Acta Mechatronica - International Scientific Journal about Mechatronics
Volume: 9 2024 Issue: 1 Pages: 1-5 ISSN 2453-7306

https://doi.org/doi:10.22306/am.v9i1.105

Received: 22 Jan. 2024
Revised: 19 Feb. 2024
Accepted: 03 Mar. 2024

Model of the regulation of the water level reservoir

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Keywords: sensor, measurement, water level, regulation.
Abstract: The goal of this work was the design of an educational model of a reservoir with water level regulation. This educational model is to be used in education in subjects about regulatory and control systems such as plants. The device contains sensors and actuators that can be connected to various control systems. The application of this model will improve the knowledge and practical skills of students who will train the design of control systems for a specific plant.

1 Introduction

A graduate of mechatronics studies should have theoretical knowledge as well as practical experience, skills and habits that improve his knowledge level.

Teaching and training the design of control systems is quite difficult without the use of practical didactic models. Theoretical education without practical devices is not very illustrative and does not adequately prepare students for practical tasks that they may encounter in practice [1-8].

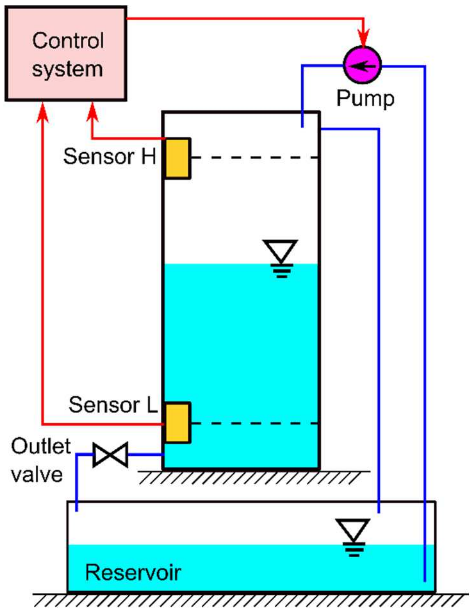

Figure 1 The concept of a controlled water tank

This work deals with the design of a didactic educational model for students' practical exercises. Students will thus have a practical space for their training in the design and creation of automated devices with control systems.

The proposed concept of the educational facility (Figure 1) contains a plate formed by a container, which is filled with water using a pump so that the water level in the tank is maintained between the upper and lower limit values. Reaching the upper or lower limit level of the water level is detected using float sensors with a switching output. Based on the information obtained from these sensors, the control system can then regulate the activity of the pump when filling the water tank (Figure 2). The tank also contains a safety outlet in case of failure of the control system to prevent overflow of the tank and uncontrolled leakage of water from the system. The system uses a gear pump in combination with a non-return valve against backflow of water in the supply pipe.

Figure 2 Practical implementation of a functional model of a water reservoir

For practical purposes and the creation of more complicated tasks, it is possible to organize these tanks into a system of tanks with a common control system (Figure 3). The design of the control task can then be based on the concept of control of the gradual filling of individual

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tanks, and the functional and energy aspects of the problem can also be solved, as well as safety application tasks.

2 Concept design of the tank system

The proposed concept (Figure 3) contains three water tanks A, B, C with separate pumps and water level sensors and an outlet valve. The students' task is to implement various types of control tasks on this system.

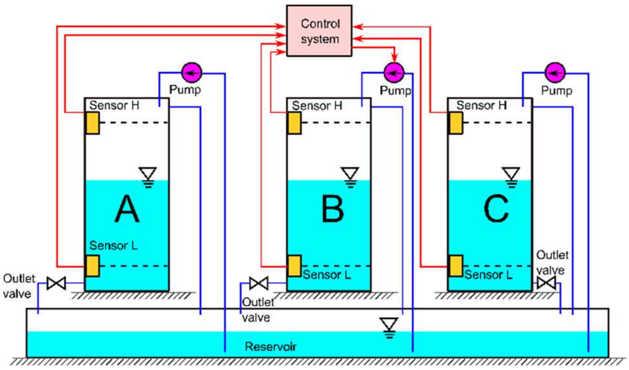

Figure 3 Concept design of the reservoir system

Specific dimensions of the tank in the shape of cylinders were proposed (Figure 4). For these tanks, it is possible to express the rate of water outflow from the tank (1):

$$v = \sqrt{(h_1 - h_2) \cdot 2g} \tag{1}$$

Where h_1 is the height of the water level in the tank and h_2 is the height of the outlet opening from the tank.

