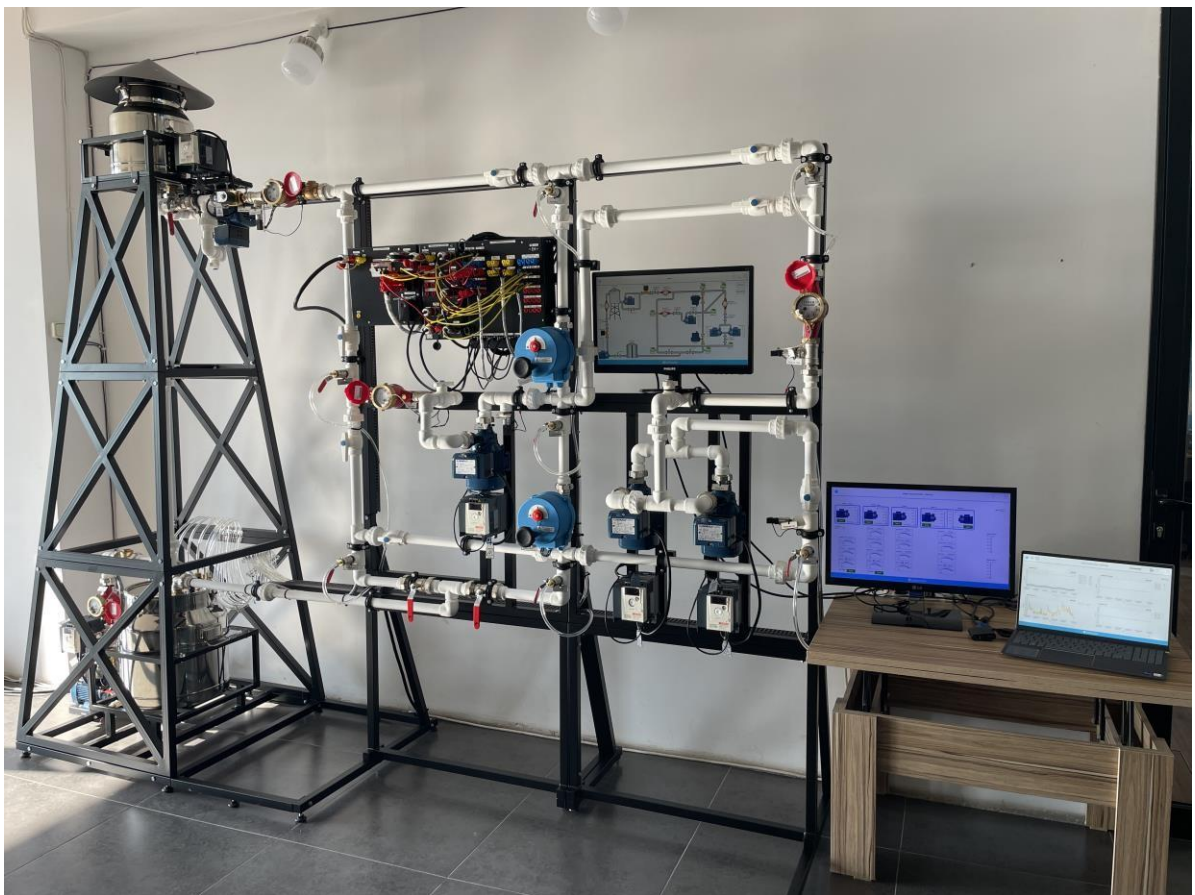


InterCONnected Critical Infrastructure Systems Engineering (CONCISE) Lab

Water Distribution Testbed SCADA



Laboratory Manual

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1. OVERVIEW

The CONCISE SCADA trainer is a small scale closed-loop model of a water distribution system of a city. It consists of water tank, reservoir, single pumps, redundant pumps, analog and solenoid valves, water pressure, flow and level meters. The system comes with a SCADA software, which allows the users to monitor the entire system and implement remote control of the valves and the VFDs of the pumps. As it is seen from the system diagram, the pump 1 pushes the water up to the upper tank. The upper tank has a water level meter to monitor the level in real-time. There is one manual valve on the input of the pump and a solenoid valve on the output. There are also pressure and water flow meters on this branch. The upper tank is also equipped with a level switch that will automatically turn off the pump to avoid any overflow. On the output of the upper tank there are two small branches. One of them goes through another pump, and the other bypasses the pump. This allows to have a pressurized flow (through the pump) or a gravity flow (bypassing the pump). On the output of this small branch there are two bigger branches. On each branch there are outputs that simulate consumers. There are also water flow meters, pumps and pressure meters on the input and on the output of the pumps to measure the pressure difference. The analog valves allow to have a control over the openness of the valve, thus making it possible to have different water flows through different sections of the branches. In one of the branches there is a redundant pump, that allows to showcase the uninterrupted water supply even if one of the pumps fails.

2. HARDWARE AND SOFTWARE CONFIGURATION

The Laboratory System includes:

2.1. STAND EQUIPMENT

Standard package includes:

1. CONCISE SCADA Trainer Laboratory Manual 1 qty.
2. CONCISE SCADA Trainer Software 1 qty.
3. Units and parts listed in the table below: 1 qty

Name	Image	Description	Quantity
Power Supply Module Type 6		This module supplies power to the entire testbed. It is switched on by a key and has short circuit protection. The input of the module is single-phase 120V.	1
Auxiliary Multi Relay Module Type 7		The Auxiliary multi relay has 9 auxiliary relays. The Auxiliary relays are based on electromagnetic principle. This relay is a real industrial electromagnetic relay used in relay protection circuitry. The Auxiliary relays are performed with the voltage coil so those should be used in parallel connections in protection circuitry.	1
Control and Measurement Module Type 9		The module is based on NI myRIO platform. It combines analog input, digital input/output modules. It implements all the signal acquisition and control of the system.	1

Upper Tank		15L. The water flows from the Ground Tank to the Upper Tank.	1
Ground Tank		38L. The 5 consumer hoses are connected to this tank.	1
Water Pump		Model: PKm 60, Centrifugal pump Voltage 110V, 5.5A Power 0.37kW(0.5hp), mouth 1"	5
Variable Frequency Drive (VFD)		Model: ATV12H075F1, Voltage supply 100-120V, 50/60Hz, output voltage 200-240V 3 phases Power 0.75kW Interface Modbus(RS-485)	5
Proportional Valve		Model: VB030, Electric Actuated Brass Ball Valve Supply 24V AC/DC, Type 2 way, input signal 0-10V, pipe size 3/4"	2
Water Flow Meter		Model: FTB8007HW-PT, Pressure 150psi, pipe size 3/4", output signal Amplified Square Wave, 0-75LPM, analog output, 20 pulse per gallon	4

Pressure Sensor		Model: PX119-030AI, Pressure transmitter, Supply 8 to 30 Vdc, output signal 4 to 20 mA, pressure 0-30psi, connection size 1/4"	6
Solenoid Valve		Model: SV224, Solenoid valve, Supply Voltage 10 W, 120 Vac, Connection Size 3/4" Pressure 150psi	2
Ultrasonic Level Transmitter		Model: LVU501-B, Media type liquid - water Supply Voltage 14-28 VDC Measurement Range 3.8 cm to 1.5 m Output signal 4-20 mA	1
Level Switch		Model: LV-10, Switch rating 20 VA Connection Size 1/8"	1

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
1.	NI myRIO Model: myRIO-1900 The National Instruments myRIO-1900 is a portable reconfigurable I/O (RIO) device that students can use to design control, robotics, and mechatronics systems.	1	
2.	USB Cable for myRIO to PC		

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 Power Supply Module +24DC to the GND
2. Misconnect the coils of the components
3. Connect Analog inputs to the Digital inputs or vice versa
4. Break the trainer
5. Cut anything on the trainer
6. Throw water on any of the components of the trainer
7. Use any other cables while assembling and mounting
8. Fill the ground tank with water more than the 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 myRIO (on the Control and Measurement Module Type 9) to the computer via USB cable.
3. Keep the circuit breakers ON on the related components

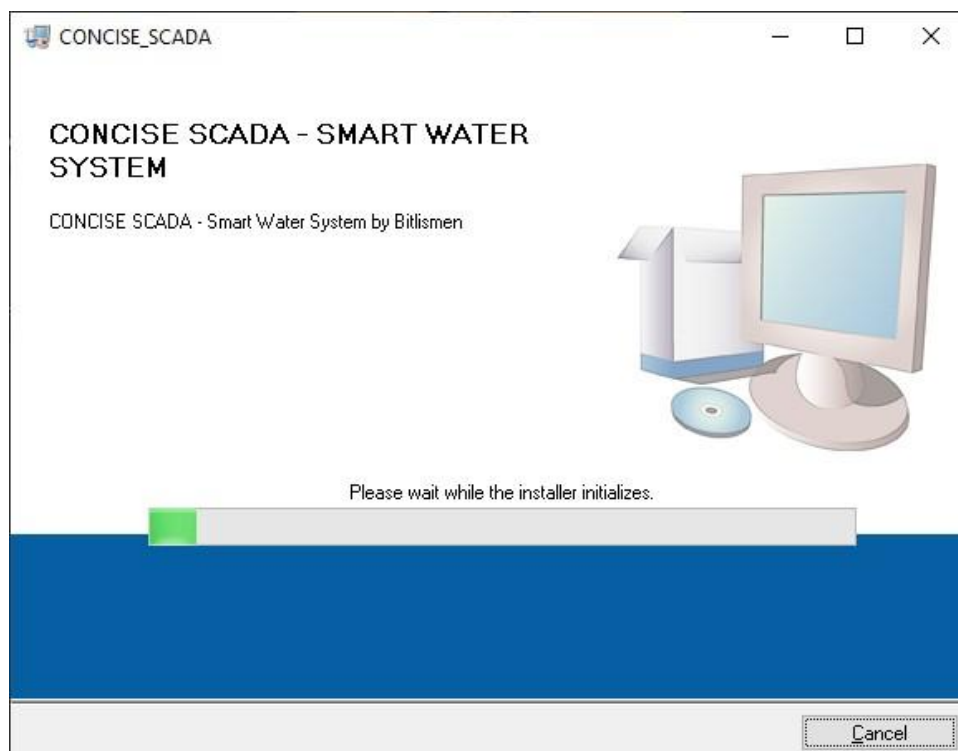
4. After completing the appropriate wiring, please switch the power cable of the *Power Supply Module Type 6* to the power socket and switch the key of the *Power Supply Module Type 6* to turn in ON
5. Please fill in the water in the Ground water tank.

