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Improvement of Energy Efficiency by Using Proportional Pressure Control Mode at the Second Stage Pumping Stations in Public Water Supply

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Abstract: **The goal of the research is estimation of the energy efficiency improvement potential when the proportional pressure control mode is used at the second stage pumping stations in public water supply systems. For this reason, a large number of energy cost analyses have been made for different centrifugal pumps and regression equations with coefficients of determination have been derived.**

As the result, the savings' potential of energy consumption has been defined, if proportional pressure is used instead of constant pressure. The decrease of water leakage has also been determined when the proportional pressure control mode is applied.

Kew words: **Efficiency, proportional pressure, pump, water leakage.**

INTRODUCTION

Nowadays, with the rapid increase of energy production costs in the world, more attention is paid to improvement of the energy efficiency level. About 20 % of the total electrical energy produced in the world is consumed by pumps and pumping systems and almost half of this energy can be saved up [1].

It is crucial to determine the appropriate pump control mode for each corresponding engineering system, thus, contributing to the total energy saving in the world. Usage of the proportional pressure control mode increases the efficiency level of functionality of pumping systems at the second stage pumping stations in public water supply systems. It can crucially influence the total efficiency of the system.

This control mode can impact the energy efficiency level of a water supply system in a positive way not only directly – by reducing the energy consumption, but also indirectly – by reducing water leakage in the network.

ESTIMATION OF SAVINGS' POTENTIAL IF PROPORTIONAL PRESSURE CONTROL MODE IS USED AT THE SECOND STAGE PUMPING STATIONS IN PUBLIC WATER SUPPLY

It is very important to keep the pressure constant at consumer side, not next to booster sets at the second stage stations. To this effect it's advisable to apply the proportional pressure control mode (the method of compensation of pressure losses) [2] and [7].

If the proportional pressure control is applied at the second stage pumping stations in public water supply systems, the whole water supply process can be crucially optimized in terms of energy saving.

Estimation of Potential Reduction of Energy Consumption

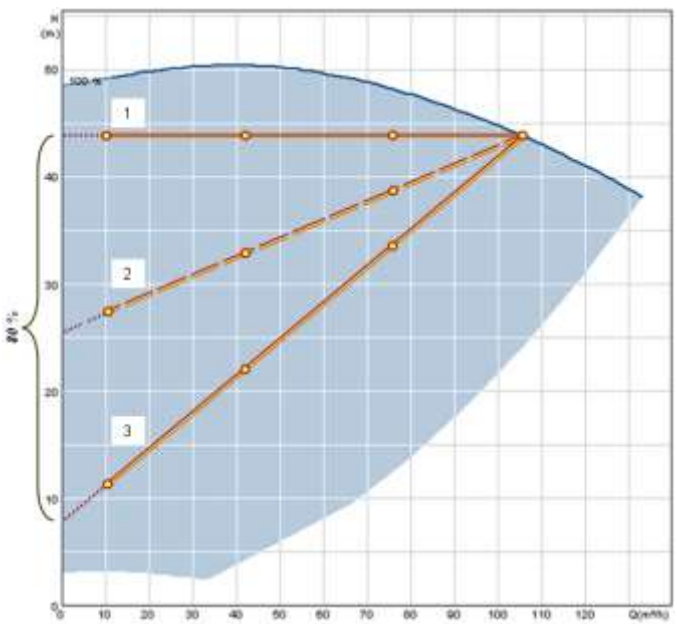

Fig. 1. Duty point control curves, if different pump control modes are applied (1 – constant pressure control mode, 2 and 3 - proportional pressure control mode) [2]

It is very important to define deviations from the head value of the duty point at zero flow rate, if the proportional pressure control mode [2] and [7] is used (in comparison with the constant pressure control mode).

It has been assumed that the maximum deviation from the head value of the duty point at zero flow rate is 80 % (Fig. 1).

The operational principle of the proportional pressure control mode is as follows: the adjusted head value of centrifugal pumps is being adapted in accordance with the flow variations during the water supply process. This pumps' control mode is very appropriate for water supply systems with the comparatively high level of pressure drop dedicated to frictional losses [2] and [3]. The longer piping network is, the higher level of energy efficiency is possible to achieve.