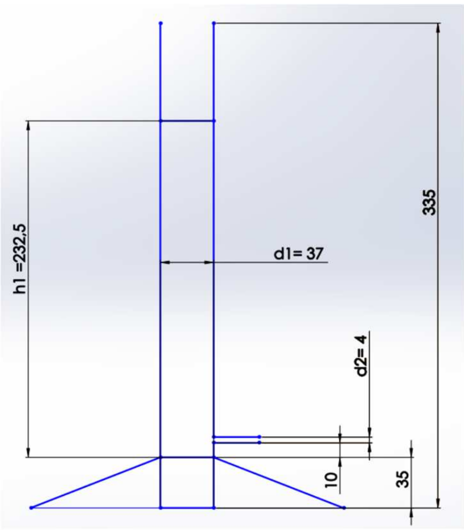

Figure 4 Design of tank dimensions A, B, C

If we consider water as an incompressible fluid, then it is possible to write the equation (2):

$$h + \frac{v^2}{2g} + \frac{p}{\rho g} = const \tag{2}$$

The proposed model of the system includes a water collector into which water is poured from cylinders A, B, C and then the water is distributed to the main water reservoir.

Figure 5 CAD model of the designed tank system

The transfer of water from tanks A, B, C is realized using electromagnetic solenoid valves (Figure 3, Figure 5) controlled by the control system.

Reed switches for water level detection are placed in the tanks (Figure 6).

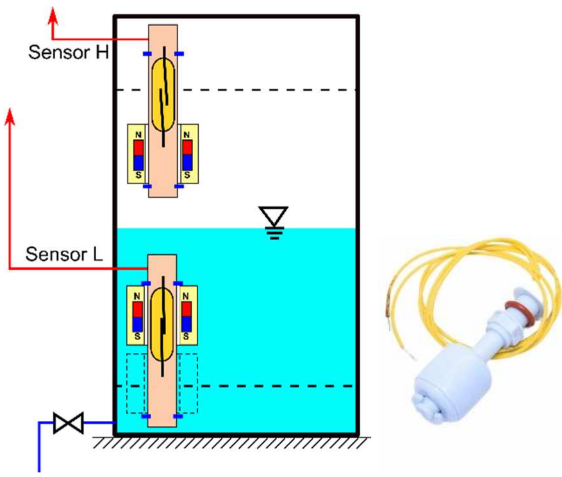

Figure 6 Float level reed sensors principle

These are switching elements that react to the presence of water by means of a float that switches on or off the relay contact located in the sensor with a permanent magnet (Figure 7). This type of sensor is small and compact and can be used even in aggressive liquids.

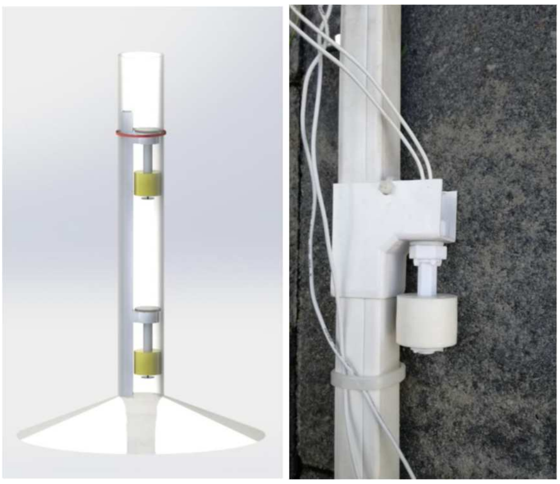

Figure 7 Float level reed sensors installation

The functional diagram with the indication of the water flow and the location of the sensors (Figure 8) is the basis for creating a program for the control system.

