A promising water supply scheme for Khomutovo village (Irkutsk district, Irkutsk region)

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Abstract: The article proposes a water supply scheme for Khomutovo village. The authors describe regulation options for domestic and drinking water supply from the existing water intake facility in Dzerzhinsk under uniform operation of pumps using a regulating capacity and a frequency converter without intermediate tanks.

1. Introduction

Currently, the urgent problem is the lack of centralized water supply in settlements of Irkutsk region. A rather intensive increase in the number of residents of suburban villages created a problem of water supply. No exception is Khomutovo village, as well as settlements that are part of Khomutovo municipal district. In 2031, the number of residents in Khomutovo will be 17,900 people.

Sources of centralized water supply are groundwater intakes. Available local sources located in the territories of departmental enterprises supply water to their own facilities. They do not supply water to the population and public institutions. For this reason, they are not dealt with in the present paper.

Surface sources of water supply (the Kuda river - Khomutovo, Kuda, Gorny; the Ushakovka river - Plishkino) are not analyzed, since they have a low flow rate, especially in winter. In addition, they are susceptible to organic and bacterial contamination from upstream settlements and horticultural partnerships [1].

2. The water supply scheme developed for Khomutovo

The water supply system is a system of engineering structures designed to produce, improve water quality and supply water of required quality and under required pressure to the consumers. The sequential arrangement of natural water intakes, its purification and disinfection, pumping, transportation to consumers, and storage are determined by the water supply scheme.

There are several water supply schemes developed for Khomutovo by employees of the technical department of the village administration and specialists from third-party organizations.

The main problem is the choice of a water supply source, because, according to hydrogeological studies, the quality of underground water is unsatisfactory due to the increased content of salts and impurities. River pollution is caused by the unorganized flow of melt and storm water from the entire catchment area. It washes away the soil, organic and inorganic fertilizers when passing through settlements, especially through territories of buildings, gardens, etc., located in water protection zones. The use of underground sources is not possible, because the rivers are hydraulically connected to groundwater horizons.
Currently, water supply to the villages of Khomutovo municipal district is carried out from municipal and private wells. That is why it is difficult to control water quality. Groundwater deposits near the boundaries of the settlement have been understudied. According to hydrogeological zoning, the territory is located in Irkutsk artesian basin. Groundwater was discovered in the Quaternary and Jurassic sediments [2].

In total, territories with a centralized water supply system make up about 10%. The rest of the settlement occupied by individual residential buildings lacks a centralized water supply system. Water supply is carried out from individual and local water sources (wells). There are several municipal (for the needs of boiler rooms) and individual (water supply of private houses) decentralized water supply systems. According to the data provided, water quality does not meet the standards established for quality of drinking water. It is used for technical needs [3].

The management company LLC Ushakovskoye developed the following water supply scheme for Khomutovo: water intake facilities take water from an underground source; pressure conduits transport water to a clean water tank (CWT); water is stored in a pure water tank; water is supplied to Khomutovo and other settlements through pressure lines; in Khomutovo, there is a distribution network (Fig. 1).

![Figure 1. The water supply scheme developed for Khomutovo village](image)

The water supply scheme has a control tank at the entry of the network. This scheme is characterized by the high-altitude location of the water storage tank (on a hill near Plishkino). Water is supplied from the tank to consumers due to the difference in elevations.

Water intake facilities in Dzerzhinsk and additional wells can be used as a source of water supply. The existing licensed underground water intake at 33 Naberezhnaya Street which was put into operation for the needs of Dzerzhinsk and Sovremennik has a productivity of 1000 m³ / day. It consists of two
artesian wells with a productivity of 40.0 m³/h. The water intake meets the sanitary standards. Groundwater reserves have been approved; all the permits have been issued:

- the sanitary and epidemiological inspection report according to which water corresponds to the sanitary-epidemiological standards of the design of the sanitary protection zone of the ZSO of the first belt, No. 38. ITS.06.T.000641.07.15 of 07.23.2015.
- the sanitary and epidemiological inspection report according to which water can be used for drinking and household purposes, No. 38. ITC.06.000.M.000604.12.15 of 01.12.2015;
- the report approving category B underground water reserves in the amount of 1000 m³ / day “Conducting prospecting and assessment work on Dzerzhinsky site aimed to organize drinking and technological water supply in Dzerzhinsk of Irkutsk region”. The report has been examined and reserves have been approved;
- the license for the use of subsurface resources IRK No. 03303 VE of July 25, 2016 for supplying drinking water to industrial facilities in Dzerzhinsk;
- quality of groundwater is assessed by quarterly monitoring within the production control program approved by the Federal Service for Surveillance on Consumer Rights Protection and Human Wellbeing.

According to [4], taking into account the development of Khomutovo and improvement of residential buildings equipped with internal water supply and sewerage systems, daily water consumption is

\[ Q = (q_i \times N_i) / 1000 = (190 \times 17900) / 1000 = 3401 \text{ m}^3 / \text{day} \]  

(1)

where \( q_i \) – water consumption per 1 person per day, l/day;
\( N_i \) is the number of residents;

According to [5], to calculate the water flow for fire fighting needs, we should use the number of residents equal to 17,900 people, the number of storeys which is no more than three, the estimated number of simultaneous fires equal to 2, the water flow for external fire fighting needs for one fire equal to 15 l/s. According to [6], the flow rate for internal fire extinguishing is 2.5 l/s in one stream. The estimated water consumption for firefighting needs is

\[ q_{\text{max}} = n \times (q_i + q_e) = 2 \times (2.5 + 15) = 35 \text{ l/d} \]  

(2)

where \( n \) – number of simultaneous fires;
\( q_i \) – consumption for internal fire extinguishing, 1/ d;
\( q_e \) – consumption for external fire extinguishing, 1/ d.