6. SOFTWARE INSTALLATION AND SETUP

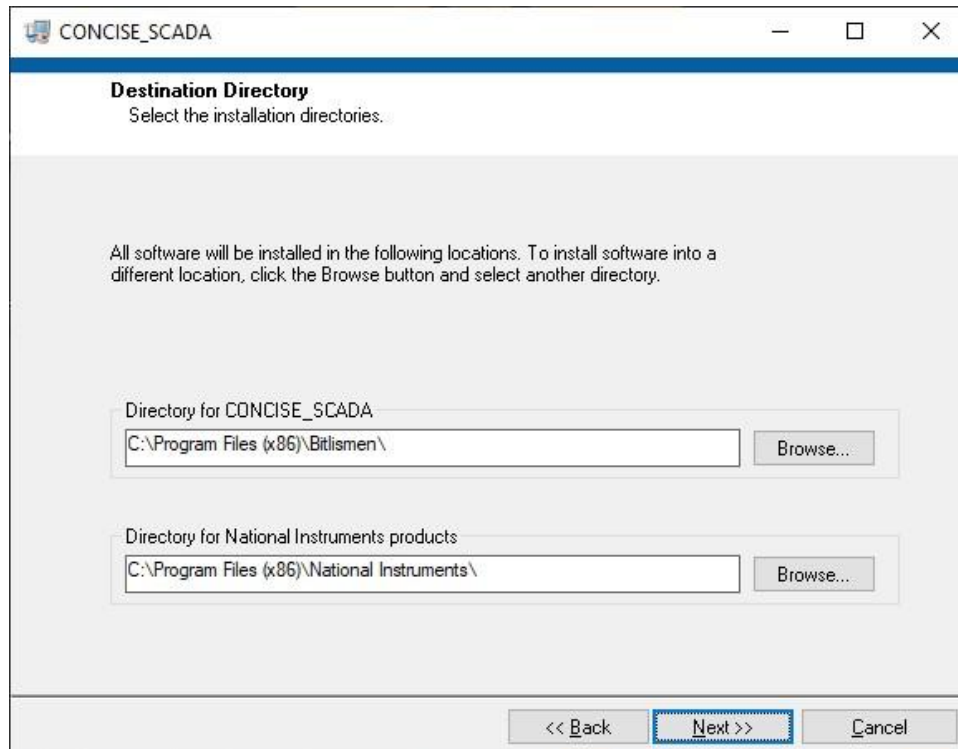
Open the CONWISE SCADA – Water Project>>Installer >>Volume. Double click on the install.exe

Name	Date modified	Type	Size
bin	20-Dec-22 11:53 AM	File folder	
license	20-Dec-22 11:53 AM	File folder	
supportfiles	20-Dec-22 11:54 AM	File folder	
install.exe	28-Sep-21 5:04 PM	Application	5,328 KB
install.ini	20-Dec-22 11:54 AM	Configuration sett...	41 KB
nidist.id	20-Dec-22 11:54 AM	ID File	1 KB

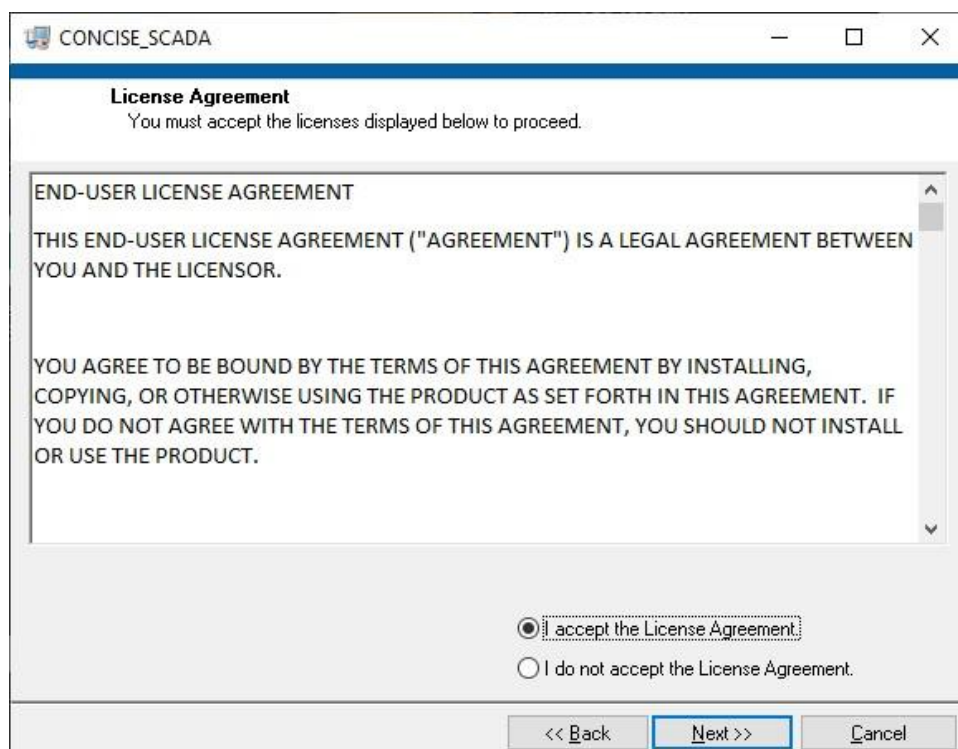
Wait until the installer initializes.



