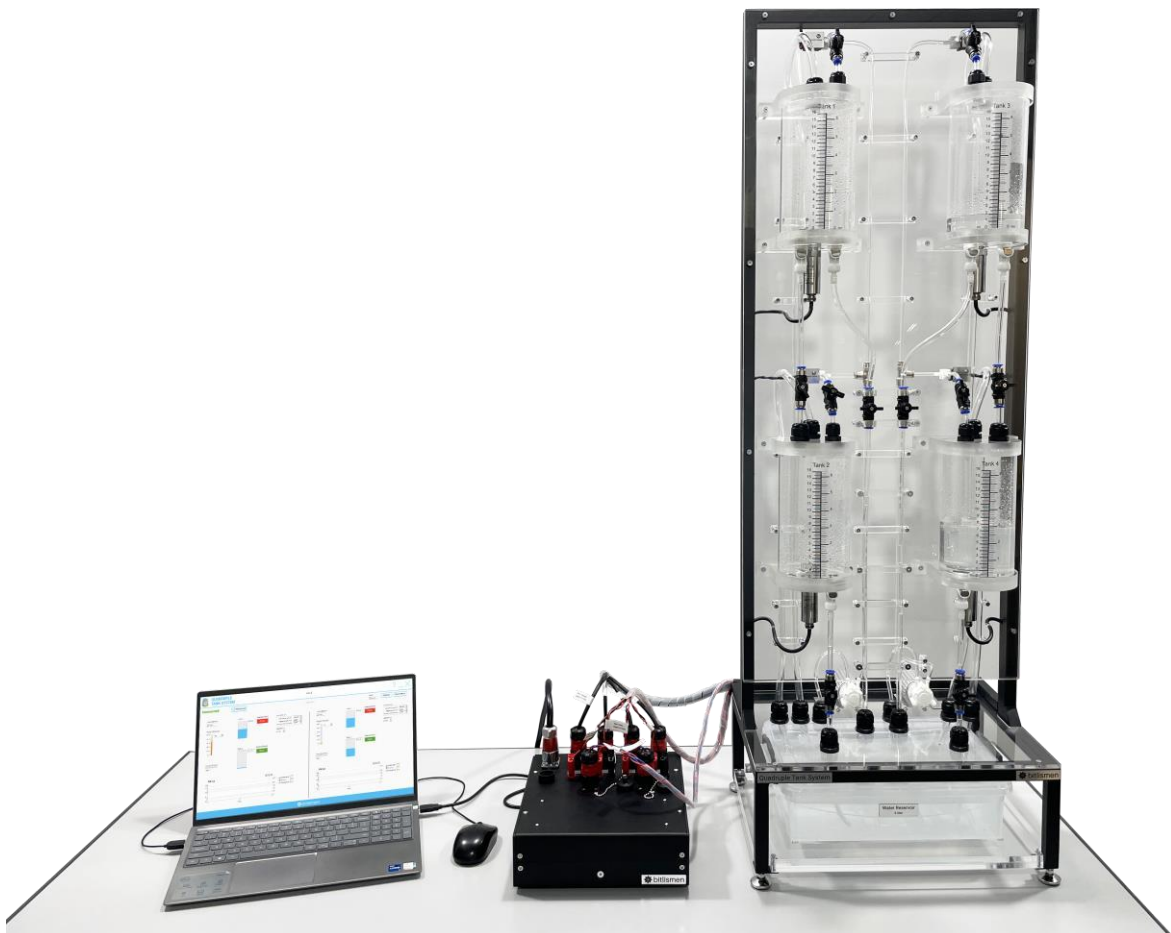


**InterCONNected Critical Infrastructure Systems
Engineering (CONCISE) Lab**

Quadruple Tank System



Laboratory Manual

www.bitlismen.com

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1. OVERVIEW

The quadruple tanks system is a widely used nonlinear system for testing control and estimation methods. This system has various applications such as wastewater treatment, water desalination, pharmaceutical industries, and petrochemical plants. Among the challenging problems is the water level estimation which is needed for controlling the system. The quadruple tanks system consists of the two coupled tanks subsystem. Each of which consists of two translucent tanks, a pump and a water reservoir. The two tanks are mounted on the frame such that flow from the upper tank can flow, through an outlet orifice located at the bottom of the tank, into the lower. Flow from the second tank flows into the main water reservoir. The upper tanks also have another outlet orifice to provide the flow directly to the water reservoir. All outlets have manual valves to control the water flow. Each tank has a pressure sensor to measure the water level. The couplings between the tanks can be modified by the use of three tubes with different diameters ($3/8"$, $5/16"$ and $1/4"$) to change the dynamics of the system imposing the use of different controllers. Water is delivered to the tanks by two independently controlled pumps. The flow of each tank can be controlled programmatically from the software. The inlet flow from the pumps can be opened and closed via solenoid valves. The system is designed for researching different control algorithms. It comes with an open-source software allowing the users to develop their algorithms in LabVIEW environment.

