

Experimental analysis of the programmable logic controller

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Abstract. This article analyses analogue temperature measurements using components of a programmable logic controller (PLC). In addition, the practical application of discrete control algorithms was examined. Real-time monitoring of temperature variations was ensured through the PLC module's input and output channels. The analogue signal in the range of 0...10 V provided by the thermocouple sensor was linearly converted within the temperature interval of 0...60 °C. This demonstrated the correspondence between the temperature and the output signal. When the specified threshold value (TUST = 45 °C) was reached, the discrete output was switched to the TRUE state. In this case, the control algorithm demonstrated the stability of the module. The results showed the high accuracy of PLC systems in working with analogue-discrete signals. They also confirmed the efficiency of automatic monitoring of temperature processes and the potential for creating adaptive algorithms in an IoT environment. This study contributes to ensuring the real-time stability of PLC systems.

INTRODUCTION

Programmable Logic Controller (PLC) components are used in the automation of technological processes. They are applied in monitoring technological process systems. PLC systems ensure real-time control of complex technological processes. They provide the capability to monitor these processes, thereby playing an important role in maintaining overall efficiency. The stability of automated systems is ensured through the use of PLC [1].

Modern technological processes widely employ Programmable Logic Controllers (PLC). Their function is not limited to controlling only discrete processes. PLC are also required to control analogue physical quantities with high accuracy. This, of course, ensures the possibility of real-time monitoring of systems [2]. In this process, measuring analogue signals such as temperature, pressure, and flow is of great importance. Moreover, converting these signals is one of the essential tasks of PLC systems [7].

In the automatic control of temperature processes through PLCs, PID or on/off control algorithms are used. These algorithms ensure the accuracy of the control process, thereby maintaining the overall stability of the system. Temperature monitoring via PLC systems is of great significance in technological processes [8]. This system provides a stable response to environmental changes and demonstrates high efficiency [3-38].

In addition, the accuracy of analogue-discrete signal converters in PLC modules is critically important. Their accuracy plays a key role in ensuring the reliability of measurement systems. During the normalisation of analogue signals in the 0...10 V or 4...20 mA standards, the technical parameters of PLC modules become crucial. Parameters such as linearity, sensitivity, and resistance to noise are among the important aspects. The quality of process automation depends on these parameters [4].

The integration of IoT with a PLC system enables the transmission of data to the cloud in real time [9]. This creates conditions for overall monitoring of the system and the intelligent analysis of data [5]. This, of course, ensures the adaptability of technological processes to the digital ecosystem [10]. The stability and safety of PLC systems depend on the variability of technological process conditions. They are characterised by their resistance to factors such as temperature and electrical noise [6].

EXPERIMENTAL RESEARCH

The programmable logic controller (PLC) is designed for use in a technological process environment. It is a digital electronic system intended for the user. It employs programmable memory that allows storing instructions in internal memory. These instructions serve to define logic algorithms. It performs tasks such as real-time measurement and arithmetic operations. It is used for monitoring various types of technological processes through digital or analogue inputs and outputs. The PLC is most commonly used for the automation of technological processes. The PLC often operates reliably even under unfavourable environmental conditions.

The PLC is a device intended for use in real-time operation. For application in automated systems, the PLC is equipped with discrete and analogue inputs and outputs.

The discrete input (DI) is intended for supplying the PLC with parameters that have only two states: on or off, signal present or absent. These states are defined by the voltage level applied to the DI.

Depending on the model of the programmable logic controller, 5 V, 12 V, and 24 V direct current are used. In addition, 110 V and 220 V alternating current are used as the most common DI voltages.

In some cases, 24 V direct current discrete inputs are used in PLCs. If 24 volts of direct current is applied to such a DI, the PLC recognises the presence of the input signal as "logical one" (TRUE). If it is 0 volts, the PLC determines the absence of the input signal as "logical zero" (FALSE).