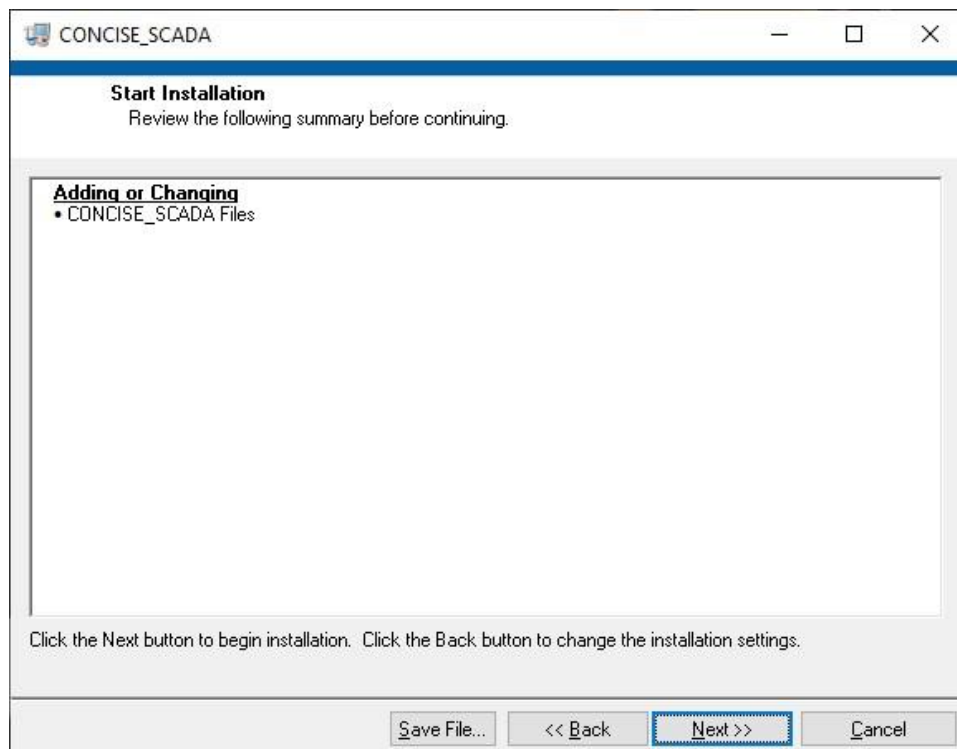
Click Next



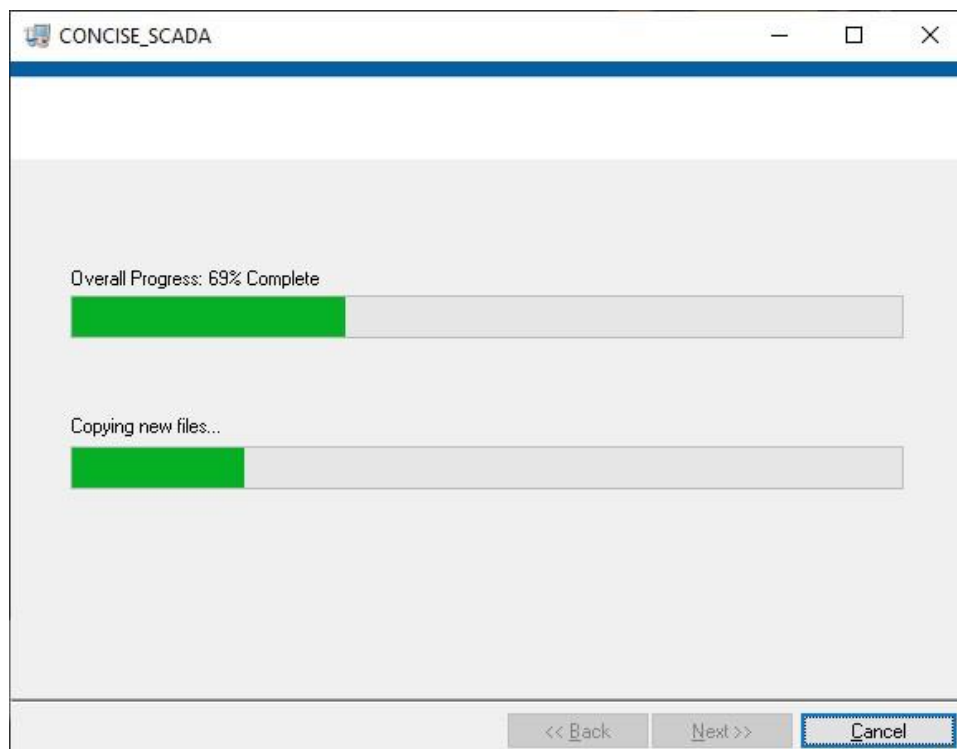
Make the point on *I accept the License Agreement*.



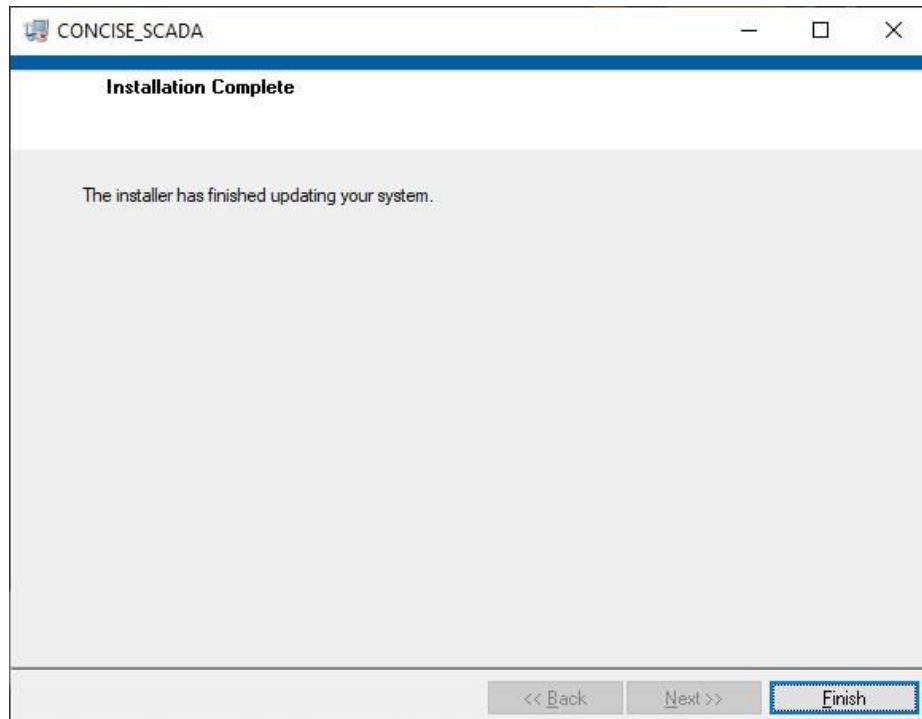
Click Next



Wait until done



Click Finish



Reboot the computer.

Before running the system, please make the connections according to the table below:

LIST OF CONNECTIONS							
FROM				TO			
No.	Component Name	Item	Pin	Component Name	Item	Pin	note
1	Power Supply		120VAC In	Power socket from mains			
2	Power Supply		120VAC Out	Auxiliary Multi Relay Type 7		120VAC In	
3	Power Supply		GND	Auxiliary Multi Relay Type 7		GND	
4	Pressure 1 Out		Power + (+24 VDC)	Power Supply		+24DC	
5	Pressure 2 Out		Power + (+24 VDC)	Power Supply		+24DC	
6	Pressure 3 In		Power + (+24 VDC)	Power Supply		+24DC	
7	Pressure 3 Out		Power + (+24 VDC)	Power Supply		+24DC	
8	Pressure 4 In		Power + (+24 VDC)	Power Supply		+24DC	
9	Pressure 4 Out		Power + (+24 VDC)	Power Supply		+24DC	
10	Water Meter 1		Power + (+24 VDC)	Power Supply		+24DC	
11	Water Meter 2		Power + (+24 VDC)	Power Supply		+24DC	
12	Water Meter 3		Power + (+24 VDC)	Power Supply		+24DC	
13	Water Meter 4		Power + (+24 VDC)	Power Supply		+24DC	
14	Level Meter		Power + (+24 VDC)	Power Supply		+24DC	
15	Analog Valve 1		Power + (+24 VDC)	Power Supply		+24DC	
16	Analog Valve 2		Power + (+24 VDC)	Power Supply		+24DC	
17	Ground Tank Light		Power + (+24 VDC)	Power Supply		+24DC	
18	Analog Valve 1		Power - (GND)	Power Supply		GND	

19	Analog Valve 2		Power - (GND)	Power Supply		GND	
20	Ground Tank Light		Power - (GND)	Power Supply		GND	
21	Control and Measurement Module Type 9		+24DC	Power Supply		+24DC	

22	Control and Measurement Module Type 9		GND	Power Supply		GND	
23	Control and Measurement Module Type 9		+12VDC	Power Supply		120VAC Out Type F	Power adapter
24	Pressure 1 Out		Signal (4-20mA)	Control and Measurement Module Type 9	Slot 1: RIOsys 9003	AI0+	
25	Level Meter		Signal (4-20mA)	Control and Measurement Module Type 9	Slot 1: RIOsys 9003	AI1+	
26	Pressure 2 Out		Signal (4-20mA)	Control and Measurement Module Type 9	Slot 1: RIOsys 9003	AI2+	
27	Pressure 3 In		Signal (4-20mA)	Control and Measurement Module Type 9	Slot 1: RIOsys 9003	AI3+	
28	Pressure 3 Out		Signal (4-20mA)	Control and Measurement Module Type 9	Slot 1: RIOsys 9003	AI4+	
29	Pressure 4 In		Signal (4-20mA)	Control and	Slot 1: RIOsys 9003	AI5+	

				Measurement Module Type 9			
30	Pressure 4 Out		Signal (4-20mA)	Control and Measurement Module Type 9	Slot 1: RIOSys 9003	AI6+	
31	Auxiliary Multi Relay Type 7		GND	Control and Measurement Module Type 9	Slot 1: RIOSys 9003	AI0-	
32	Control and Measurement Module Type 9	Slot 1: RIOSys 9003	AI0-	Control and Measurement Module Type 9	Slot 1: RIOSys 9003	AI1-	

33	Control and Measurement Module Type 9	Slot 1: RIOSys 9003	AI1-	Control and Measurement Module Type 9	Slot 1: RIOSys 9003	AI2-	
34	Control and Measurement Module Type 9	Slot 1: RIOSys 9003	AI2-	Control and Measurement Module Type 9	Slot 1: RIOSys 9003	AI3-	
35	Control and Measurement Module Type 9	Slot 1: RIOSys 9003	AI3-	Control and Measurement Module Type 9	Slot 1: RIOSys 9003	AI4-	
36	Control and Measurement Module Type 9	Slot 1: RIOSys 9003	AI4-	Control and Measurement Module Type 9	Slot 1: RIOSys 9003	AI5-	
37	Control and Measurement Module Type 9	Slot 1: RIOSys 9003	AI5-	Control and Measurement Module Type 9	Slot 1: RIOSys 9003	AI6-	

38	Analog Valve 1		Signal+ (0-10VDC)	Control and Measurement Module Type 9	Slot C: AI	AI0+	
39	Analog Valve 1		Signal- (GND)	Control and Measurement Module Type 9	Slot C: AI	AI0-	
40	Analog Valve 2		Signal+ (0-10VDC)	Control and Measurement Module Type 9	Slot C: AI	AI1+	
41	Analog Valve 2		Signal- (GND)	Control and Measurement Module Type 9	Slot C: AI	AI1-	
42	Analog Valve 1		Control+ (0-10VDC)	Control and Measurement Module Type 9	Slot C: AO	AO0+	
43	Analog Valve 1		Control- (GND)	Control and Measurement Module Type 9	Slot C: AO	AO0-	

