# Control of reactor temperature and pressure using cascade control during polyvinyl chloride production

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**Abstract.** Improvement and modernization of the technological process of polyvinyl chloride production requires the appropriate development of computer modelling systems, which ensure the following: identification and maintenance of optimal modes of technological processes that contribute to continuous operation, as well as the use of intelligent systems of modelling and control of technological devices. The article proposes pressure-dependent control of the temperature in the reactor, which affects the quality indicators of the technological process, using the cascade control method during the production of polyvinyl chloride. In this work an imitation model of the technological process was developed.

## 1 Introduction

Polyvinyl Chloride (PVC) is one of the most widely used polymers in the world. Due to its versatile nature, PVC is used extensively across a broad range of industrial, technical and everyday applications including widespread use in building, transport, packaging, electrical, electronic and healthcare applications [1-4].

PVC is a very durable and long lasting material which can be used in a variety of applications, either rigid or flexible, white or black and a wide range of colors in between [5].

The essential raw materials for PVC are derived from salt and oil. The electrolysis of salt water produces chlorine, which is combined with ethylene (obtained from oil) to form vinyl chloride monomer (VCM). Molecules of VCM are polymerized to form PVC resin, to which appropriate additives are incorporated to make a customized PVC compound [6-8].

## 2 Materials and methods

Currently, mainly SIMATIC S7 300, S7 400, S7 1200, S7 1500 controllers are used to implement the software of automatic control systems of technological processes. HMI (Human Machine Interface) Comfort TP 700, 900, 1200 control panels are also used in this regard. Their quality and accuracy are high, and it allows to control all parameters

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simultaneously. In this article, we have created cascade temperature and pressure control logic in TIA Portal V15.1 software environment using S7 1500 and Comfort TP 900 devices. In this case, we can simultaneously monitor the value of all parameters by looking at the graph [9-10].

Since it is an effective way to remotely control and monitor production processes using an automatic control system, this paper presents a method for controlling a reactor in a polyvinyl chloride production process using this system. It is desirable to transfer hot and cold water to the heat exchanger on the surface of the reactor using the recuperative heat exchange process to control the pressure and temperature when transferring substances to the reactor in series [11-14].

In Figure 1 below, it is necessary to adjust the temperature in the process by the pressure value through the heating and cooling water using heat exchangers installed on the sides of the reactor designed for the reaction process, where the pressure is 8 kgc/m$^2$, and the temperature should be in the range of 45-60°C. Below is a schematic diagram of the process [14-16].

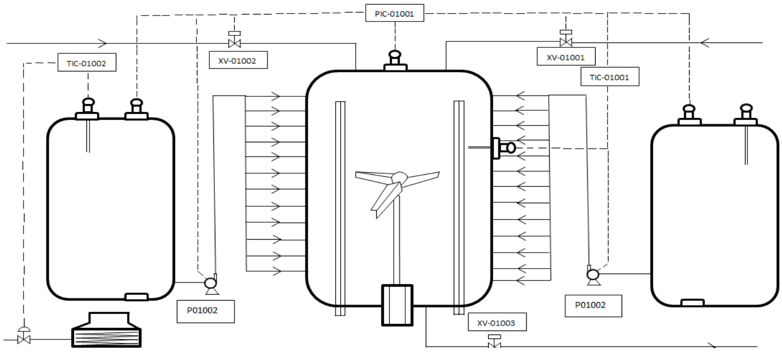


**Fig. 1.** Structural scheme of the PVC preparation process.

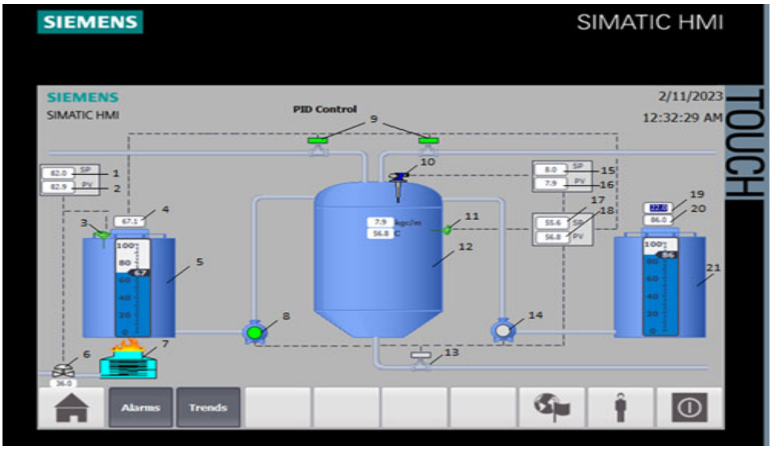
1-hot water tank, 2-reactor, 3-cold water tank.