Having analysed the consumption of electrical energy, a load profile of drinking water consumption should be taken into account.

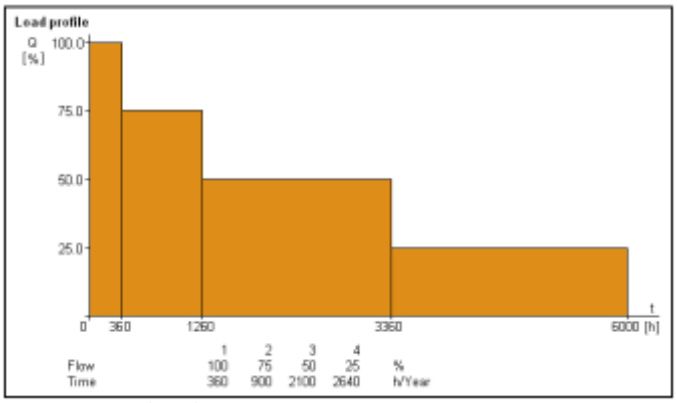

Fig. 2. Load profile of drinking water consumption (according to Blue Angel Profile) [12]

Annual operation of pumps at the second stage stations is assumed as 6000 hours per year and the load profile [11], [12] and [13] is divided into four parts with different flow values: 100%, 75%, 50% and 25% (Fig. 2). In its turn, each flow value corresponds to certain duration of time (according to the Blue Angel profile) [12].

Each flow component corresponds to certain duration of the operational time in the following way (Fig. 2):

100% -> 6%,
75% -> 15%,
50% -> 35%,
25% -> 44%.

The levels of energy consumption have been compared, if different variants of proportional pressure and constant pressure control modes are used [2-3] (Fig. 1).

The proportional pressure control mode with different deviations from the head value of the duty point at zero flow rate (20%, 40%, 60% and 80% from duty point value) has been analysed, and the calculation of annual energy consumption for centrifugal pumps of various designs [4] and [5] has been carried out in this study (the proportional pressure control mode has been chosen with linear influence [2]).

It has been observed that with the increase of deviation from the head value of the current duty point at zero flow rate the possibility of defining precisely the reduction of energy consumption is considerably decreasing, in comparison with the constant pressure control mode (Fig. 3).

During the investigation of energy savings' potential (Fig. 3) the regression equation with the respective coefficient of determination has been derived. The regression equation of the linear trend type ($y = a_0 + a_1 * x + \varepsilon$) has been chosen.

