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INVESTIGATION OF THE AUTOMATIC START-UP PROCESS OF THE STANDBY PUMP

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Abstract: In industrial enterprises, especially in mining, dewatering, and technological processes, the continuous operation of pumping equipment is of critical importance. Failure of a pump unit can lead to the interruption of technological processes, reduced production efficiency, and significant economic losses. Therefore, the implementation of an automatic start-up system for a standby pump is considered one of the urgent and relevant engineering tasks. This article investigates the operating principle of the automatic standby pump start-up system, including its control algorithm, technical solutions, and its impact on overall system reliability. The study results demonstrate that the application of an automatic control system significantly improves the reliability of the pumping station, prevents emergency situations, and minimizes the negative influence of the human factor.

Keywords: standby pump, automatic control, pumping station, reliability, automation, water drainage system, sensors, relay protection.

Introduction

Pump units are among the key components that ensure the continuous operation of technological processes in mining, metallurgical industries, and water drainage systems. In particular, underground mining operations are characterized by the constant accumulation of groundwater, which requires highly reliable pump performance to maintain safe and uninterrupted production conditions. Failure of a pump unit may lead to a rise in water level, resulting in process interruptions, equipment damage, and significant economic losses.

To improve system reliability, pumping stations are typically equipped with both primary and standby pumps. In the event of failure of the primary pump or deviation of its operating parameters beyond permissible limits, it becomes necessary to quickly activate the standby pump. In conventional systems, this process is performed manually by an operator, which may cause delays and increase the likelihood of errors associated with the human factor.

Modern automatic control systems enable continuous monitoring of pump operating conditions using sensors and protection devices. When abnormal operating conditions or pump failure are detected, the standby pump is automatically activated without operator intervention. This ensures uninterrupted operation of the technological process, enhances overall system reliability, and reduces the risk of emergency situations.

Therefore, the investigation of automatic standby pump start-up systems and the evaluation of their effectiveness are of significant scientific and practical importance. The objective of this study is to analyze the operating principle of the automatic standby pump start-up system in pumping stations and to determine its impact on system reliability and operational efficiency.

Literature review

The continuous operation of pumping systems plays a crucial role in ensuring the stability and reliability of technological processes in industrial enterprises. Scientific studies have shown that systems equipped with standby units exhibit higher reliability compared to systems without backup equipment, as they are capable of maintaining operational functionality in the event of primary pump failure [1; pp. 5173–5176].

The operational efficiency and reliability of pump units largely depend on the applied control methods. Automatic control systems enable continuous monitoring of key parameters such as pressure, fluid level, and electric current, and automatically activate the standby pump when the primary pump fails or operates outside permissible limits [2; pp. 125–130]. This

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ensures the uninterrupted continuity of technological processes and enhances overall system stability.

Research on the technical condition monitoring of pumping equipment indicates that faults can be effectively detected through the analysis of vibration and electrical signals [3; pp. 2565–2569]. Early fault detection makes it possible to initiate timely activation of the standby pump, thereby preventing system failure and minimizing downtime.

Furthermore, the implementation of automatic control systems in pumping installations contributes to reducing energy consumption and improving equipment performance [4; pp. 1485–1489]. As a result, the overall efficiency and operational effectiveness of pumping systems are significantly enhanced.

Reliability assessment studies of pumping systems confirm that the use of standby units substantially improves system stability and operational continuity [5; pp. 103–107]. Therefore, the automatic start-up system of a standby pump plays a vital role in ensuring reliable and safe operation of pumping stations, particularly in critical industrial applications such as mining and water drainage systems.

Research methodology

In this study, the automatic start-up process of the standby pump was investigated based on a two-pump water drainage system. The principle diagram of the system is shown in Figure 1.