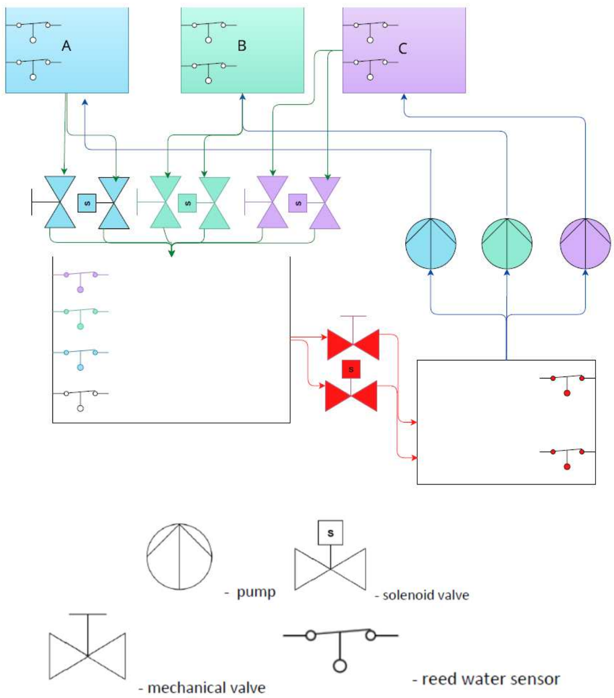

Figure 8 Location of the tested sensor

3 Control program

A PLC system consisting of a CPU module and an HMI module was selected for controlling. The program for the PLC was created in FBD (Function Block Diagram) language. For better clarity, individual subprograms are organized into separate networks. Valve Va is controlled by the program (Figure 9) and has the task of draining water into the main tank.

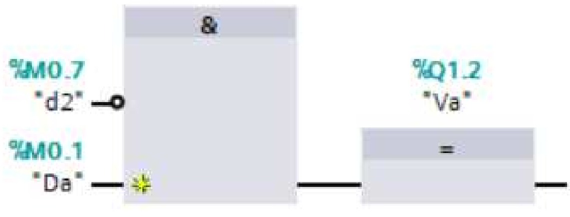

Figure 9 Network for valve A

Pump A pumps water when cylinder A is empty until the moment when the cylinder is filled up to the upper sensor (Figure 10).

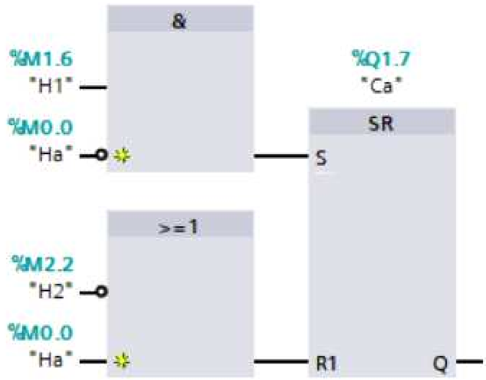

Figure 10 Network for pump A

Analogously, it is possible to create a network for valves B, C and pump B, C. Another network is created for the collection container (Figure 11).

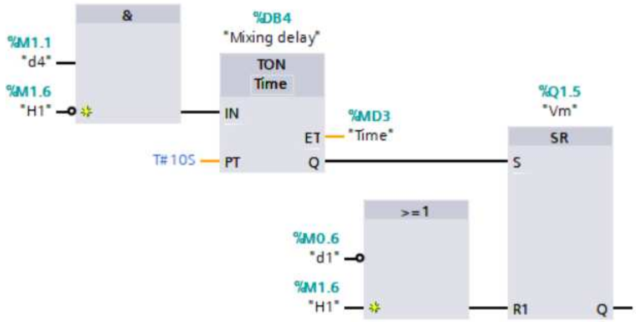

Figure 11 Network for collection container

During the operation of the real device, errors related to the operation of the device such as sensors, actuators, installation, data communication and other problems may also occur in the system. For this purpose, in order to increase the safety of the device, program codes are designed to detect such error states (Figure 12).