$$y = 0.5367 * x + 0.0056 \quad (1)$$
$$R^2 = 0.9808$$

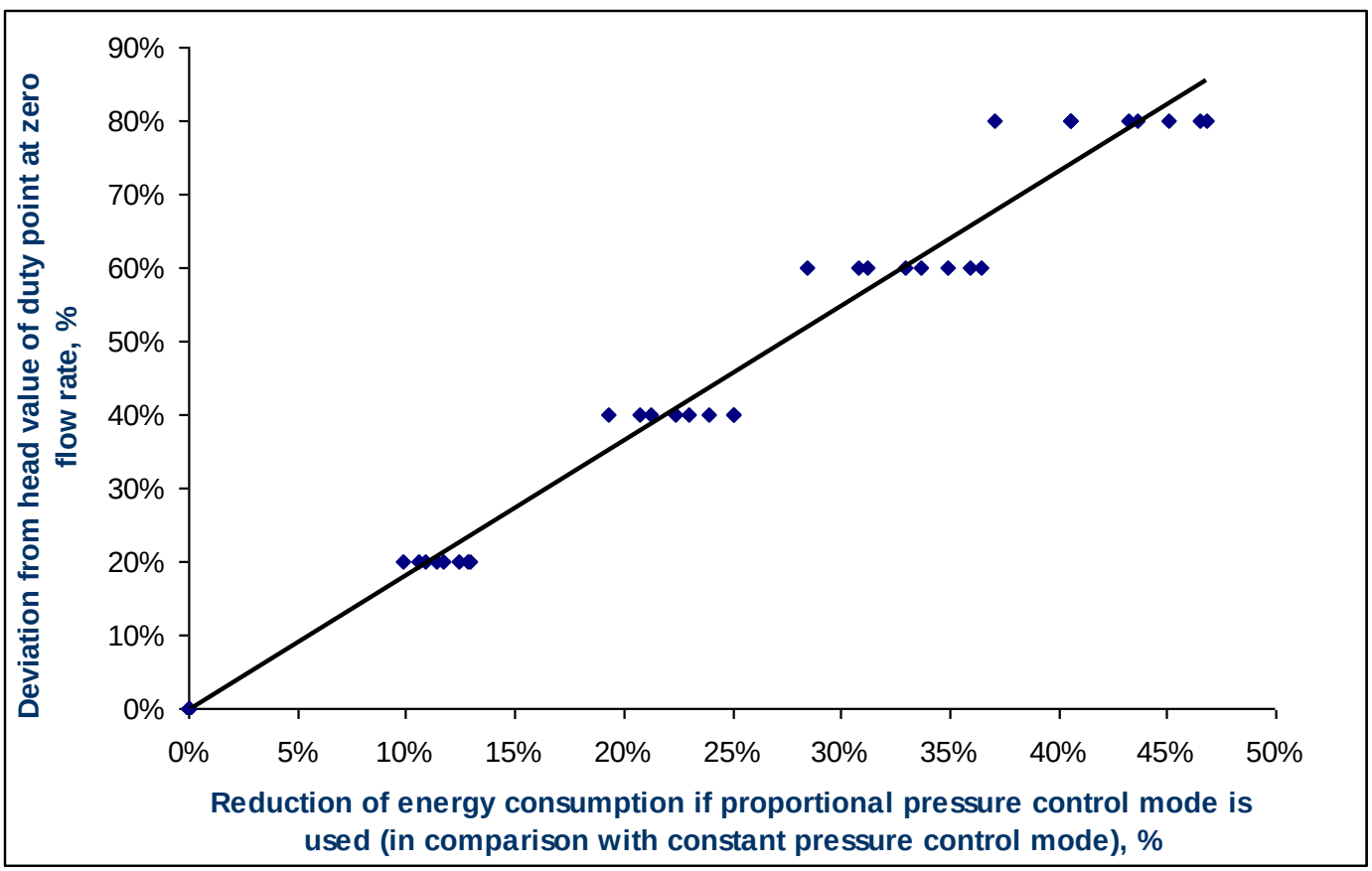

Fig. 3. Reduction of annual energy consumption if proportional pressure control mode with different deviations from head value of duty point at zero flow rate is used (in comparison with constant pressure control mode)

In this equation (1), y represents the reduction of annual energy consumption in percentage, if the proportional pressure control mode with different deviations from the head value of the duty point at zero flow rate is applied (in comparison with the constant pressure control mode), and x denotes the deviation from the head value of the specific duty point at zero flow rate in percentage.

It is possible to use the regression equation (1) as a tool for estimating the decrease rate of energy consumption at different deviations from the head value of the duty point at zero flow rate. This is realized in comparison with constant pressure control mode, if the value of duty point remains constant.

It's assumed that up to 80% of the total pump head is related to frictional losses in low and medium-size public water supply systems (Fig. 1). This means that the maximum deviation from the head value of the duty point at zero flow rate is 80%. The savings' potential at this deviation is estimated as 43.5% (if the Blue Angel profile [12] is applied for the LCC calculation).

There are different limitations taken into consideration during the study. The limitations are as follows:

- The deviation from the pump efficiency optimum is up to 3% at the maximum duty point.
- The duty points are met with different pumps.
- The deviation from the head value of the duty point at zero flow rate varies from 0 up to 80%.

During the study, eight centrifugal pumps of different design have been analysed.