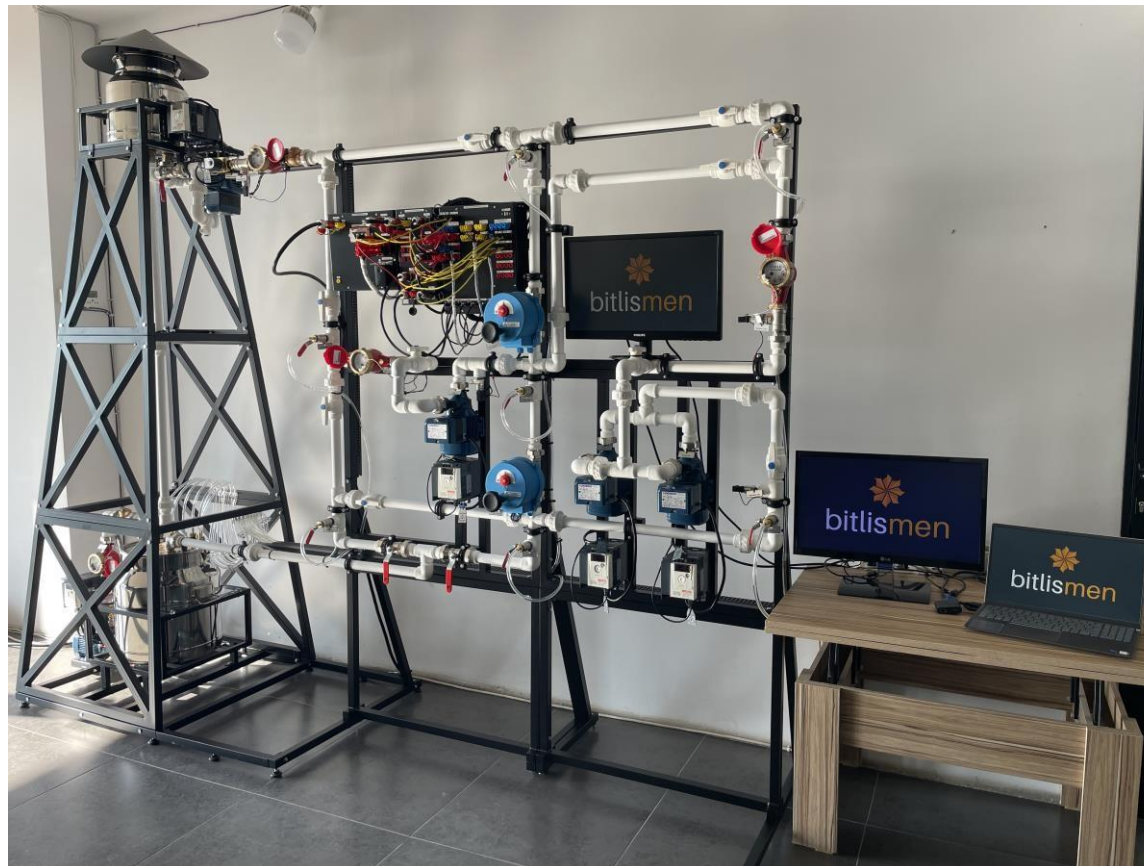
44	Analog Valve 2		Control+ (0-10VDC)	Control and Measurement Module Type 9	Slot C: AO	AO1+	
45	Analog Valve 2		Control- (GND)	Control and Measurement Module Type 9	Slot C: AO	AO1-	
46	Water Meter 1		Signal (+24VDC Pulse)	Control and Measurement Module Type 9	Slot 3: RIOsys 9002	DIO0	

47	Water Meter 2		Signal (+24VDC Pulse)	Control and Measurement Module Type 9	Slot 3: RIOSys 9002	DIO1	
48	Water Meter 3		Signal (+24VDC Pulse)	Control and Measurement Module Type 9	Slot 3: RIOSys 9002	DIO2	
49	Water Meter 4		Signal (+24VDC Pulse)	Control and Measurement Module Type 9	Slot 3: RIOSys 9002	DIO3	
50	Level Switch		Signal (+24VDC)	Control and Measurement Module Type 9	Slot 3: RIOSys 9002	DIO4	
51	Auxiliary Multi Relay Type 7	Relay 1	14	Control and Measurement Module Type 9	Slot 3: RIOSys 9002	DIO5	
52	Auxiliary Multi Relay Type 7	Relay 2	14	Control and Measurement Module Type 9	Slot 3: RIOSys 9002	DIO6	
53	Auxiliary Multi Relay Type 7	Relay 3	14	Control and Measurement Module Type 9	Slot 3: RIOSys 9002	DIO7	
54	Auxiliary Multi Relay Type 7	Relay 4	14	Control and Measurement Module Type 9	Slot 3: RIOSys 9002	DIO8	
55	Auxiliary Multi Relay Type 7	Relay 5	14	Control and Measurement Module Type 9	Slot 3: RIOSys 9002	DIO9	

56	Auxiliary Multi Relay Type 7	Relay 8	14	Control and Measurement Module Type 9	Slot 3: RIOsys 9002	DIO10	
57	Auxiliary Multi Relay Type 7	Relay 9	14	Control and Measurement Module Type 9	Slot 3: RIOsys 9002	DIO11	
58	Pump 1		Power (120VAC)	Auxiliary Multi Relay Type 7		Relay 1	
59	Pump 2		Power (120VAC)	Auxiliary Multi Relay Type 7		Relay 2	
60	Pump 3		Power (120VAC)	Auxiliary Multi Relay Type 7		Relay 3	
61	Pump 4		Power (120VAC)	Auxiliary Multi Relay Type 7		Relay 4	
62	Pump 5		Power (120VAC)	Auxiliary Multi Relay Type 7		Relay 5	
63	Solenoid Valve 1		Control (120VAC)	Auxiliary Multi Relay Type 7		Relay 8	
64	Solenoid Valve 2		Control (120VAC)	Auxiliary Multi Relay Type 7		Relay 9	
65	Pump 1		Modbus	Control and Measurement Module Type 9		Modbus 1	
66	Pump 2		Modbus	Control and Measurement Module Type 9		Modbus 2	
67	Pump 3		Modbus	Control and Measurement Module Type 9		Modbus 3	

68	Pump 4		Modbus	Control and Measurement Module Type 9		Modbus 4	
69	Pump 5		Modbus	Control and Measurement Module Type 9		Modbus 5	

The picture below shows how the connections are made.