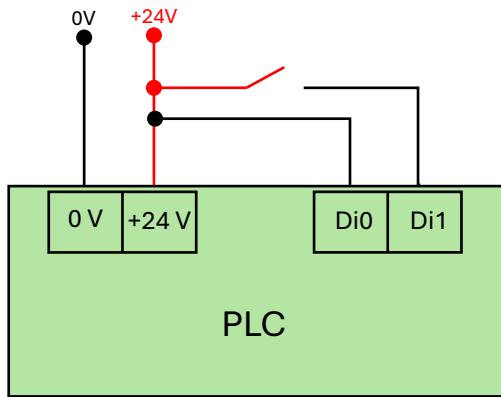


FIGURE 1. Operating principle of discrete inputs

Limit switches, level sensors, and other discrete sensors are connected to the DI. Some sensors are connected to several DIs simultaneously. In this case, the electromechanical manometer provides two discrete signals: the minimum and maximum pressure levels.

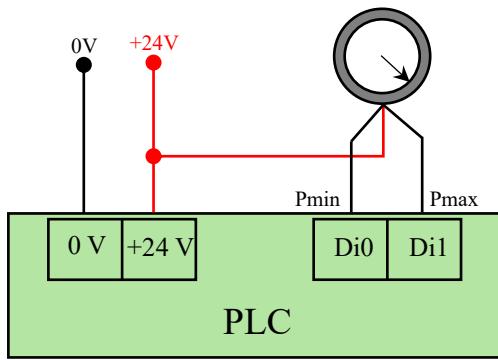


FIGURE 2. Connecting the electromechanical manometer to two discrete inputs

The discrete output (DO) in a PLC is used to switch on devices connected to it: valves, magnetic starters, and intermediate relays. In this case, the discrete output is a switch that is closed by the command of the programmable logic controller. The discrete output can have two states: open (FALSE) and closed (TRUE). If the output is in the closed state, the connected device is switched on. If it is in the open state, it is switched off.

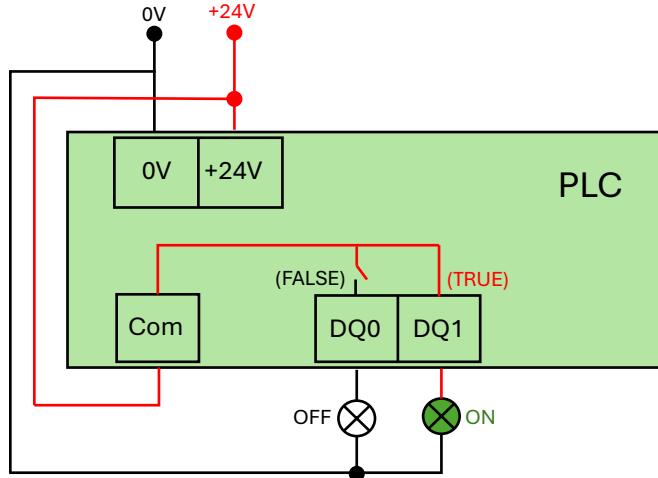


FIGURE 3. Operating principle of discrete outputs

Procedure for conducting the experiment. Our experiments were carried out to analyse the number of inputs and outputs in the PLC and their parameters (Figure 3). In this process, a thermocouple sensor with a measurement range of 0...60 °C and an output signal range of 0...10 V was used. When the PLC module switch is turned on, the thermocouple sensor is activated. When the temperature reaches the specified value, the light indicator turns on. In this case, the output signal range was set to 0...10 V and the measurement range was set to Ain low = 0 and Ain high = 60. A value of 45 °C was assigned to the TUST variable. The switch of the technological data sensors module was turned on. The temperature processes in the system were monitored. The temperature element was adjusted by means of a regulator.