The existing water intake in Dzerzhinsk has one working well and one reserve well with a depth of 75.0 m. The water flow rate of one well is 10-35 l/s depending on the pump load and its supply [2]. According to experimental pumping, the recommended load is 50.0 m.

To supply water to Khomutovo and nearby settlements, five additional working wells having the same characteristics as the existing ones are required. The ECV 10-65-225 NRK* pump with a nominal flow rate of 65.0 m³ / h and a pressure of 225.0 m is installed in each well.

Water from the water intake is transported along two lines of water pipes to a clean water tank located on the hilltop near Plishkino. The pipe material is PE 100 SDR 7.4 polyethylene (GOST 18599-2001). The length of the pipelines (from the water intake in Dzerzhinsk to the tank) is 16,500 m, the elevation of the water intake facilities is 450.00 m, the mark of the location of the tank is 593.00 m, the geometric elevation is 143.00 m. The diameter of the pipelines is 280 mm.

The length of the pipelines from the CWT to the first well in Khomutovo is 15.2 km. The diameter of the water conduits is 355 mm.

3. Options for regulating water supply for the needs of Khomutovo

Let us analyze the cost of electricity for water supply by pumps during their step-by-step operation under the same maximum water consumption mode. All 5 ECV pumps 10-65-225 operate simultaneously. To
regulate the flow, a clean water tank near Pliskino is used. The pumps operate for 21 hours a day, the break in supply is between 1:00 and 4:00 p.m. The pumps lift water to a height of 188.0 m, the flow rate of the pumping station is 326.18 m³ / h.

The easiest way to change the rotational speed of the rotor is to change the current frequency. Frequency drives with semiconductor converters whose application improves the economic efficiency of pump parameters have been developed [7].

To calculate the power consumption when using a frequency converter for pump motor revolutions, we use the following method [8]:
- the nominal data of the pump are recorded: flow rate $Q$, m³ / s; pressure $N$, wcm; efficiency; frequency $\omega$, rpm; engine power $P$, kW;
- at the operating pump, power $P$, kW and capacity $Q$, m³ / h within the limit of the flow control limit allowed by the manufacturer are established or calculated. The minimum and maximum powers are 42 and 59 kW (for open and close valves, respectively). According to the pump certificate [9], the minimum and maximum costs are 70-120% of the nominal flow, that is, 46.0 and 78.0 m³ / h;
- the graph of the dependence of power $P$ on the relative flow rate determined by the following formula is built:

$$ Q' = \frac{Q}{Q_{\text{max}}} $$

(3)

where $Q$ - current consumption, m³ / h; $Q_{\text{max}}$ - maximum consumption, m³ / h;
- the required power of the frequency converter is determined by formula:

$$ P_{fc} = (1,1 \div 1,2) \times P_{\text{max}} $$

(4)

$P_{fc}$ - the dependence of power consumption $P_{d}$ when controlling the pump flow by throttling the valve on the relative flow rate $Q'$ obtained by connecting $P_{\text{max}}$ and $P_{\text{min}}$ is built
- the dependence of power consumption $P_{fr}$ when using frequency regulation on relative flow rate $Q'$ is built by calculating expression (5) and substituting $P_{\text{max}}$ and several values of $Q'$ into it (from 0 to 1 with a step of 0.25) [10].

$$ P_{fr} = P_{\text{max}} \left( \frac{Q}{Q_{\text{max}}} \right)^3 $$

(5)
Figure 2. The graph of dependence of power consumption on the pump flow control method depending on the relative consumption

However, the above graph can be misleading, as it is based on the rated power, flow rate and pressure of the pump, and does not take into account the actual graph of water consumption in Khomutovo. Based on real costs, it is more convenient to interpret the energy consumption of pumping units using a daily graph (Fig. 3).

Figure 3. The graph of power consumption on the method of regulating the pump supply by daily hours

Analyzing the graphs, several facts can be emphasized:
- according to the data obtained, when using a frequency converter, energy savings are due to low energy consumption. However, this requires the pump to be proportionally slow that is impossible according to the manufacturer’s passport, since proper cooling cannot be ensured by the flow of pumped water;
- due to the small number of residents, there is increased unevenness in hourly water consumption. Increased water consumption increases the number of revolutions of the unit and the consumption of electricity;
- too large unevenness of water consumption makes pumps regulated by the frequency converter ineffective and increases pressure losses in the water conduits during hours of maximum water consumption.

**Conclusion**

Currently, the sanitary and epidemiological well-being of sparsely populated areas depends on a well-organized water supply system. The supply of water whose quality meets the requirements of current regulatory documents is of great technical and social importance.

To choose the most optimal water supply system, the network diagram, the type of a pumping unit, the technical assessment is required.

The authors analyzed options for regulating the water supply from the water intake facility in Dzerzhinsk to Khomutovo under uniform operation of pumps using a regulating capacity and a frequency converter without intermediate tanks.

An analysis of the power consumption graphs showed the inappropriateness of using a frequency converter for the developed water supply system in Khomutovo.

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