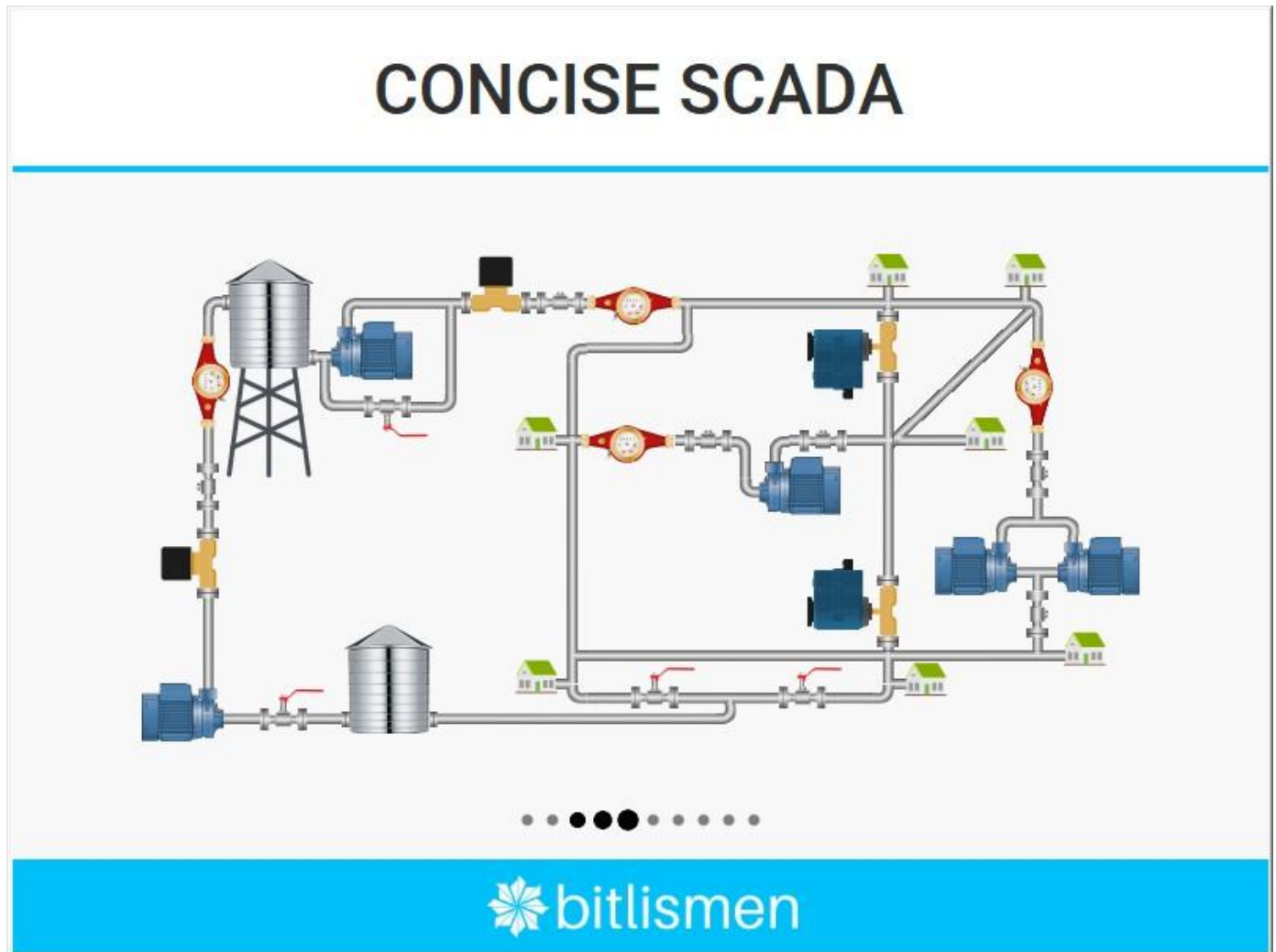
Please run the CONCISE SCADA



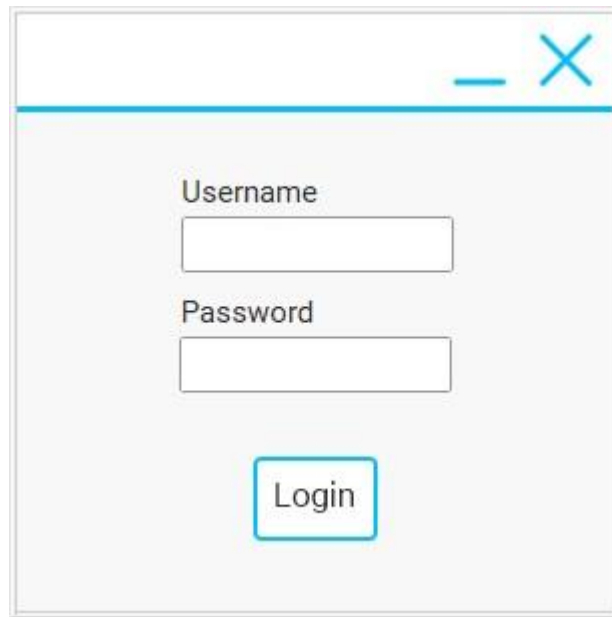
on the desktop.

7. SOFTWARE DESCRIPTION

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



After 3 seconds this window is closed and the Login page is open

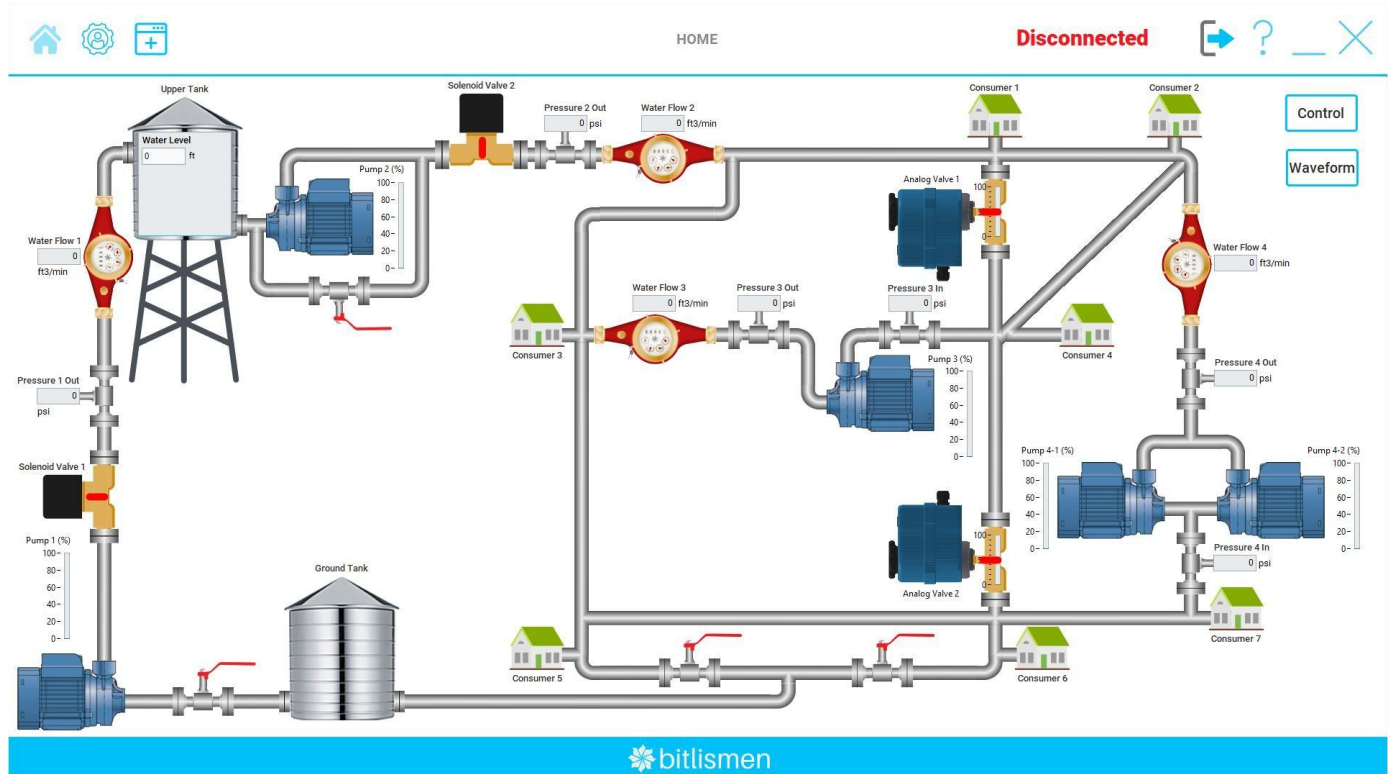


The default administrator credentials are as follows:

Username: *Administrator*

Password: *admin*

After successful Login, the Main window is opened.



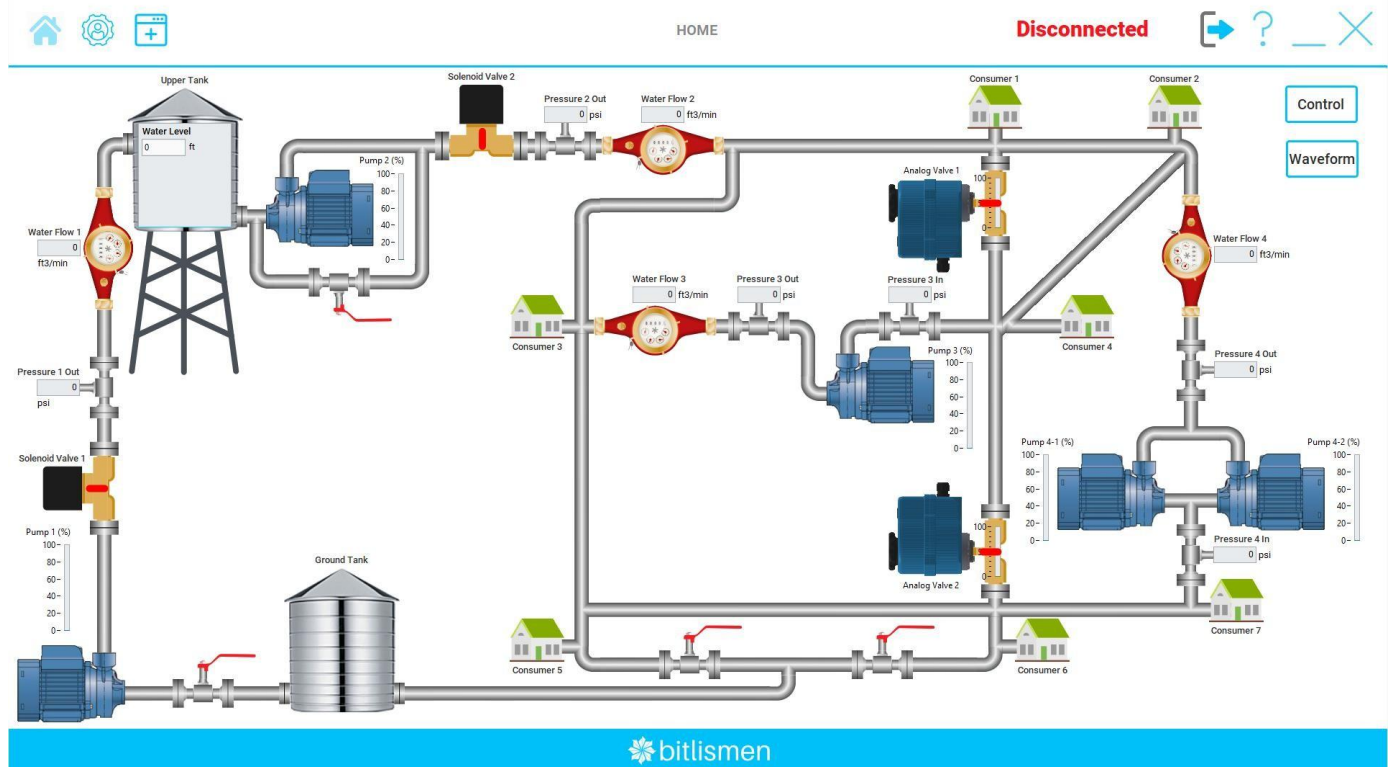
7.1. MAIN MENU ELEMENTS

ICON	DESCRIPTION
	Home - navigates to the home page
HOME	defines the path line
	User Settings - opens the NI Domain Account Manager where the administrator can manage the users
	New Window - opens a new window on the next available monitor. If all monitors are already used, then a new window will not open and the appropriate popup will notify you.
Connected or Disconnected	shows the Connected/Disconnected mode of the myRIO device inside the Control and Measurement Module.
	Logout - logs out from the system. After logging out the system continuous working in background.
	Help - navigates to the CONCISE SCADA.pdf
	Minimize - minimizes the software