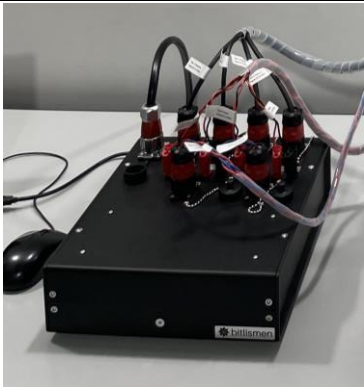
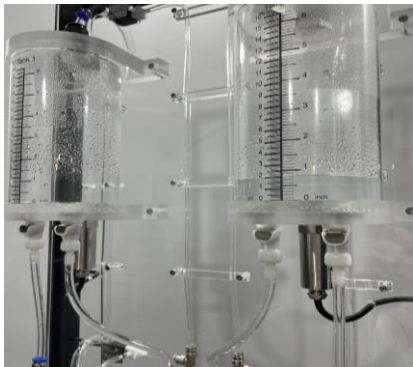
2. HARDWARE AND SOFTWARE CONFIGURATION

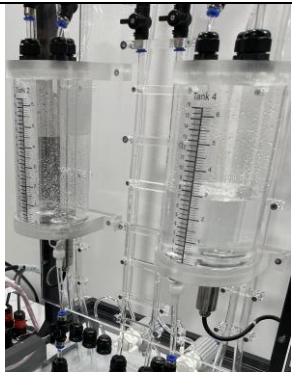
The Laboratory System includes:

2.1. STAND EQUIPMENT

Standard package includes:

1. Quadruple Tank System Laboratory Manual 1 qty.
2. Quadruple Tank System Software 1 qty.
3. Units and parts listed in the table below: 1 qty

Name	Image	Description	Quantity
Control and Measurement Module		The module is based on NI USB 6001 platform. It implements the measurement from the pressure sensors and controls the solenoid valves and pumps.	1
Upper Tanks (Tanks 1 and Tank 3)		Transparent tank from organic glass	2
Lower Tanks (Tanks 2 and Tank 4)		Transparent tank from organic glass	2

			
Water reservoir		Transparent plastic water reservoir (6liter capacity)	1
Pump		Maximum Pressure: 20 PSIG (or 12 PSIG with optional AC adapter) Primary Power Source: 12V	2
Pressure sensor		Range: 0 - 0.3psi (0.02bar) 0- 10V, SS304, Power supply: 12VDC	4
Solenoid valve		DC 12V	4



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Manual valve		10
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2.2. SYSTEM EQUIPMENT REQUIREMENTS

No	Name	Qty.	Pictures
	- Personal Computer (CPU: Intel Core i3 - RAM: 4 GB - HDD: 100GB) - Mouse, keyboard - Monitor (Full HD) 2 large monitors (Full HD) <i>Please note that the computer, mouse, keyboard and the monitors should be provided by the customer.</i>	1	

2.3. SOFTWARE REQUIREMENTS

□ Windows 10 or later

2.4. HARDWARE REQUIREMENTS

No	Name	Qty.	Pictures
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1.	NI USB 6001	1	
2.	USB Cable for NI USB 6001 to PC	1	