In this scheme, initiator, dispersant, vinyl chloride monomer and hot water are poured into the main raw materials for PVC production through XV-01001 and XV-01002 executive mechanisms, semi-finished products are obtained through XV-01003 executive mechanism. In this case, the initiator accelerates the polymerization, i.e. chain reaction, of substances inside the reactor. By painting the walls of the reactor before starting the reaction, the risk of products sticking to the walls of the vessel during the reaction is avoided. The amount of raw materials required for one reaction is given below [17-20].

- 45-50 °C hot water quantity: 30 t.;
- regenerated VCM: 3 t.;
- pure VXM: 21 t.;
- dispersing agent: 1 ALCOTEX 8048 -480 kg;
- disperser: 2 LM-10HD-135 kg;
- dispersant: 3 Hydroxypropyl MethylCellulose-315 kg;
- initiator: 1 AROX TBPND-75-80 kg;
- initiator: 2 AROX from CPND-75-253 kg;

After the above raw materials are loaded into the reactor, the mixer is started and the reaction starts. The reaction process takes an average of 3.5 hours. 35 kg of terminator is used to stop the polymerization process. PVC is a white powder with a density of 1350-1460 kg/m³. Industrially produced polyvinyl chlorides have a molecular weight of 30,000-150,000.

Below (Figure 2) is the technological process based on the structural scheme of the process an imitation model of automatic control is proposed.



1. Installation of hot water temperature in the tank, 2. Hot water temperature in the tank, 3. Hot water temperature sensor, 4. Hot water tank level, 5. Hot water storage tank, 6. Gas o tooth valve, 7-gas burner, 8-hot water pump, 9-executive mechanisms, 10-pressure sensor, 11-sensor measuring the temperature inside the reactor, 12-reactor, 13-output part of semi-finished product, 14-cold water pump, 15-reactor pressure setting point, 16-reactor pressure value, 17-reactor temperature setting part, 18-reactor temperature, 19-cold water temperature, 20-cold water tank level, 21 - cold water tank.

**Fig. 2.** Simulation model of PVC reaction process plant elements.

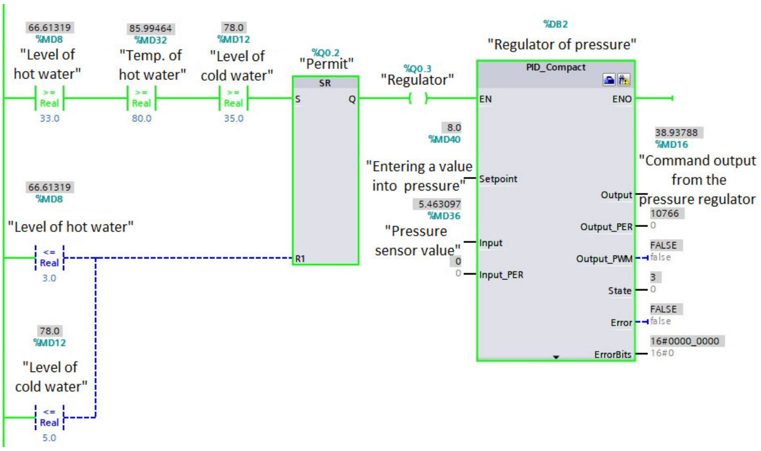


**Fig. 3.** A logical diagram of the parameters required to initiate a reaction.

With the help of 2 pumps, hot water is directed from the left side and cold water from the right side. A heat exchange process is used inside the reactor, which affects the process by transferring the temperature of hot water flowing through it to the surroundings. The signal transmitted from the temperature sensor is fed to the PID controller. The signal from the regulator is fed to the frequency converter and from there it is transmitted as a continuous output signal to the hot water pump and to the cold water pump to raise the temperature. A logic diagram representing the operation of the model is presented in Figure 3 below.