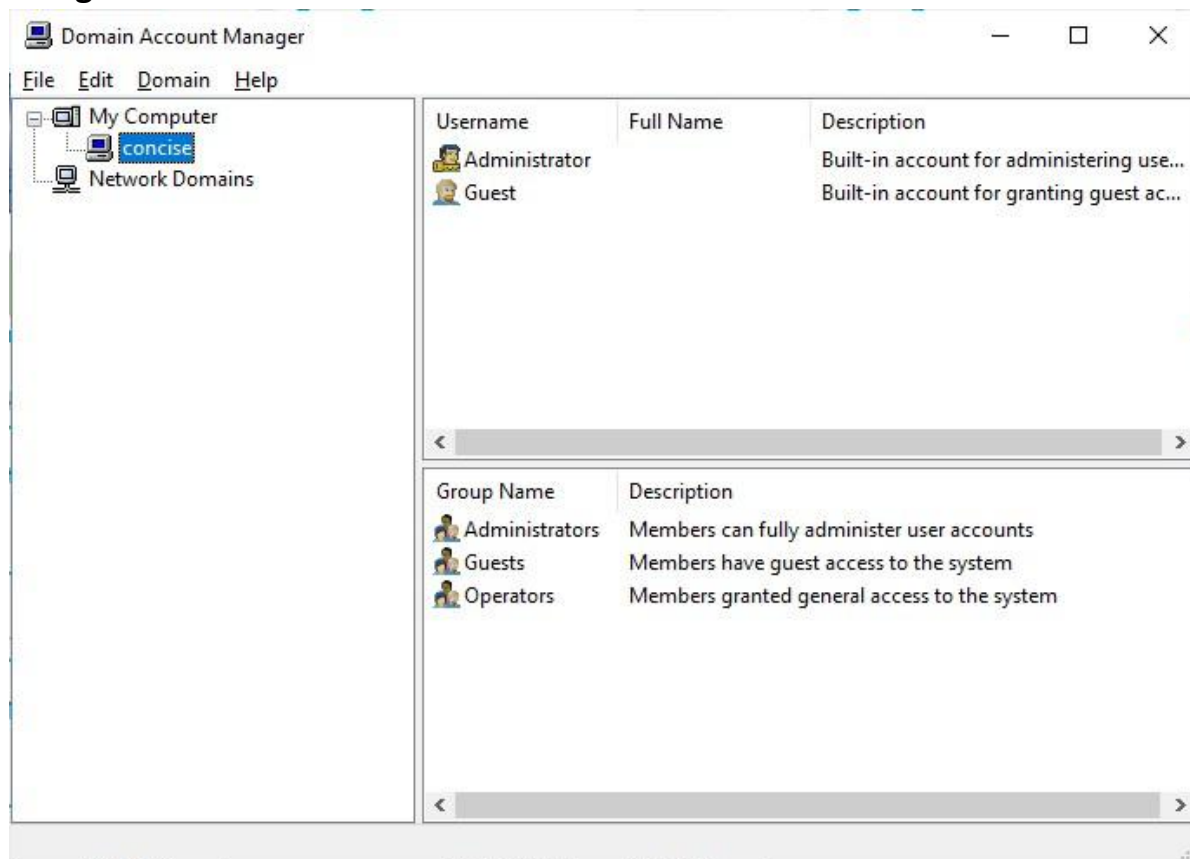
Exit - closes the software

7.2. HOME PAGE

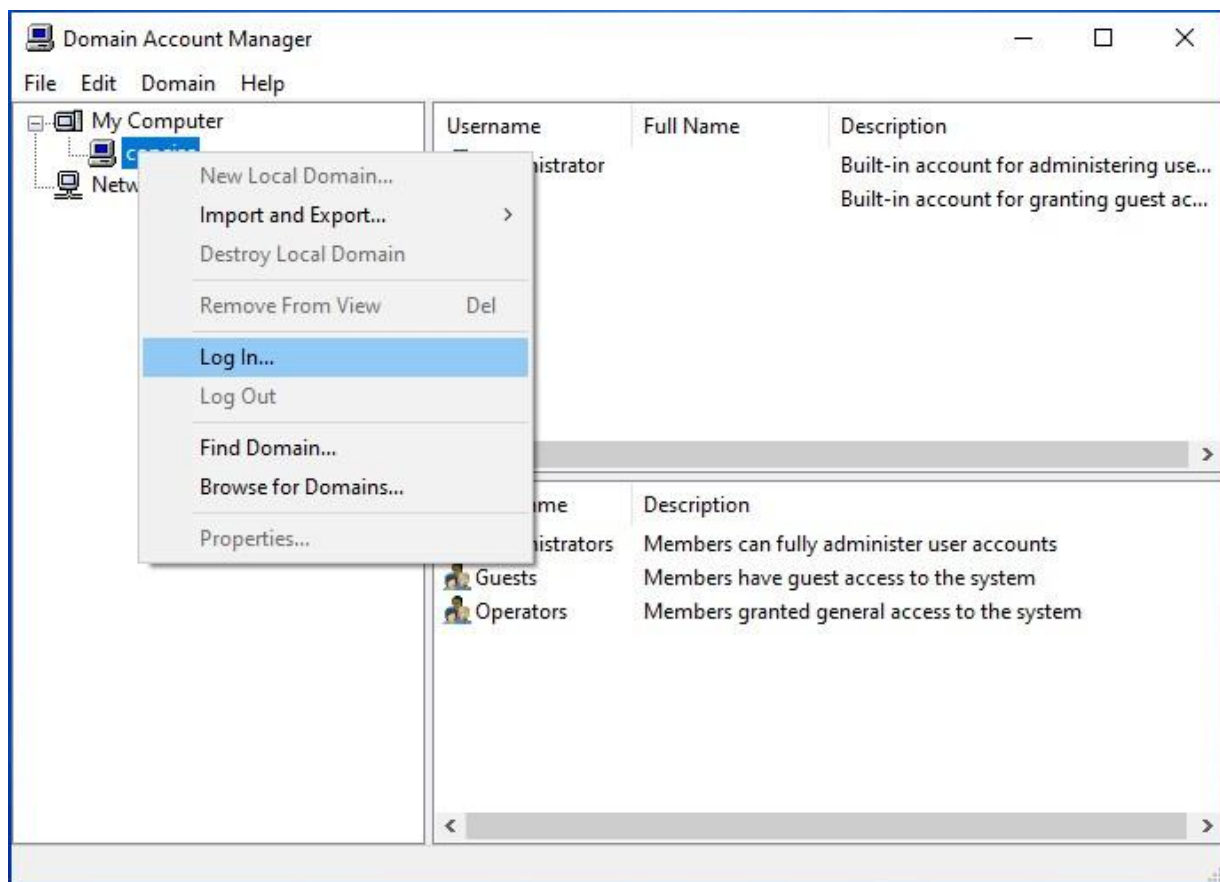


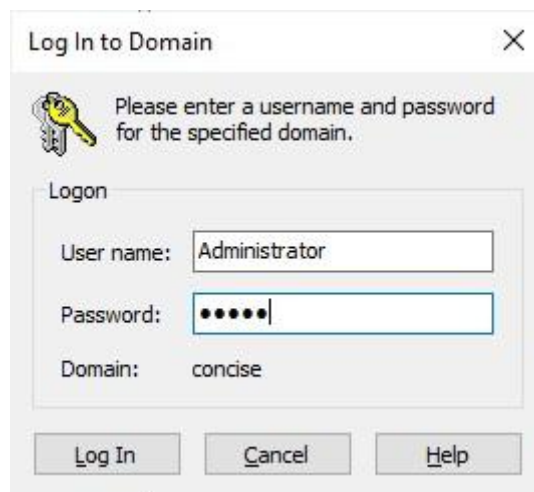
As you press the  User settings button, the NI Domain Account Manager will be open where the administrator can manage the users.