3. SAFETY REQUIREMENTS

Safety requirements of the system

1. Safety requirements before starting the work

- 1.1 Remove all the unnecessary equipment, materials, etc. from the workplace.
- 1.2 It is prohibited to put papers, books, documents or other things on the computer cases.
- 1.3 It is prohibited to throw water, dust, any big or small items on the equipment.
- 1.4 In order to prevent electricity overload it is prohibited to connect any other device together with the system to the same power plug.
- 1.5 If necessary, turn on the artificial lighting of the room.
- 1.6 Visually check all the connections of the wires, plug-in connectors, cables, switches. No single item should be damaged. Check if all the hardware components are connected in a reliable way.
- 1.7 Verify that the monitor is not covered with dust and the paper is inserted in the printer host box in a right way (if applicable).
- 1.8 Do not allow any clogs with dust or with any extraneous things in the ventilation holes of the computer cases.
- 1.9 Adjust the seat and its height.

- 1.10 Adjust the monitor position for personal vision.
- 1.11 In case of detecting any damages or defects, which may cause substantial danger or significant inconveniences, please turn to the head immediately (laboratory head, lecturer, etc.).
2. Safety requirements during the work
 - 2.1 Laboratory equipment have a low voltage supply. It is prohibited to dismantle the network power supply of the laboratory equipment, connect it to any other power supply or to implement other external connections.
 - 2.2 The power supply of the laboratory equipment must be grounded.
 - 2.3 The laboratory equipment should be used only in the rooms (indoor usage).
 - 2.4 The maintenance of the laboratory equipment should be performed only by the qualified technical staff.
 - 2.5 While connecting computer to the power supply, touch only isolated parts of the power plug.
 - 2.6 To avoid static electricity short-circuit it is not allowed to tip the monitor screen.
 - 2.7 If laboratory equipment is connected to the power supply, it is prohibited to
 - Open the cases
 - Make internal configurations or clean the items
 - Change the fuses
 - Change the fixed configuration in the workplace and remove the computer cases
 - Implement wet cleaning of the cases surface
 - 2.8 It is strictly prohibited to smoke or use an open flame near the laboratory equipment.
 - 2.9 It is strictly prohibited to keep any flammable explosive and chemically active substances, which can damage electrical wire insulation.
 - 2.10 Don't leave the laboratory equipment unattended when it is powered on.
3. The personnel actions in the emergency situations
 - 3.1 The main characteristics of the emergency situations in the lab room are the following:
 - Computers or laboratory devices stop working, the image on the screen gets lost
 - Short circuit, spark dissolves smell, burning flock, strong warming of the power plug or the connecting wires, voltage drop in the network, etc.
 - 3.2 In case of an emergency situation, it is necessary to:
 - Stop working, turn off the computer and the laboratory equipment.
 - In case of the fire, use carbonaceous or dust extinguisher.
 - Take actions for evacuation and first aid assistance to the injured people.
 - Tell the head of the team about the accident.

- If necessary, call emergency.

3.3 The vendor of the laboratory equipment doesn't bear any responsibility caused by the emergency situation.

4. Safety requirements after the work

- 4.1 Close the working applications, prepare the computer and the laboratory equipment for switching off.
- 4.2 Turn off computers and laboratory equipment from power socket.
- 4.3 Clean the workplace and collect all the used documents.
- 4.4 Ensure that there is no danger for fire.
- 4.5 Tell the head of the team about all the defects that were revealed during the work.

3.1. SAFETY INSTRUCTIONS

It is not permitted to:

1. Connect the Control and Measurement Module to the GND
2. Misconnect the plug of the components
3. Break the system
4. Cut anything on the system
5. Throw water on any of the components of the system
6. Fill the water reservoir with water more than the maximum limit

4. REQUIRED BACKGROUND KNOWLEDGE AND SKILLS

Before starting the operation, the student must:

1. Get acquainted with the safety requirements of the system.
2. Get acquainted with the further chapters of this laboratory manual.

