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Automation of Water Drainage Systems Using a Programmable Logic Controller in Mining

Volodya Vladimirov Dzharov

Abstract: This article examines the automation of drainage systems in the mining industry, emphasizing the urgent need to modernize this critical component of mining infrastructure. The proposed system is based on open-source hardware and software, making it suitable for use by designers working in small enterprises as well as for educational and training purposes. Drainage systems are used to pump water from underground mines to maintain safe working conditions and prevent flooding. The presented solution enables automatic control of pumps based on parameters such as current water level, pipeline pressure, actuator positions, and the presence of a cooling water flow. The developed system provides a convenient platform for experimentation with large-scale mining control applications, such as water drainage systems. The introduction of automation in the management of drainage processes significantly enhances their efficiency and reliability by reducing the need for continuous human supervision and minimizing the risk of operational errors. The architecture of a typical automated drainage system is described, comprising water level sensors, programmable logic controllers (PLC), and monitoring and control systems (SCADA). Modern automated drainage systems in the mining sector utilize PLCs to provide reliable and flexible process control. The automation of pumping stations with PLCs requires adherence to specific operational principles to ensure safe and fault-free equipment performance. One of the innovative solutions in this category is the Arduino Opta, which combines industrial-grade reliability with open-source flexibility. The article describes the system's operational algorithm and its ability to respond in real time to variations in the hydrogeological environment. The advantages of automation are analyzed, including reduced human intervention, improved operational safety, and increased efficiency.

Keywords: Drainage Systems, Automation, Algorithms, Programmable Logic Controllers, Underground Mines.

Nomenclature:
PLC: Programmable Logic Controllers.
SCADA: Supervisory Control and Data Acquisition.
IEC: International Electrotechnical Commission.
TCP: Transmission Control Protocol.
RTU: Remote Terminal Unit.
RBT: Rules on Occupational Safety in Underground Coal Deposits.
OTA: Over The Air
HMI: Human Machine Interface

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*Correspondence Author(s)
Volodya Vladimirov Dzharov*, Chief Assistant, Department of Electric Power Engineering and Automation, University of Mining and Geology St. Ivan Rilski, Sofia, Bulgaria, Email ID: volodya.dzharov@mgu.bg, ORICD ID: 0009-0005-1809-3078

I. INTRODUCTION

Efficient management of mine water drainage systems is It is essential for maintaining operational safety and optimising energy consumption in underground mining. Traditionally, these systems were operated manually, with pumps switched on and off according to the measured water level. The evolution of electronic and industrial automation technologies has created the opportunity to implement intelligent control solutions that allow remote operation, real-time monitoring, and improved energy efficiency.

This study aims to develop and present an operational algorithm for controlling water drainage systems using open-source software based on the Arduino Opta platform. The proposed approach demonstrates the feasibility of implementing flexible, low-cost automation technologies for both experimental and practical applications. The developed algorithm is intended to simulate the operation of large-scale drainage systems, allowing researchers and engineers to conduct experiments focused on optimizing pump performance and preventing emergency operational modes. Furthermore, the integration of the proposed system with Arduino Cloud and the implementation of OTA (Over-the-Air) firmware updates ensure secure data transmission, remote programming capabilities, and real-time human–machine interface (HMI) visualization. These features make the system suitable not only for educational purposes and laboratory simulations but also for real industrial deployment in underground mining environments.

II. BASIC REQUIREMENTS FOR DESIGN AND OPERATION

The automation of water drainage systems leads to increased reliability, safety and reduced operating costs. The central drainage systems of underground mines are equipped with powerful asynchronous electric motors with a short-circuited rotor and have a free (independent) mode of operation, i.e. the operation of the central drainage system is not related to the technological processes in the underground mine. In [1,2], conceptual solutions for automation of water drainage complexes are proposed, implemented at three levels - emergency, local and remote, with the possibility of integration into a SCADA system.

In [3], the authors investigate the energy efficiency of the main water pumping stations in underground iron ore mines, taking into account the electricity tariff and the time of day. Methods for analyzing the influence of the electrical capacity of the pumps on the price of electricity, based on multifactor regression models, are developed and proposed.

In [4], the possibility of designing a solar pump automation system using a programmable logic controller for pumped-storage energy is investigated. The pump will only turn on if there is an excess of power from the solar panels. When there is no water, the motor protection is designed to prevent overheating and will activate again when the lower tank is full.

Mining Safety Regulations in 2025 are shaping safer, sustainable, and eco-friendly mining operations through advanced technologies and comprehensive risk management frameworks, protecting workers, local communities, and the environment. By 2025, Mining Safety Regulations have evolved significantly, fully embracing sustainability, technology, and data-driven decision-making. These new frameworks enable the industry to move toward safer, more adaptive, and transparent mining operations, promoting a balance between economic gains and community/environmental stewardship [5], [6]. Table 1 presents the main requirements for the design and operation of the central water drainage systems in underground mines.