Estimation of potential decrease of water leakage

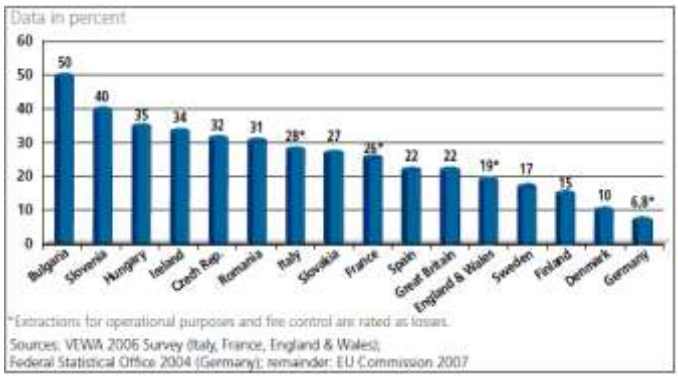

Fig. 4. Water leakage indicator in different EU countries [8]

One of the most important indicators of the quality and safety of a public drinking water network is the water leakage rate [8], [9] and [10] (Fig. 4).

Water leakage can be significantly decreased, if the proportional pressure control mode is applied.

The Torricelli's equation can be used to determine the decrease level of water leakage in a piping system [6] by decreasing the head value of the pump (2).