5. POWERING UP THE SYSTEM AND PREPARING TO OPERATE

In order to start operating, the following steps should be implemented:

1. Turn on the computer.
2. Connect the Control and Measurement Module to the computer via USB cable.
3. After connecting the wires to the appropriate pins of the control and measurement module, please connect the Control and Measurement Module to the power source
4. Fill in water in the water reservoir



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The picture below shows how the connections are made.



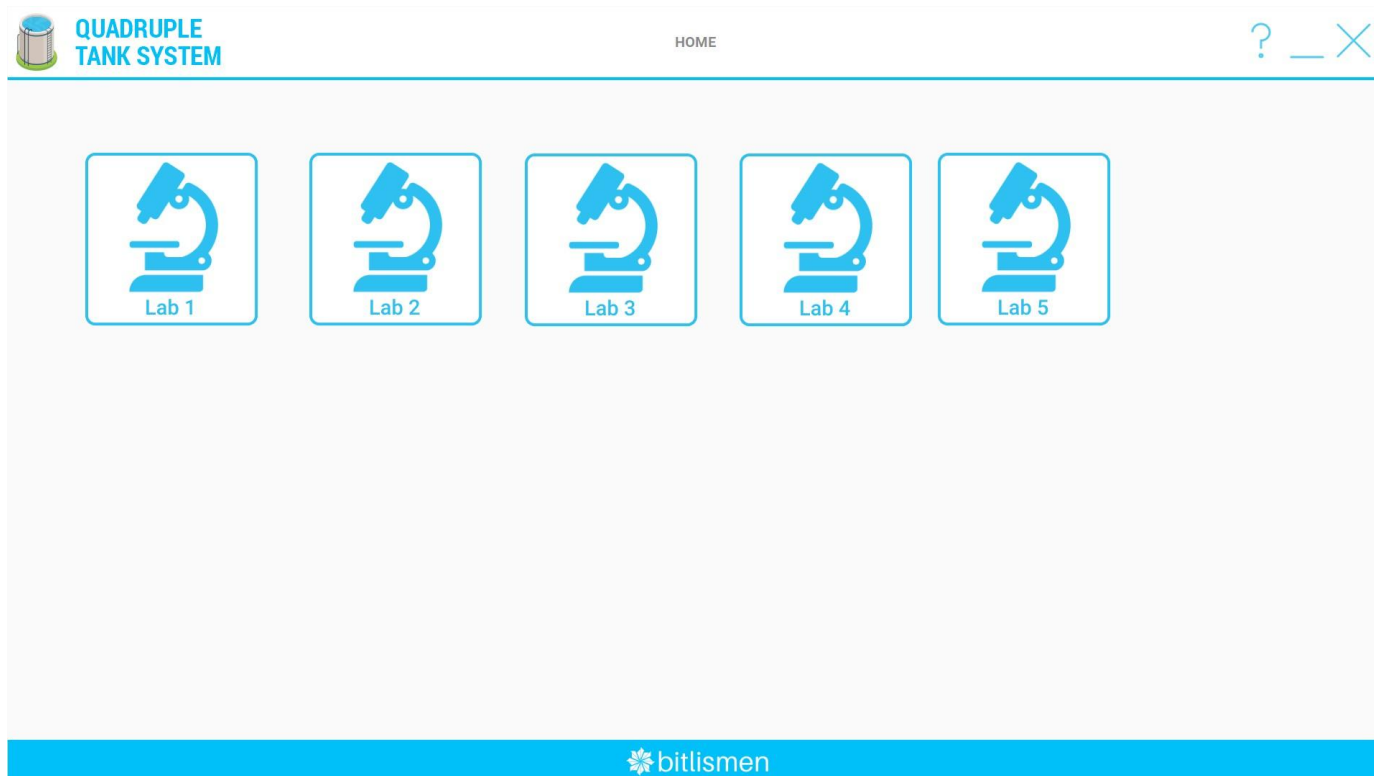
Please run the Quadruple Tank System



software on the desktop.