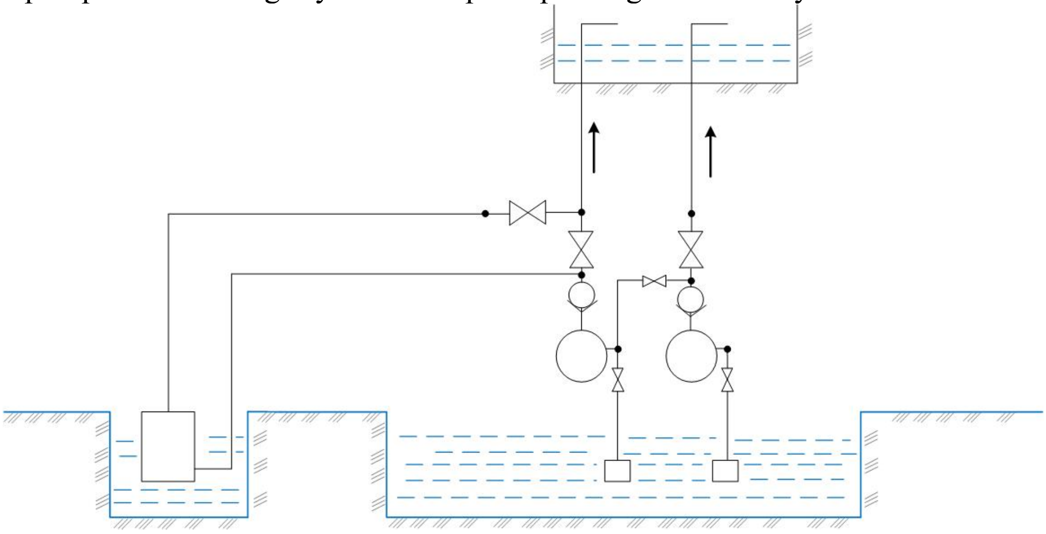

Figure 1. Principle diagram of the automatic standby pump start-up system

The schematic diagram shows the primary pump N1 and the standby pump N2, the suction reservoir, the discharge pipeline, check valves, and shut-off valves. Both pumps are connected to a common suction line, through which fluid is drawn from the lower reservoir and delivered to the upper reservoir via the discharge pipeline. A check valve is installed in the discharge line of each pump to prevent reverse flow through the inactive pump and to ensure stable system operation.

Under normal operating conditions, the primary pump continuously delivers fluid and maintains the required pressure in the system. The standby pump remains in standby mode and is activated only when the primary pump fails or when its operating parameters fall below the specified limits. The monitoring elements installed in the system detect changes in fluid level and pressure. If the primary pump stops operating or the discharge pressure decreases, the control unit automatically generates a command signal to start the standby pump.

After the standby pump is activated, the fluid transfer process is restored, and normal system operation is maintained. At the same time, the check valve prevents reverse fluid flow through the inactive pump, thereby ensuring the safe operation of the pump units and enhancing overall system reliability.

The proposed system configuration enables automatic activation of the standby pump in the event of primary pump failure, ensuring uninterrupted fluid transfer and improving the overall operational reliability of the pumping station.

Mathematical model

The variation of the fluid level in the lower reservoir over time is based on the law of mass conservation. According to this law, the rate of change of the fluid volume in the reservoir is determined by the difference between the inflow rate and the outflow rate of the fluid. If the inflow rate to the reservoir exceeds the outflow rate through the pump, the fluid volume in the reservoir increases and the fluid level rises. Conversely, if the outflow rate through the pump exceeds the inflow rate, the fluid volume decreases and the fluid level drops.

The fluid volume in the reservoir depends on its geometric dimensions. Assuming that the cross-sectional area of the reservoir remains constant, the fluid volume can be expressed by the following relationship:

$$V_1(t)=A_1 H_1(t)$$

where:

$V_1(t)$ – fluid volume in the reservoir, m³;

A_1 – cross-sectional area of the reservoir, m²;

$H_1(t)$ – fluid level, m.

Taking the derivative with respect to time, the rate of change of the fluid volume can be determined as follows:

$$\frac{dV_1(t)}{dt}=A_1\frac{dH_1(t)}{dt}$$

According to the law of mass conservation, the rate of change of the fluid volume in the reservoir is equal to the difference between the inflow rate $Q_{in}(t)$ and the total outflow rate $Q(t)$ through the pumps:

$$\frac{dV_1(t)}{dt}=Q_{in}(t)-Q(t)$$

As a result, the generalized differential equation describing the variation of the fluid level in the reservoir can be expressed as follows:

$$A_1\frac{dH_1(t)}{dt}=Q_{in}(t)-Q(t)$$

This equation fully describes the variation of the fluid level in the reservoir over time and enables the determination of the dynamic state of the pumping system.

$$A_1\frac{dH_1(t)}{dt}=Q_{in}(t)-[u_1(t)Q_1(t)+u_2(t)Q_2(t)]$$

This mathematical expression serves as the fundamental governing equation for describing the dynamic behavior of the pumping system, the variation of the fluid level, and the conditions for automatic activation of the standby pump. Based on this equation, the steady-state operation of the system can be analyzed, fault conditions can be identified, and optimal activation criteria for the standby pump can be determined.

The research results demonstrated that in a pumping system based on (ЦНС 180/500) pumps, the automatic start-up of the standby pump via the AUMA automatic control unit ensures stable preservation of volumetric capacity. During primary pump failure, a temporary pressure drop was observed in the system; however, following the automatic activation of the standby pump, the fluid transfer process was quickly restored, and the volumetric flow rate stabilized near its nominal operating value.

The observations confirmed that the automatic engagement of the standby pump maintained the overall volumetric capacity at an approximately constant level, and no interruption in fluid transfer was observed. This demonstrates that the system operation remains unaffected and ensures the uninterrupted continuity of the technological process.