Table 1: Basic Requirements for the Design and Operation of Central Drainage Systems in Underground Mines

№	Indicators	Regulatory Documents	
		PBT (V-01-01-01)	**PBT (V-01-02-04)**
1. 1.1	Categorization of mines by daily water flow Normal water flow to 50 m^3/h over 50 m^3/h Q_n - Normal water flow m^3/h Seasonal water flow Q_s	$Q_n \leq 50$ $Q_n > 50$	$Q_n \leq 50$ $Q_n > 50$
2. 2.1 2.2	Determining the number of pumping units: At normal water flow, $Q_n \leq 50$ At normal water flow, $Q_n > 50$	2 3 pieces	2 3 pieces
3	Determining the number of pressure pipelines	2 pieces	2 pieces
4 4.1 4.2	Speed of water In a pressure pipeline In the suction pipe	- -	V<3 m/s V<2.5 m/s

Table 2 presents the drainage system of an underground mine in operation, the object of research, the initial data characterizing the water flow in the underground mine and the operating mode. These initial data are necessary for the computational verification of the main elements of the central drainage system.

№	Name of the Source Data	Designation
1	Head	Hr.
2	Normal 24-hour water flow	QNormal
3	Maximum water in flow	Qmax
4	Bulk density of mine water	ρ
5	Working days per year	T
6	Working days per year with normal 24-hour water flow	TN
7	Working days per year, with a maximum 24-hour water flow	TM
8	Operating mode in an underground mine	3 shifts

[7] Considers the synthesis of an expert system for controlling the electricity consumption of pumps of main drainage facilities of an underground mine, based on Mamdani's fuzzy inference algorithm. In [8], the issue of the drop in water level during the four seasons, which affects normal water intake pressure, is addressed. A water intake pressure mode is designed, connecting the centrifugal pump in series with a submersible pump that has uniform flow at the end of the suction pipe. The software and hardware of the system have been developed. System functions such as real-time data collection and monitoring, intelligent rotation and switching of the water pump, a combination of multiple control modes, fault protection, and emergency alarms are implemented. The intelligence and reliability of the water intake supply system have been improved. In [9], the optimized dynamic scheduling method using the three-dimensional fuzzy controller combined with the “peak valley filling avoidance” strategy is discussed, which can make full use of the difference in the peak hour of the electricity price compared with the previous one, and give complete freedom to the water storage capacity in the mine, so that the pumps remain in the peak hour of the electricity price and then turn off during the general electricity price. The water pumps stay off during peak hours and then take advantage of the low electricity price to drain the water during off-peak hours. This can reduce daily consumption by 20.69% compared to the previous method, while ensuring the safety of the mine.

In [10], the study examines how the complex drainage system of an underground mining enterprise ensures the safety and continuity of mining operations. Deterioration in the reliability of the mine drainage system can lead to the following serious consequences. The central unit of the mine drainage system is equipped with centrifugal pump-based pumping units. One of the main criteria for the safe operation of a mine drainage system is ensuring it is equipped with sufficient pumping units.

[11] The main historical stages of the technical development of centrifugal pumps for mine drainage and their relationship. The absolute depths of mining operations are highlighted, proposing design solutions to increase the energy efficiency and hydrodynamic load of centrifugal pumps by using vortex methods to control flow in the pump impeller.

A. Automated Drainage System

A modern automated system includes:

i. Level sensors – installed in manholes and water tanks.
ii. Flow and pressure sensors – monitor the actual flow and pressure in the pipelines.
iii. Position sensors – control of flaps and valves.
iv. Temperature sensors – for motors and bearings.
v. Vibration sensors – diagnosis of mechanical damage.
vi. Float switches – for overflow and emergency conditions.
vii. Contactors and relays – for controlling electric motors.
viii. Electric and solenoid valves – for flow control.
ix. Frequency converters (inverters) – for smooth speed control and increasing energy efficiency.

The core of the control is PLC controllers, which provide reliability and flexibility. An interesting example is the Arduino Opta (Figure 1), an industrial micro-PLC that

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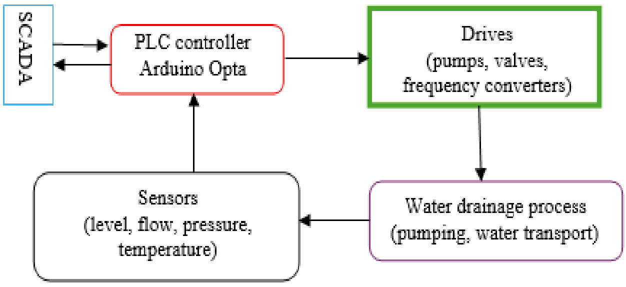
combines easy programming with compliance with industry standards.

The device supports IEC 61131-3 PLC languages, Modbus TCP/RTU protocols, and expandability via Arduino Pro Opta Ext D1608S. This allows integration with SCADA systems and implementation of real-time predictive maintenance.