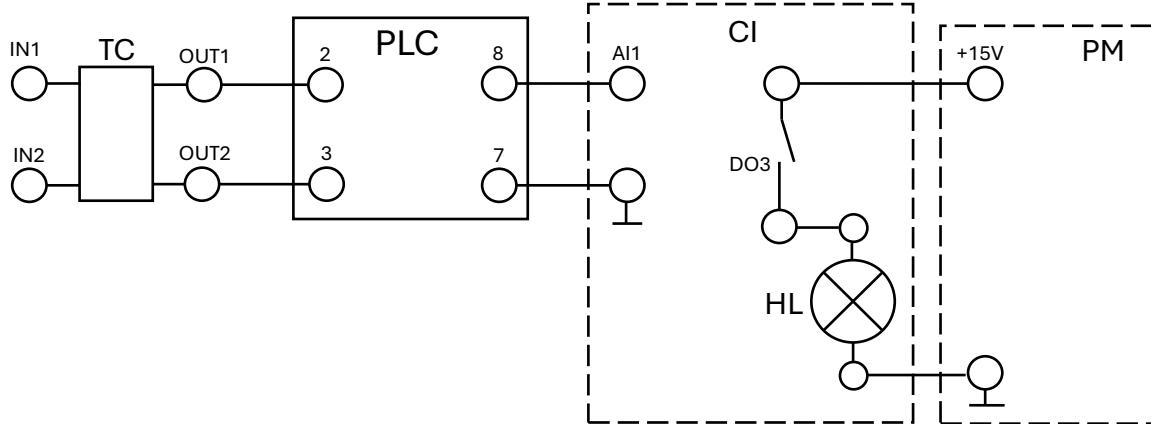


FIGURE 4. Connection diagram of the PLC module
 TC – mini module “thermocouple”; CI – control and indicator module; PM – power module

RESEARCH RESULTS

During the experiment, temperature measurements were recorded through the thermocouple sensor connected to the analog input channel of the PLC module. According to the parameters of the analog input module, the range was set to Ain low = 0 °C and Ain high = 60 °C. The output signal range was adjusted to 0...10 V. As a result of this calibration, each 1 °C change corresponded to 0.166 V. This demonstrated the system's linear variation principle, as shown in the following graph (Fig. 5).

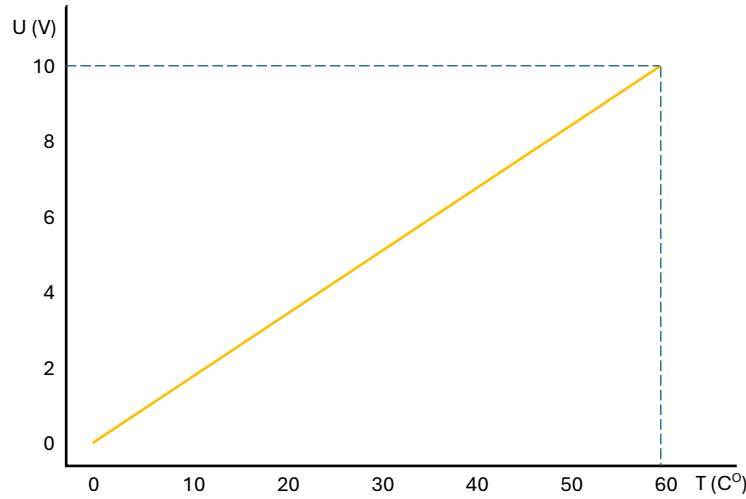


FIGURE 5. Temperature and voltage graph

According to the results of our experiments, when the temperature value reached the $T_{UST} = 45^{\circ}\text{C}$ limit, the PLC algorithm switched the discrete output to the TRUE state. This activated the indicator module. It enabled the PLC to monitor the analog signal from the sensor in real time. When the temperature value decreased, the indicator turned off, and the system returned to the standby mode. In addition, the stability of the analog signal and the accuracy of digital conversion were analysed. No significant delays were observed in the system. This demonstrated that the PLC module performs analog-to-discrete conversion at high speed.

Overall, our experiments demonstrated the sensitivity of the system to temperature changes through the PLC component. It responded to the specified limit value. This highlighted the practical significance of automatic monitoring of temperature processes across various measurements.

CONCLUSION

These experiments studied the analysis of analog temperature measurements through programmable logic controller (PLC) components. In addition, the execution of the discrete control algorithm was examined through the experiments. The analog signal in the range of 0...10 V from the thermocouple sensor was linearly converted in the PLC's analog input module to a temperature range of 0...60 °C. The results demonstrated a proportional increase of the output voltage with the upper temperature limit. This showed the stability of the PLC modules when working with analog signals.

During the experiment, when the specified $T_{UST} = 45^{\circ}\text{C}$ limit was reached, the discrete output channel was activated by the PLC. This demonstrated the PLC system's ability to monitor analog signals in real time. In addition, it showed the capability to make control decisions with high accuracy. The timely response of the output module indicated that the control algorithm was correctly configured and that the module operated without delays.

The obtained results demonstrated that PLC systems are stable and effective in the automatic monitoring of temperature processes. The results of our experiments indicate the possibility of analysing data in an IoT-based monitoring environment. At the same time, these results provide the opportunity to develop adaptive algorithms.

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