User Settings

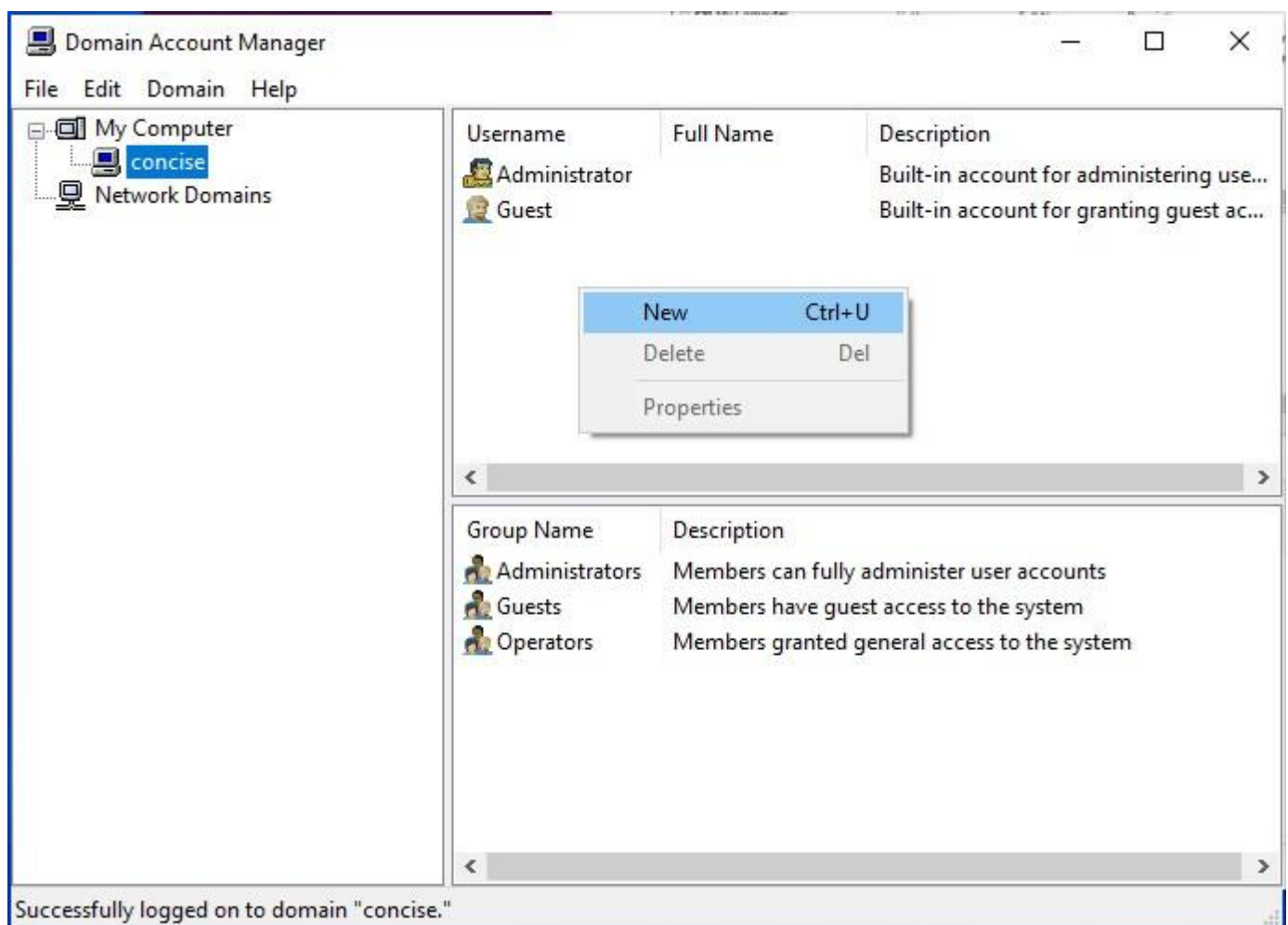


In order to configure the users, you need to login as an administrator.

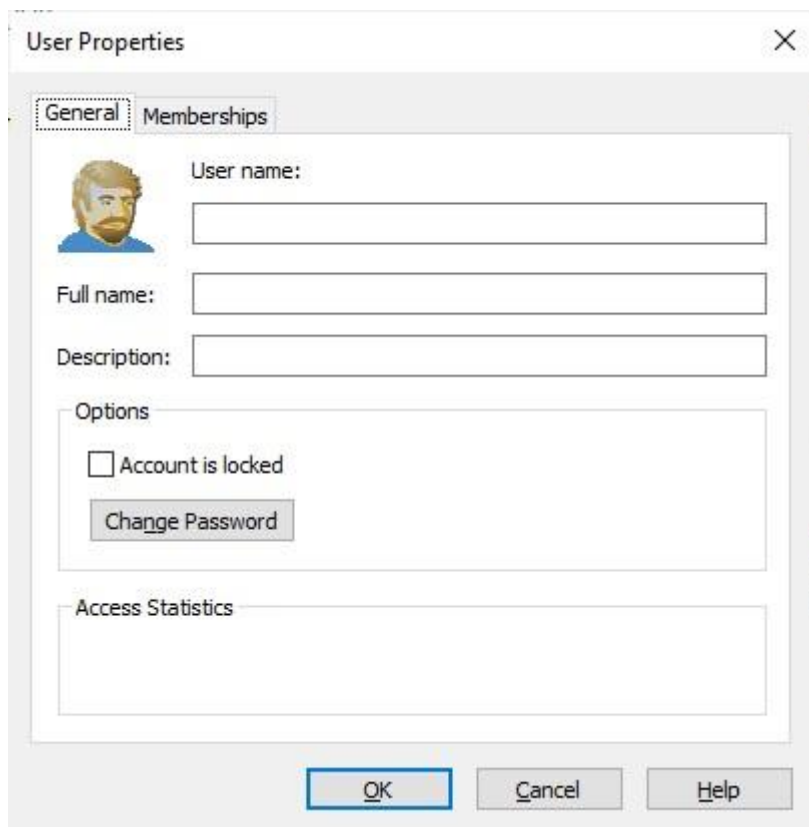




Right-click on the right side of the window and press New.

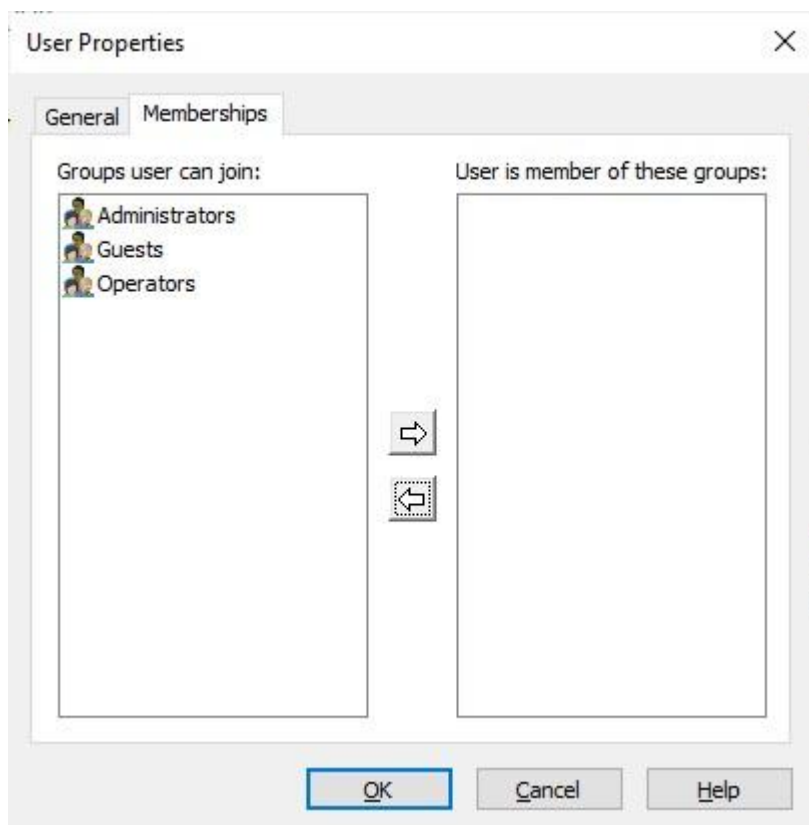


Specify a username. The password can be changed optionally.



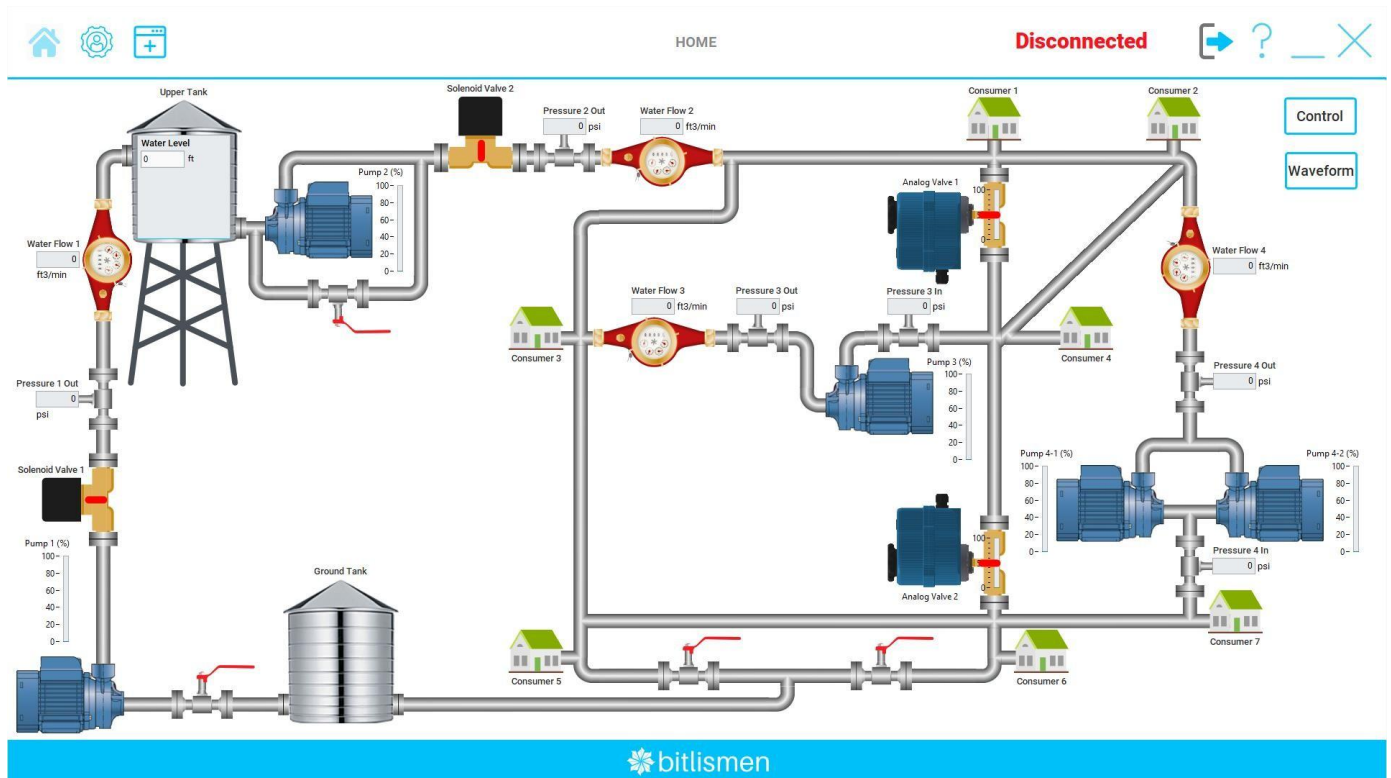
The 'User Properties' dialog box is shown with the 'General' tab selected. It features a user icon placeholder on the left. To the right, there are input fields for 'User name:', 'Full name:', and 'Description:'. Below these is an 'Options' section containing a checkbox for 'Account is locked' and a 'Change Password' button. At the bottom is an 'Access Statistics' section. The dialog has 'OK', 'Cancel', and 'Help' buttons at the bottom right.