$$C = \sqrt{2 * g * H} * 0.6 \qquad (2)$$

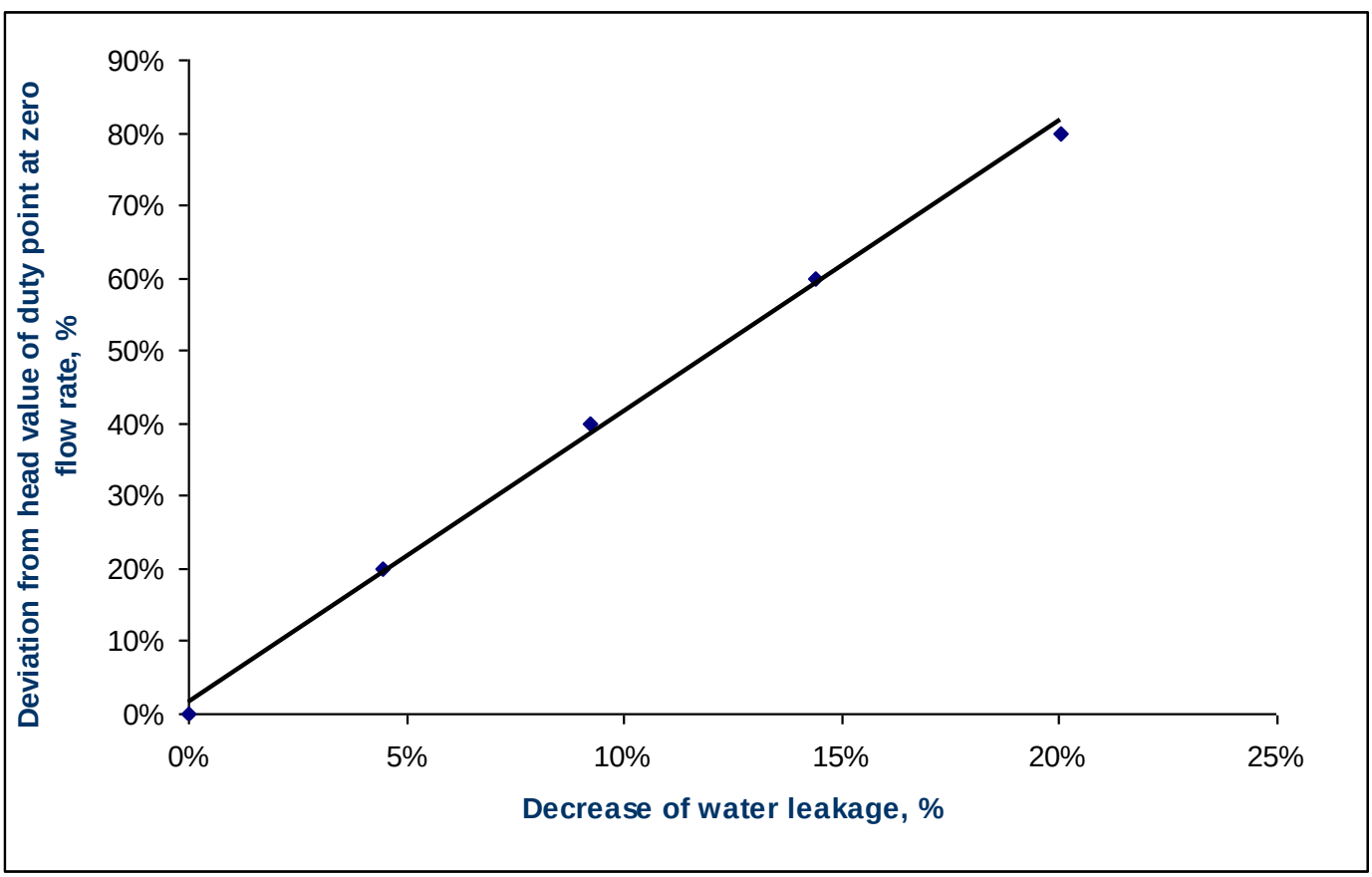

Fig. 5. Annual decrease of water leakage at different deviations from the head value of the duty point at zero flow rate, if the proportional pressure control mode is applied

In the equation (2), C represents the water speed at the pipe rupture in m/s, g is the acceleration of gravity (constant: 9.80665 m/s^2) and H denotes the pump head in m

Having analysed the decrease of water leakage at different deviations from the head value of the certain duty point at zero flow rate (Fig. 5), the following regression equation of the linear trend type ($y = a_0 + a_1 * x + \varepsilon$) with the coefficient of determination has been derived in the study.

$$y = 0.2501 * x - 0.0038 \qquad (3)$$
$$R^2 = 0.9977$$

In this equation (3), y represents the annual decrease of water leakage in % and x denotes different deviations from the head value of the duty point at zero flow rate in %, if the proportional pressure control mode is used (in comparison with the constant pressure control mode).

80% of the total pump head of the duty point are assumed to be frictional losses and accepted as the maximum deviation from the head value of the duty point at zero flow rate. The annual decrease of water leakage is estimated at 19.6% for this deviation (if the Blue Angel profile [12] is applied for LCC calculation).

The annual decrease of water leakage can be determined in comparison with the existing water leakage rate in the system by using the regression equation (3).

It is possible to define the reduction of the annual water flow in the specific water supply system in relation to the current water leakage rate in the system. It can be done, if the proportional pressure control mode with certain deviations from the head value of the duty point at zero flow rate is applied (Fig. 6).

After some modifications with the equation (3) another equation has been derived.

$$z = (0.2501 * x - 0.0038) * y \qquad (4)$$

In the equation (4), z represents the annual water flow reduction in % in the specific water supply system, if the proportional pressure control is applied; y represents the current water leakage rate in the water supply system and x denotes different deviations from the head value of the duty point at zero flow rate in % (if the proportional pressure control is used in comparison with the constant pressure control [2] and [7]).

It has been assumed that 80% of the head value of the duty point refers to frictional losses. At the same time, this is accepted as the maximum deviation from head value of the duty point at zero flow rate (Fig. 1). In its turn, the current water leakage in the system has been assumed as 25% (Fig. 4). Thus, under these conditions, the reduction of the annual water flow in the systems can achieve 4.9% (if the Blue Angel profile [11] and [12] is applied for the LCC calculation).

