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Development of electric drive for centrifugal mine pumps in Solikamsk Potassium Mine Group Based on Industrial OMRON Controller

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Abstract. The electric drive for automation pumping out of filtration waters in the Second Solikamsk Potassium Mine Group is developed. The emergency situation of flooding of the Mine has been considered in the course of development of the Upper Kama deposits of potash-magnesium salts. The functional scheme of automation of a drive of the pump is developed. The scheme is stipulated with manual and automatic control. To decrease the risk of flooding of mine, it is recommended to establish gauges of both bottom and top level control of a brine and other equipment in the collector of a brine: the gauge of measurement of a level, the gauge of the signal system of a level, the gauge of the pump control, the gauge of the signal system of a level with remote data transmission. For regulation of the charge of sewage, the P-regulator with the executive mechanism is stipulated. The ladder diagram of a pump control is developed to improve the work of centrifugal pumps and to prevent the cases of mines flooding.

1. Introduction
Threat of flooding of mines in Permski Krai has considerably increased because of the raised quantity of rainfall. In November, 2014 in the Second Solikamsk Mine (SKRU-2), volumes of receipt of brines had increased. Peak inflow of brine made 8–10 thousand m³/hour; the established pumps TSNSK 300–300 with the charge of water of 300 m³/hour had not coped with the situation. The authors submit the developed control system of pumps for brine pumping with the use of a Ladder diagram (LD) [1,2].

2. Equipment and devices used in studies
In the research, the authors used controller OMRON. The operator’s panel is connected to controller OMRON [3]. The studies on monitoring and control of the pump with the OMRON CX-Programmer version 7.1 and CX-Designer software version 2.1 are presented.

3. The results of the study and their discussion
At the Second Mine there are pumps TSNSK 300–300 intended for pumping out of acid waters with a hydrogen parameter pH=3.5–8.5, in the temperature from 1 up to 45°C with the maintenance of
mechanical impurity no more of 0.2 % on weight, the size of firm particles no more than 0.2 mm, micro hardness no more than 1.47 GPa on water-outflow of collieries function. For prevention of an emergency situation and flooding of the mine, the control system of the pump work has been developed. A general scheme of pumping out brine is shown in Figure 1.

The principle of work of the circuit of gathering and pumping out brine consists in the following: the brine flows down in the brine collector (memory developments). In the brine collector, the gauges for bottom (Bottom) and top level (Top) control of filtration drains are established. It is provided with manual and automatic control of the pump. Automation of production processes in mines is described in work [4]. For regulation of the charge of sewage, the P-regulator with the executive mechanism [5] is stipulated. The function chart of automation of a drive of the pump is resulted in Figure 2.

Figure 1. Schema of pumping out brine.

Figure 2. The function scheme of automation of a pump drive.
As hardware-software maintenance controller Omron [6] has been chosen; the programming language of the OMRON CP1L controller was relay-contact logic (IEC61131-3). Necessary logic elements are entered for the description the column of the pump work on the basis of controller Omron (Table 1).

**Table 1. Logic elements for the description of the pump work.**

| In-Y   | Out-Y   | Bit Address in controller RAM | Notation | Operator panel | Explanation                        |
|--------|---------|--------------------------------|----------|----------------|-------------------------------------|
| $X_4$  | $Y_3$   | CIO 0.04                        | Bottom   |                | Lower-level brine sensor            |
| $X_6$  | $Y_5$   | CIO 0.06                        | Top      |                | High-level brine sensor             |
| $W_4$  |         | CIO 100.03                      | Q        |                | Pump                               |
| $W_5.06$ |       |                                 |          |                | Auto / Manual                       |

In the offered circuit, manual and automatic control of the pump has been stipulated (W4). For manual control, the button (W5.06) is stipulated, thus the collector of brine has gauges for bottom ($X_4$) and top levels ($X_6$).

Algorithm of work of the pump is the following: the pump ($Y_3$) is switched on when a brine level achieves the mark "Top" ($X_6$) and it is disconnected from the mark "Bottom" ($X_4$). The graph of conditions and transitions of driving the pump is shown in Figure 3.

![Graph of conditions and transitions of pump control.](image)

The logic functions corresponding to the graph of conditions and transitions of pump control are submitted in dependence:

- $W_4 \land (X_6 \lor Y_3) \land X_4$ \quad Automatic rule
- $\overline{W_4} \land W_5.06 \land (X_6 \lor Y_3) \land X_4$ \quad Manual

The developed ladder diagram is shown in Figure 4.

![Ladder diagram of pump control.](image)

The description of work of the circuit of pump control is resulted in Table 2.
Table 2. Description of operation of the pump control circuit.

| Description of work | LD | Operator panel |
|---------------------|----|----------------|
| Automatic control   | ![LD and Operator panel] | ![Operator panel] |
| Put the switch in the "Auto" position |
| Manual control      | ![LD and Operator panel] | ![Operator panel] |
| Put the switch in the "Manual" position |
| The pump switch is on. The pump does not work because the top level of the brine is not reached |
| The upper sensor is flooded, the pump starts |
| The brine was pumped out, the upper level was dry, the engine was powered by a lock |
| When the brine is pumped below the lower level, the pump shuts down |

Beginning pumping out brine, the top level has dried, the engine connected through blocking. When pumping out brine of below bottom level, the pump is disconnected.

Conclusions

The situation of flooding of the Second Potash Mine "Uralkali" is considered. The analysis of using pumping installations on a site of a hydro bookmark for pumping out brine from mine is executed. Recommendations have been worked out; the automated system of monitoring and control of centrifugal pumps is developed. The automated system of pumping out brine from mines will allow one to lower risks of flooding of mines and to prevent occurrence of emergencies and accidents. Offered hardware-software maintenance for automation of a control system for pumping out brine will provide increase of safety for workers in the mine.

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