6. SOFTWARE DESCRIPTION

As you run the system, the HOME page is opened.



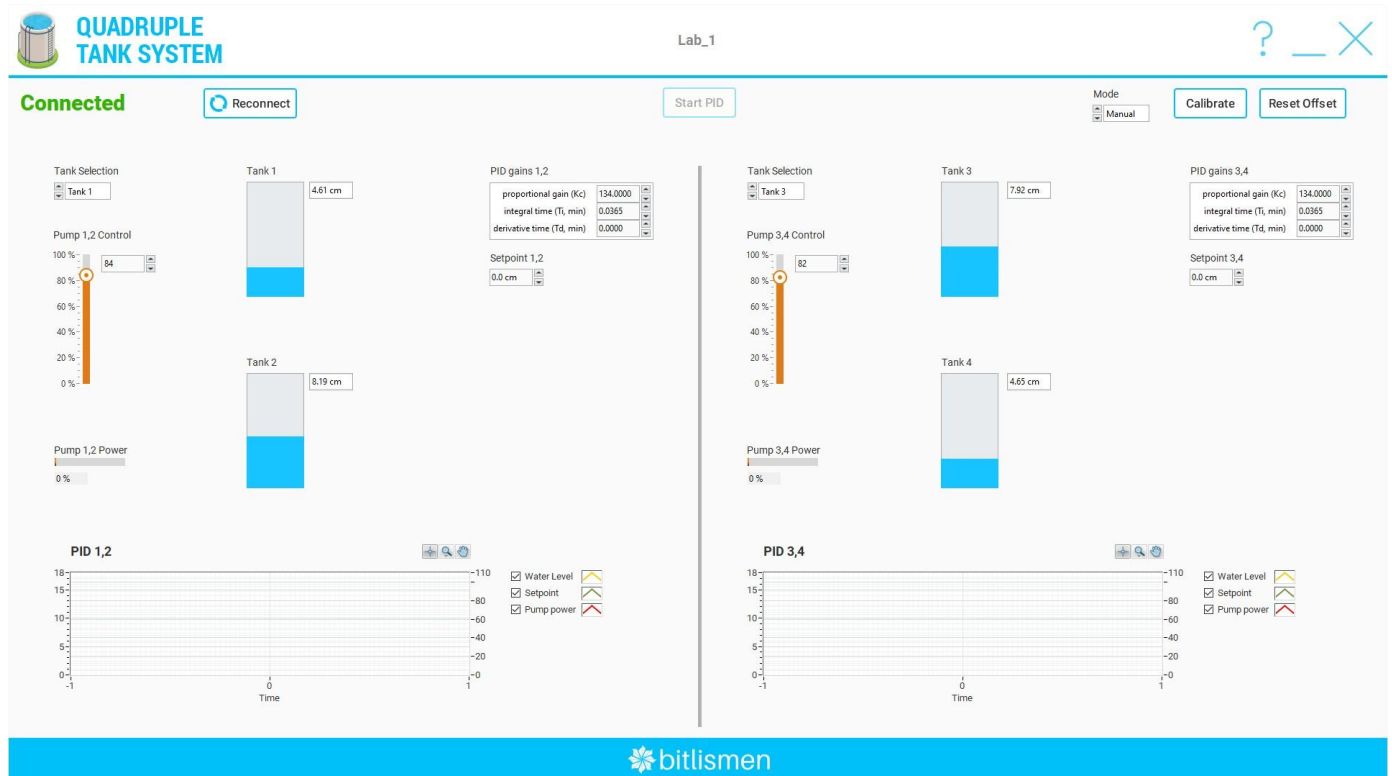
MAIN MENU ELEMENTS

ICON	DESCRIPTION
	navigates to the home page

	defines the path line
	Help - navigates to the Quadruple Tank System.pdf
	Minimize - minimizes the software
	Exit - closes the software

6.1. LAB 1

Below please find the screenshots of LAB 1.