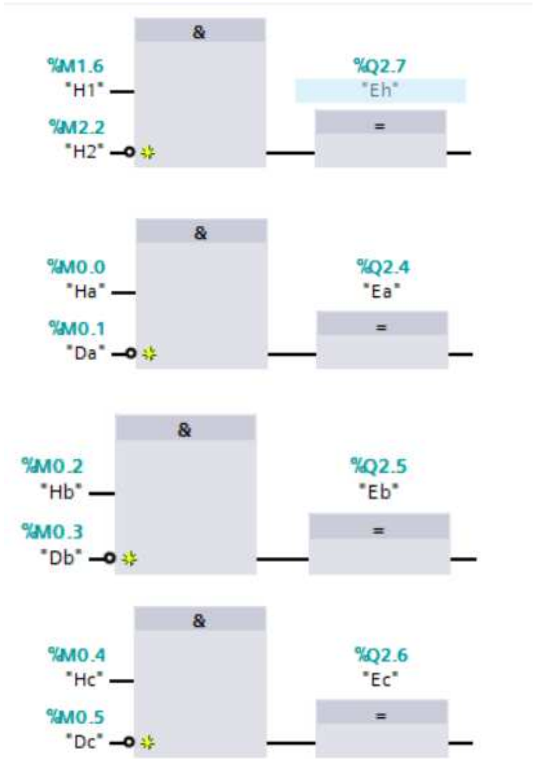

Figure 12 Program codes for device error states

A program was created for the HMI interface (Figure 13), where the flow of liquid inside this system will be indicated by changing colors. This interface will be used for monitoring the entire system and possibly user intervention.

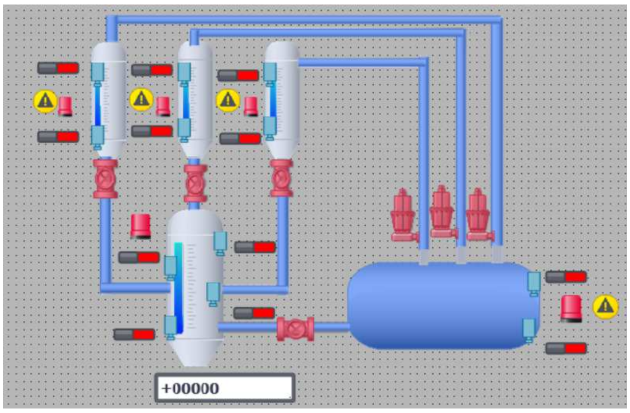

Figure 13 Control concept design

Subsequently, simulations of this control system together with the controlled system were carried out. The simulation confirmed the correctness of the proposed control system solution.

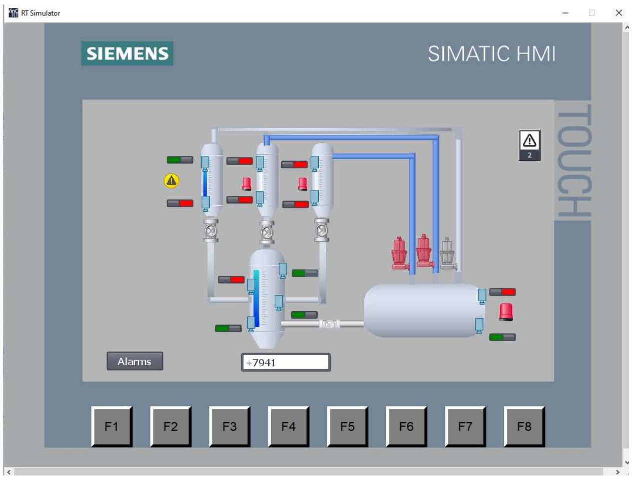

Figure 13 Simulation of the operation of this system

4 Conclusion

A control concept was designed for the defined task of pumping fluids, which was subsequently tested. Simulations of the operation of the device confirmed the correctness of the proposed solution. By testing with the help of simulation, conditions were also verified experimentally, which would not be possible to test on a real device due to the high risk of damage to the system or the risk of liquid leaking into the surroundings of the system. The importance of such simulation testing lies in the early diagnosis of the proposed device, even at the concept design stage, which can significantly facilitate the design of such a device and save not only time but also the costs associated with device repair and modification [9-23].

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