Network 1: it does not allow to install a pressure device if the amount of products needed to carry out the reaction inside the reactor is not at the specified value. Because if the temperature increases during the reaction, the amount of cold water or hot water may not be enough if it decreases. In order for PID to be allowed, the following conditions must be met.

- hot water reservoir level – 33%
- cold water tank level - 35%
- hot water temperature - 80°C

If the amount of hot or cold water gets too low, it automatically shuts down the PID after warning to safely stop the reaction and prevent the pumps from failing.

- if the hot water level drops below 3%
- if the cold water level drops below 5%

At the same time, it ensures that the pumps do not turn off.

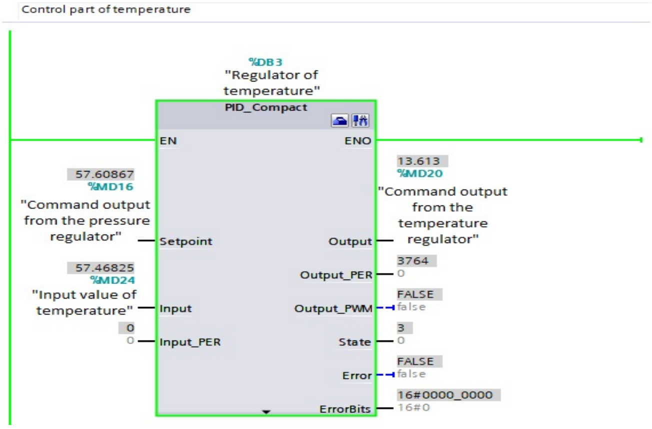


**Fig. 4.** Cascade temperature control scheme.

In this case, the pressure regulator acts as a master, and the temperature regulator acts as a slave. For the cascade control method, the first regulator must be in auto mode and the second regulator must be in cascade mode. Address MD16 is the output value from the pressure regulator, and MD24 is the value coming from the temperature sensor inside the reactor. The MD20 controller is commanded to operate the cold water or hot water pump depending on the difference between the inlet temperature and the set temperature.

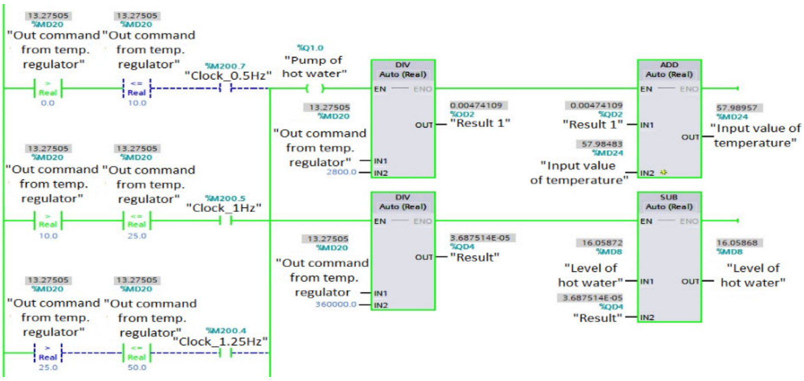


**Fig. 5.** Logic diagram of temperature rise and decrease of hot water tank level.

In this case, the value output from the temperature controller affects the amount of temperature rise inside the reactor. M200.7 pulses every 0.5 s from the memory address and sets the value by adding an amount to the temperature. At the same time, it also sets a value for the decrease in the level in the hot water tank. The reason we use Div (division element) is because the value in the MD20 address is calculated as the value of 1 hour and adds or subtracts so much value every second, so we need to divide the value of 1 hour into 1 second by 3600. The higher the value of MD20, the faster the pulse will pass through the line. The diagram below includes a logical diagram of the operation of hot water and cold water pumps.