In Lab 1, there are the following controls and indicators:

Connected

- shows the Connected/Disconnected mode of the myRIO device inside the Control and Measurement Module.

Reconnect

- when pressed, reconnects with the DAQ target, after the connection has been lost.

Mode

Manual

- specifies whether the system is in manual control mode or in auto mode where the pumps are being controlled via a PID control.

Pump 1,2 Control / Pump 3,4 Control - controls the pumps in manual mode by specifying the percentage of the pump power.

Tank 1, Tank 2, Tank 3, Tank 4 - shows the water level of the tanks in centimeters.

Start PID

- starts the PID control process, when the control mode is Auto mode.

Tank Selection - selects the tank to be used in the PID control.

PID gains 1,2 /PID gains 3,4 - specifies the corresponding proportional, integral and derivative gains of the PID control.

Setpoint 1,2 / Setpoint 3,4 - specifies the water level setpoints of the selected tanks that the PID controllers should reach.



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Pump 1,2 Power / Pump 3,4 Power - shows the power of the pumps in percentages during PID control process.

PID 1,2 / PID 3,4 - graphical monitoring of the water level, setpoint and selected pump power during the PID control process.

Reset Offset

- removes the offset of the water level measurement. Before pressing it, make sure there is no water in the tanks.

Calibrate

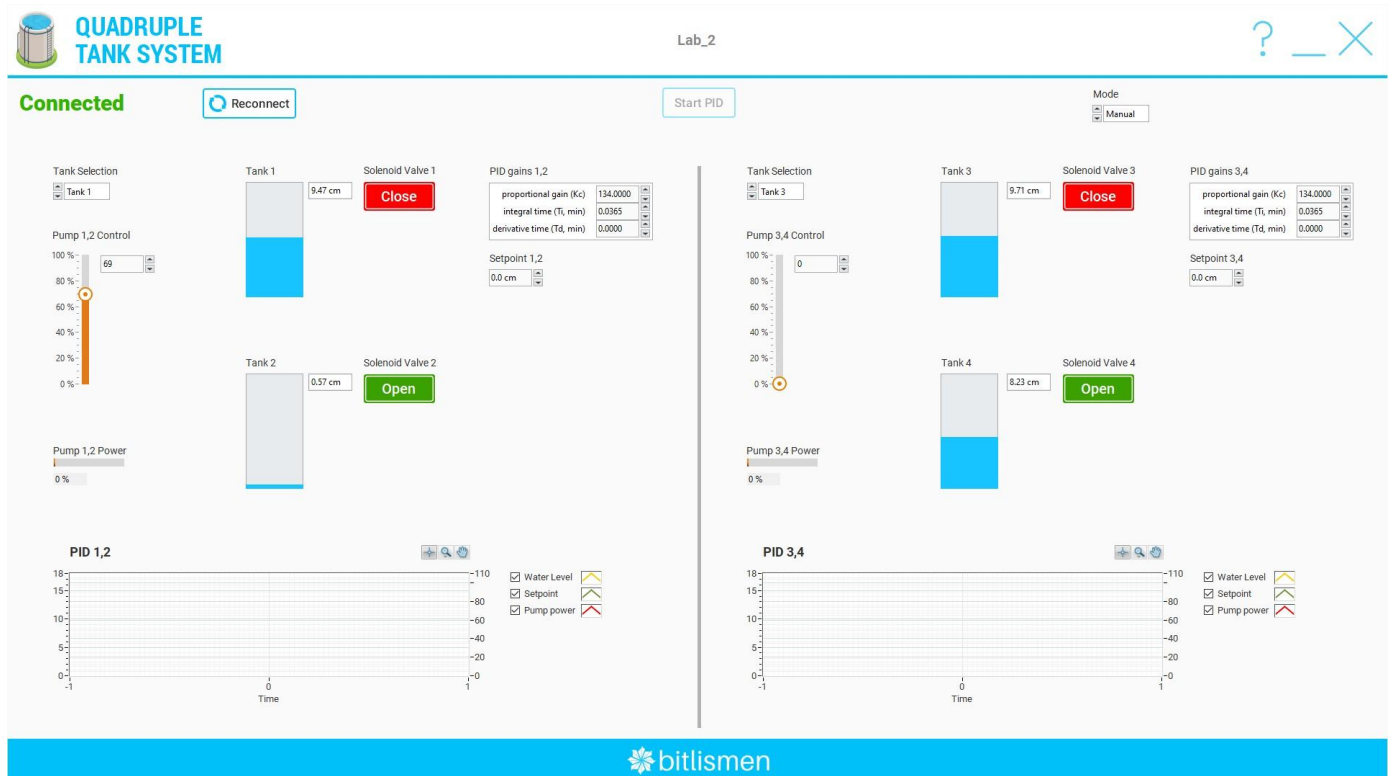
- calibrates the water level measurement. Before pressing it make sure each Tank is filled with water with precisely 5cm water level by using the rulers attached on each tank.