As a result of the rapid activation of the standby pump, the hydraulic regime was restored within a short period. The pressure in the discharge pipeline returned to its nominal value, and no significant fluctuations in the fluid level within the reservoir were observed. Consequently, the operating mode of the system remained stable, and disturbances to the technological process parameters were successfully prevented.

The obtained results confirm that the automatic standby pump start-up system based on (ЦНС 180/500) pumps and controlled by the AUMA device represents an effective technical solution for maintaining volumetric performance, ensuring uninterrupted technological operation, and improving the overall operational stability and reliability of the pumping station.

Analysis of the time variation of volumetric flow rate

During system operation, the variation of volumetric flow rate over time was observed. Under normal operating conditions, when fluid was delivered by the primary (ЦНС 180/500) pump, the volumetric flow rate remained stable within the range of Q=175–180 m³/p. This indicates that the system was operating under a stable hydraulic regime.

Following the failure of the primary pump, the volumetric flow rate decreased rapidly and reached its minimum value within a short time interval. The control system promptly detected the fault and issued a start-up command to the standby pump via the AUMA electric actuator. After activation of the standby pump, the volumetric flow rate was quickly restored and stabilized within the range of 170–180 m³/h. Graphical analysis confirmed that the recovery time was minimal, ensuring that the overall volumetric capacity of the system was effectively maintained without significant performance degradation.

Discussion

The results of the conducted research demonstrated that the automatic standby pump activation system, implemented using the AUMA automatic control unit in a pumping system based on (ЦНС 180/500) pumps, plays a crucial role in maintaining the hydraulic and technological stability of the system. During primary pump failure, a temporary reduction in volumetric flow rate and discharge pressure was observed; however, following the automatic activation of the standby pump, these parameters were rapidly restored, and the system returned to a stable operating regime.

The results showed that the automatic activation of the standby pump makes it possible to maintain the overall volumetric performance of the system. This ensures uninterrupted fluid transfer and prevents disturbances in technological process parameters. If the standby pump is not activated automatically, an increase in fluid level may occur, leading to disruption of the technological process and possible interruption of production operations.

The automatic standby pump activation system using the AUMA electric actuator operates with high responsiveness and significantly reduces the influence of the human factor. In conventional manually controlled systems, activation of the standby pump requires a certain amount of time, which may result in temporary interruption of the technological process. In contrast, the automatic control system performs this function within a minimal time interval, ensuring continuous system operation and improving overall reliability.

The mathematical model of the system showed strong agreement with the experimental observations. After activation of the standby pump, the volumetric flow rate and discharge pressure were restored to values close to their nominal levels. This confirms that the developed mathematical model accurately describes the real operating behavior of the pumping system.

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Table 1 presents the results of the automatic activation of the standby pump using the AUMA device in the (ЦНС 180/500) pumping system.

Table 1.

1	Automatic activation of the standby pump in the (ЦНС 180/500) pumping system was ensured using the AUMA control device.	Upon failure of the primary pump, the standby pump was automatically activated, resulting in the rapid restoration of normal system operation.
2	It was established that the overall volumetric capacity of the system remained stable.	After activation of the standby pump, the fluid flow rate recovered to a level close to its nominal value, ensuring stable and uninterrupted volumetric performance of the system
3	The continuity of the technological process was successfully maintained.	The automatic engagement of the standby pump ensured uninterrupted fluid transfer and maintained the stability of the technological operating regime.
4	A rapid recovery of the hydraulic parameters of the pumping system was observed.	Following the activation of the standby pump, the discharge line pressure and hydraulic head were rapidly restored to their nominal operating values.
5	The results confirmed an improvement in the operational reliability of the pumping station.	The automatic start-up of the standby pump ensured stable system operation and significantly reduced the risk of emergency situations.

The obtained results confirm that the implementation of automatic standby pump activation systems is an effective and justified solution for improving the operational reliability of water drainage systems in mining enterprises. Such systems enhance the operational stability of pumping stations, ensure uninterrupted technological processes, and contribute to increased production efficiency.

Conclusion

This study investigated the operational efficiency of an automatic standby pump start-up system based on (ЦНС 180/500) pumps and controlled using the AUMA automatic control unit. The results demonstrated that in the event of primary pump failure, the standby pump was automatically activated, and the hydraulic parameters of the system were rapidly restored within a short period of time.

The automatic activation of the standby pump ensured that the volumetric performance of the system was maintained and prevented interruptions in the fluid transfer process. This guaranteed the continuity of the technological process and prevented negative impacts on the production regime. The rapid response and reliable operation of the automatic control system contributed to maintaining stable hydraulic and technological conditions.

Furthermore the implementation of the automatic standby pump control system significantly improved the operational reliability of the pumping station and reduced the risk of emergency situations. The obtained results confirm that the use of the AUMA-based automatic standby pump activation system represents an effective and reliable technical solution for improving the performance, stability, and safety of pumping systems in mining enterprises.

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