[Fig.1: Arduino Opta]

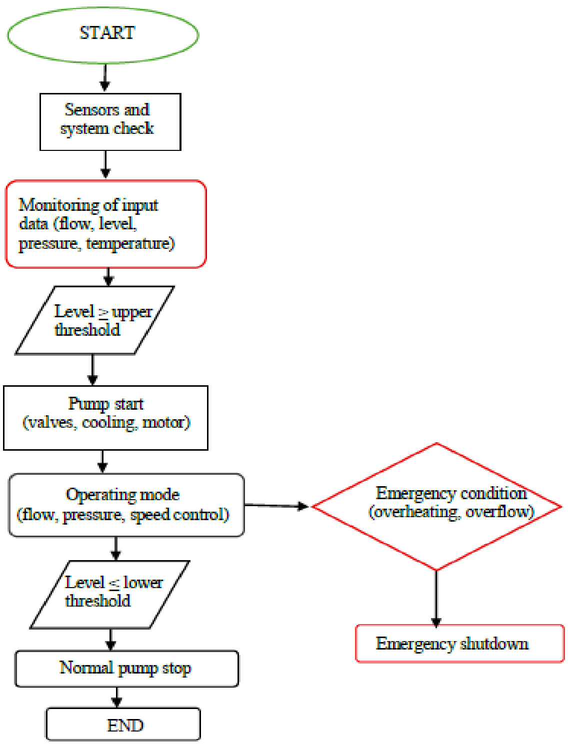
III. STRUCTURE AND CONTROL ALGORITHM OF AN AUTOMATED DRAINAGE SYSTEM

The mine water enters through channels and is directed to settling tanks and water catchments through automated valves driven by servomotors. An example configuration includes three pumps (two working and one standby), each with a flow rate of 6.67 m^3/min, connected to two main pipelines. The average daily outflow is 538 m^3, and the maximum is 2000 m^3.



[Fig.2: Block Diagram of an Automated Drainage System]

A block diagram of an automated drainage system is presented in Figure 2, and its control algorithm is shown in Figure 3.



[Fig.3: Drainage System Control Algorithm]

It consists of the following commands:

1. System startup
   - Check for power supply and PLC/SCADA readiness.
   - Self-diagnosis of sensors and actuators (valves, contactors, frequency converters).
2. Monitoring input data
   - Reading the water level in the water tank (level sensors, float switches).
   - Checking the flow rate and pressure in the pipelines.
   - Monitoring the temperature and vibrations of the motors and bearings.
3. Pump start condition
   - If level ≥ upper threshold → activate pump start sequence.
   - If level ≤ lower threshold → stop pump (to avoid dry running).
4. Pump start-up sequence
   - Opening the suction valve.
   - Checking for the presence of cooling water.
   - Starting the electric motor (via contactor/inverter).
   - Smoothly increasing the speed using a frequency converter.
   - Opening the discharge valve.
5. Operating mode
   - Maintaining flow rate and pressure within optimal limits.
   - Automatic switching between operating pumps in case of load or failure.
   - Speed regulation according to the current water flow.
6. Emergency shutdown condition
   - Overheating of an electric motor or bearing.
   - Lack of flow rate when the pump is running.
   - Vibrations above permissible limits.
   - Overflow of the water tank (alarm level).
   - Failure of a critical sensor or communication.
7. Pump stop (normal)
   - Closing the discharge valve.
   - Smooth speed reduction (if there is a frequency converter).
   - Stopping the electric motor.
   - Closing the suction valve.
8. SCADA Integration
   - Level, flow rate, pressure, pump status and alarm signals are visualized in real time.
   - The operator can choose:
     - o Automatic mode (algorithm-based).
     - o Manual mode (direct control of pumps and valves).

IV. RESULT AND DISCUSSION

As a result of the conducted research, an automated control system for mine water drainage based on the Arduino Opta platform and open-source software has been developed and experimentally verified. The proposed algorithm ensures reliable operation, higher efficiency, and improved safety during pump operation while simultaneously reducing human intervention and optimizing energy consumption.

The system enables intelligent pump switching,

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real-time monitoring, and flexible control based on dynamic water inflow conditions, contributing to extending equipment service life and enhancing the overall reliability of the drainage network. The integration with Arduino Cloud and the implementation of OTA (Over-the-Air) updates provide high levels of data security, remote management, and easy adaptation for real industrial environments.

V. CONCLUSION

The obtained results confirm that the proposed system can be effectively applied both for educational purposes and student training, as well as for practical use in the mining industry, representing a cost-effective, sustainable, and scalable solution. Future work will focus on extending the control algorithm with advanced features for predictive diagnostics, energy consumption optimisation, and integration with complex SCADA systems to further enhance automation and system resilience.

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AUTHOR'S PROFILE

Volodya Vladimirov Dzharov, Chief Assistant, Doctor in the professional field 5.2. "Electrical Engineering, Electronics And Automation", Doctoral Program "Manufacturing Automation (By Industries)", Master in Computer Control in Mining in University of Mining and Geology "St. Ivan Rilski", Bachelor of Automation, Information and Control Engineering in University of Mining and Geology "St. Ivan Rilski", Scientific interests: Electronics, programming languages, identification, automation and optimization of technological processes, computer control systems, embedded systems, Membership in scientific organizations: Union of Electronics, Electrical Engineering and Communications - https://ceec.fnts.bg/index_en.html, Union of Automation and Informatics - https://sai-bg.com/en/about-us/, 20 publications in the field of Automatic control, programming, electron beam processes and technologies:

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