Calibration process

1. Enter to Lab 1
2. Resetting the offset. Empty all the tanks. Press Reset Offset button to remove the offset from the measurement. The water level of the tanks should be shown zero on the software
3. After removing the offset, implement the calibration. Turn off all the outlet valves of all tanks. Open all inlet valves (manual valves). Turn on the pumps. Follow the water level on the rulers attached on the tanks. When the water level is equal to 15cm close the corresponding inlet valves. When all tanks are filled, turn off the pumps. Press Calibrate button. The water level of the tanks should show 15cm on the software.

6.2. LAB 2

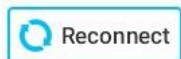
Below please find the screenshots of LAB 2.



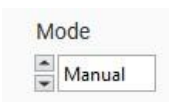
In Lab 2, there are the following controls and indicators:

Connected

- shows the Connected/Disconnected mode of the myRIO device inside the Control and Measurement Module.



- when pressed, reconnects with the DAQ target, after the connection has been lost.



- specifies whether the system is in manual control mode or in auto mode where the pumps are being controlled via a PID control.

Pump 1,2 Control / Pump 3,4 Control - controls the pumps in manual mode by specifying the percentage of the pump power.

Tank 1, Tank 2, Tank 3, Tank 4 - shows the water level of the tanks in centimeters.



- starts the PID control process, when the control mode is Auto mode.

Tank Selection - selects the tank to be used in the PID control.

Solenoid Valve 1, Solenoid Valve 2, Solenoid Valve 3, Solenoid Valve 4 - opens and closes the respective solenoid valves to allow the water input from the pumps.

PID gains 1,2 /PID gains 3,4 - specifies the corresponding proportional, integral and derivative gains of the PID control.

Setpoint 1,2 / Setpoint 3,4 - specifies the water level setpoints of the selected tanks that the PID controllers should reach.

Pump 1,2 Power / Pump 3,4 Power - shows the power of the pumps in percentages during PID control process.

PID 1,2 / PID 3,4 - graphical monitoring of the water level, setpoint and selected pump power during the PID control process.

The following 3 icons are available in the top of the graph:

- Default cursor
- Zoom – used for Zoom mode selection
 - Zoom selected area
 - Zoom vertically
 - Zoom horizontally
 - Zoom full page
 - Zoom out
 - Zoom in
- Dragging tool – used to drag the Zoomed graph

A plot palette on the right to the graphs includes the following

- Plot visibility checkboxes for each plot;
- Plot legends
- Plot visibility checkboxes for each 3-phase system



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In the plot visibility checkboxes any number of available plots can be selected.

If any of the plots is unchecked, the waveform disappears

The legend can be controlled by right-clicking on the legend area.

Right click on an axis to enable/disable auto scaling for the specified axis.

To auto scale the X axis right-click on it and check AutoScale X

Several options are available through a right-click on the graph

Clear graph – clears the image on the graph

Export data to Excel – it will automatically open an Excel file where all the data will be presented.

Export data to Simplified Image - allows copying the image on the graph, where can then be pasted to Word, Paint, Photoshop.



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