On the Membership tab you can assign the user to a group.



The 'User Properties' dialog box is shown with the 'Memberships' tab selected. It displays two lists: 'Groups user can join:' on the left, which contains 'Administrators', 'Guests', and 'Operators', and 'User is member of these groups:' on the right, which is currently empty. Between the lists are two arrow buttons for moving items. The dialog has 'OK', 'Cancel', and 'Help' buttons at the bottom right.

On the Main window, there are the following controls and indicators:



Pump 1 (2, 3, 4-1, 4-2) – shows the power level of each pump (in %)

Pressure 1 (2, 3, 4) out – shows the pressure at the output of the pump (in psi)

Water flow 1 (2, 3, 4) - shows the water flow rate (in ft³/min)

Pressure 3 (4) In – shows the pressure at the input of the pump (in psi) Water

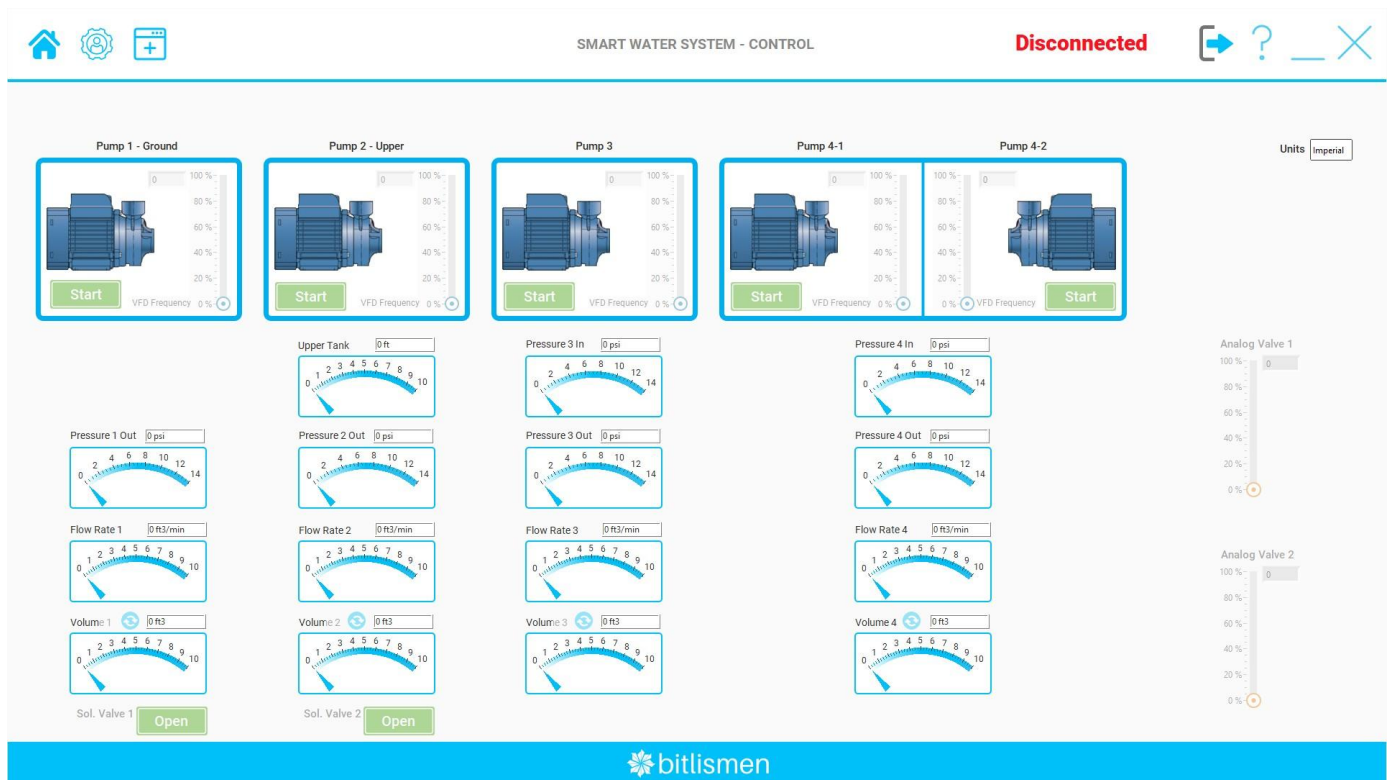
Level – shows the water level of the upper tank (in ft).

Solenoid Valve – shows the open (green vertical line) closed (red horizontal line) state of the valve

Analog Valve 1 (2) – shows the level of openness of the valve (in %)

Control

As you click on the button, the following page is open.



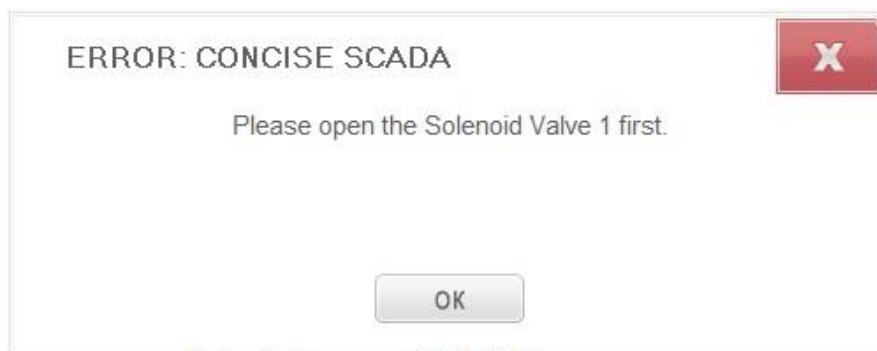
You can Start and Stop each pump and also set the power level (in %).

The system operates in two modes:

- Mechanical flow
- Gravity flow

In case you want the system to operate in the mechanical flow, you should close the valve of the gravity flow and start the Pump 2.

When you start Pump 1 (or Pump 2), and if the Solenoid Valve 1 (Solenoid Valve 2) is not open, then the Pump will not start until the Solenoid Valve is open first.



When you close the Solenoid Valve 1 (or Solenoid Valve 2) and if the Pump 1 (or Pump 2) is not stopped, then the valve will not close until the Pump is stopped first.



The user can select the units (imperial or metric) of the measured parameters.



For Pump 1 – Ground you can control the following actuators and monitor the sensor values.

Pressure 1 Out – shows the pressure at the output of Pump 1 - Ground

Flow rate 1 –shows the water flow rate flowing through Pump 1 - Ground

Volume 1 – shows the current volume that has flown through Pump 1 - Ground



- resets the water flow meter value



- opens and closes the solenoid valves.

For Pump 2 – Upper you can control the following actuators and monitor the sensor values.

Upper tank – shows the water level of the Pump 2 - Upper

Pressure 2 Out – shows the pressure at the output of Pump 2 - Upper

Flow rate 2 –shows the water flow rate flowing through Pump 2 - Upper

Volume 2 – shows the current volume that has flown through Pump 2 – Upper



- resets the water flow meter value



- opens and closes the solenoid valves.

For Pump 3 you can control the following actuators and monitor the sensor values.

Pressure 3 In – shows the pressure at the input of Pump 3

Pressure 3 Out – shows the pressure at the output of Pump 3

Flow Rate 3 - shows the water flow rate flowing through Pump 3

Volume 3 – shows the current volume that has flown through Pump 3

For Pump 4-1, (4-2) you can control the following actuators and monitor the sensor values.

Pressure 4 In – shows the pressure at the input of Pump 4 -1 (4-2)

Pressure 4 Out – shows the pressure at the output of Pump 4 -1 (4-2)

Flow Rate 4 – - shows the water flow rate flowing through Pump 4 -1 (4-2)

Volume 4 - shows the current volume that has flown through Pump 4 -1 (4-2)

Analog Valve 1, 2 - you can set the openness level of the Analog valves

Waveform

As you click on the button, the following page is open.



Here you can monitor the sensor values on the graphs.

The user can select the units (imperial or metric) of the measured parameters.



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

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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