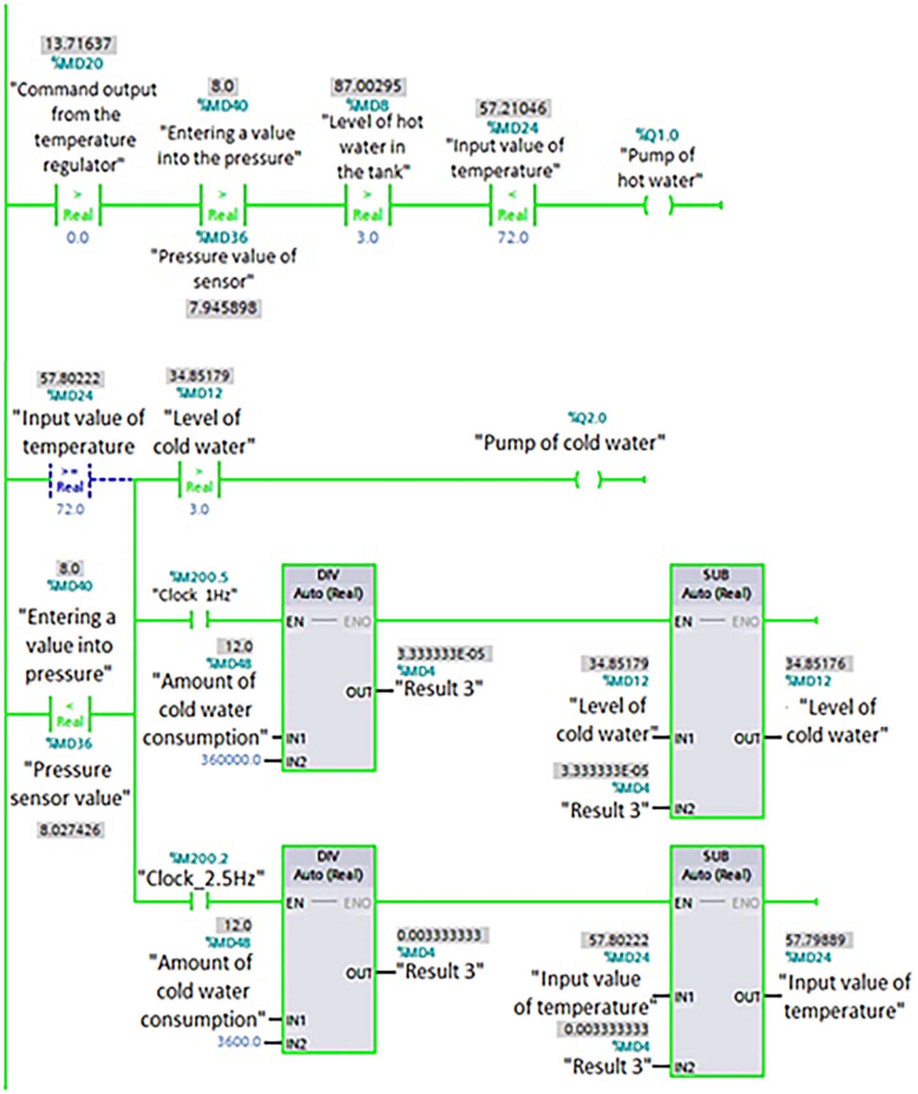


**Fig. 6.** Logical scheme of operation of hot water and cold water pumps.

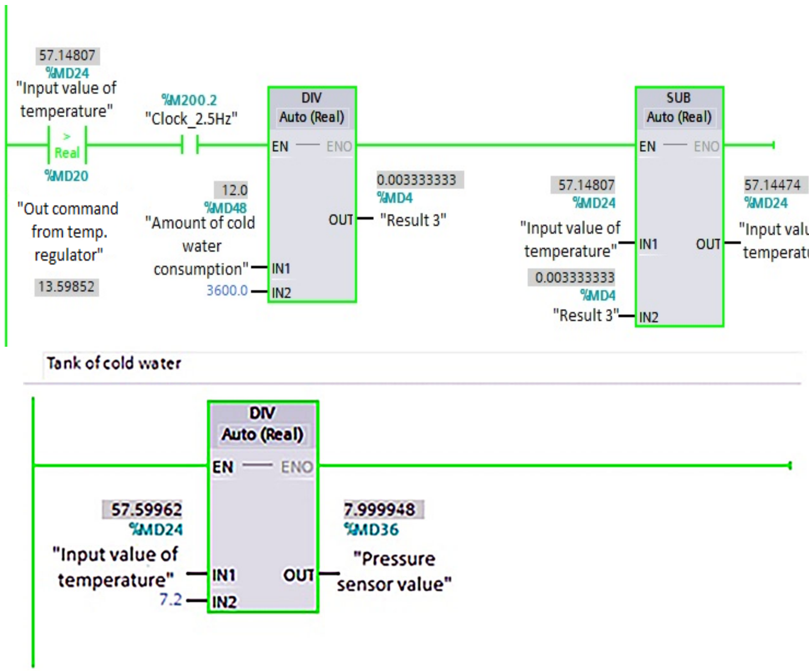


**Fig. 7.** Logical scheme of dependence of the temperature value inside the reactor on the pressure value.

In this case, several conditions must be met at the same time for the hot water pump to work. Our input setting for pressure must be greater than the value inside the reactor and the hot water tank level must not be below 3%. If the temperature inside the reactor is 72°Ceven if it exceeds MD24>72°Cautomatically stops the reaction process and commands the operation of the cold water pump to lower the temperature inside the reactor. Also, the level of the cold water tank at address MD12 starts to drop.

When the level of the cold water tank drops below 5%, the pump is commanded to turn off. Because if there is no water in the tank, the pump may run dry and burn the motor.

## 3 Results

Since the pressure is integrally related to the temperature, we can calculate the value of the temperature only through the value of the pressure. For this, we use the Mendeleev Clapeyron equation:

$$PV = \frac{m}{\mu} RT, \tag{1}$$

where the expression of mass in terms of density and volume is as follows:

$$m = \rho V \tag{2}$$

If we put the formula (1.2) into the formula (1.1), it will look like this:

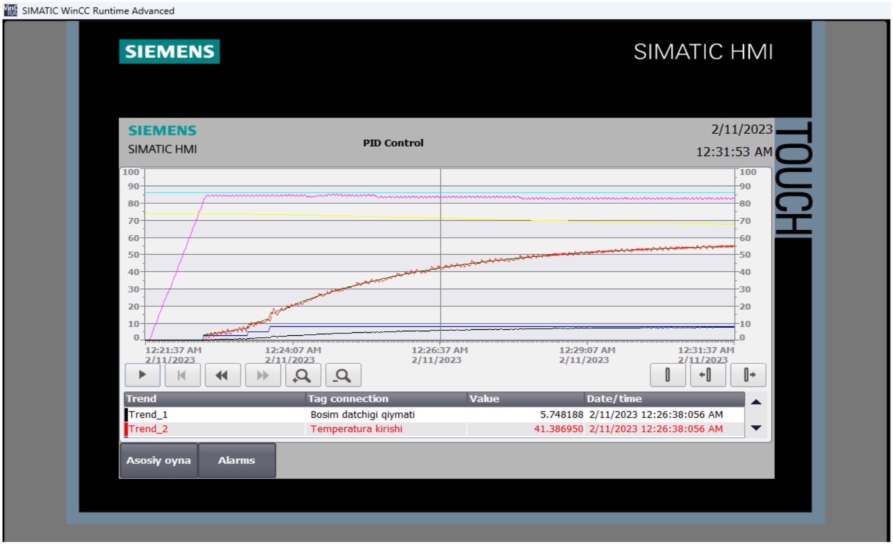
$$PV = \frac{\rho V}{\mu} RT \rightarrow P = \frac{\rho RT}{\mu} \tag{3}$$

Using the values given above, we calculate the relationship between pressure and temperature:

$$\rho = 1400 \text{kg/m}^3,\ \text{R}=8.31, \mu = 16000$$

$$P = \frac{\rho RT}{\mu} = \frac{1400 kg/m^3 \cdot 8.31 \cdot T}{16000} = 0.72 \cdot T$$

It can be seen from the above that pressure and temperature are directly proportional to each other, and when the pressure is 72 MPa, the temperature is 100 K. It follows that the correlation coefficient is equal to 7.2.



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| Trend_2 | Temperatura kirishi | 41.386950 | 2/11/2023 12:26:38:056 AM |

**Fig. 8.** The result of the control graph of temperature and pressure in working condition.

The graph shows the value of each parameter in a different color: yellow color - hot water reservoir level, air color - cold water reservoir level, green color - temperature setting value, red color - temperature inside the reactor, blue color - pressure is the set value, black color is the pressure value inside the reactor.

We can see the result in the graph that the set values can be reached in a short period of time and the stability can be maintained. Also, the level of accuracy of the selected cascade control mode is high.

## 4 Conclusion

In the article it was proposed to control the temperature in the reactor, which affects the quality parameters of the technological process, using the cascade control method, depending on the pressure. An imitation model of the technological process was also developed.

The resulting model can then be used to implement a cascade adjustment circuit

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