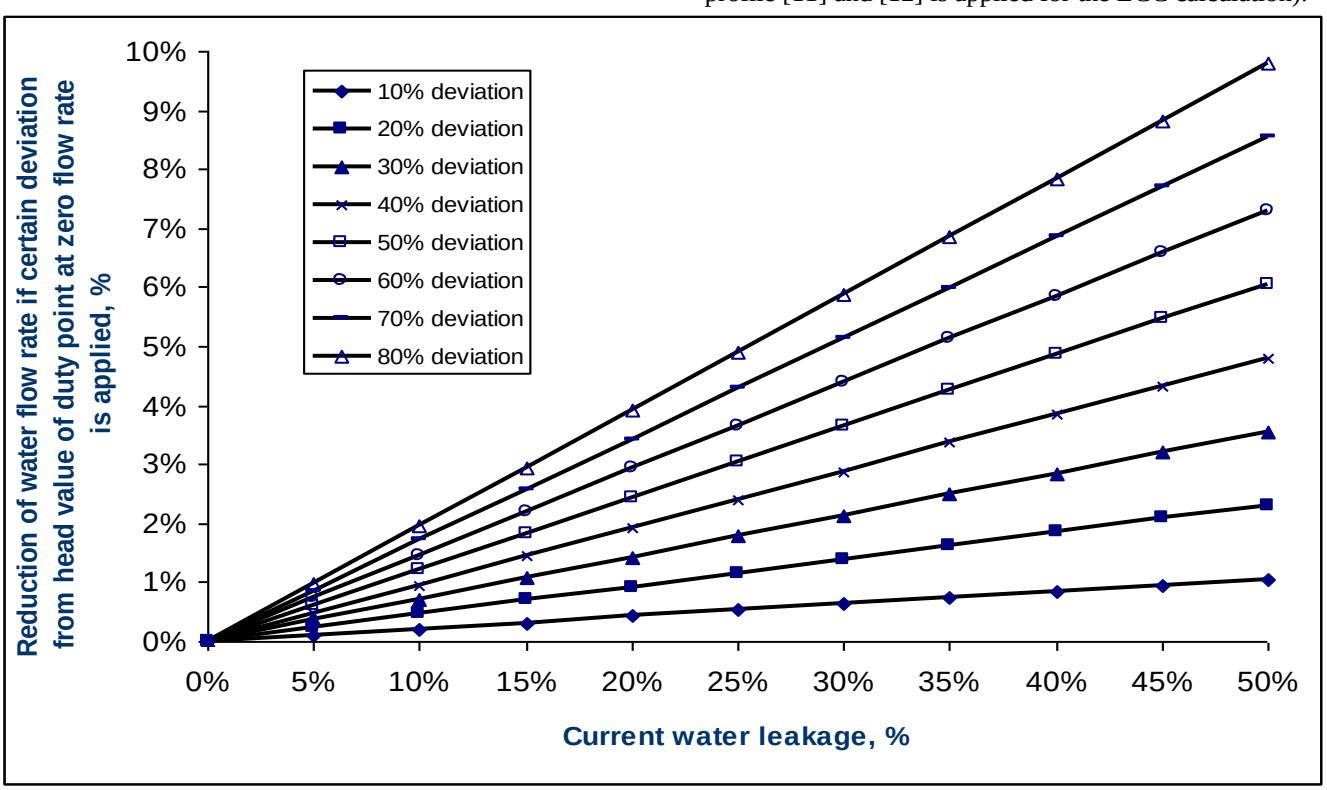

Fig. 6. Reduction of the annual water flow in a water supply system in relation to the current water leakage rate in the system, if certain deviations from the head value of the duty point at zero flow rate are applied (the proportional pressure control mode is used in comparison with the constant pressure control mode)

CONCLUSIONS

This research shows the area of the potential reduction of annual energy consumption and the total water flow at the

second stage pumping stations in water supply systems by using the proportional pressure control mode.

It has been found that the reduction of annual energy consumption can be achieved up to 43.5%. This reduction is possible if proportional pressure control mode is applied with 80% of the head deviation at zero flow. The savings' potential is estimated in comparison with constant pressure control mode.

The research also demonstrates that the annual water flow reduction in a water supply system can be reduced up to 9.8%, if the proportional pressure control is applied, in comparison with the constant pressure control. It is done if the deviation from head value of duty point at zero flow rate declines up to 80% and the current water leakage is up to 50%.

The higher level of deviation from the head value of the duty point at zero flow rate, the higher level of energy saving.

RECOMMENDATIONS

It is very much recommended to estimate potential energy savings at the second stage pumping stations in public water supply systems, when the traditional constant pressure control mode is used.

To this effect the regression equation can be used ($y = 0.5367 * x + 0.0056$). The energy savings' potential can be estimated if proportional pressure control mode is applied in comparison with constant pressure control mode.

It is also possible to estimate the potential reduction of the annual water flow in a water supply system by using the regression equation ($z = (0.2501 * x - 0.0038) * y$), when the proportional pressure control mode is applied, in comparison with the constant pressure control mode.

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Deniss Piļščikovs, Egīls Dzelzītis. Energoefektivitātes uzlabošana izmantojot proporcionālā spiediena vadības metodi otrā pacēluma sūkņu stacijās sabiedriskajās ūdensapgādes sistēmās
Pētījuma mērķis ir energoefektivitātes uzlabošanas potenciāla novērtējums, ja tiek izmantota proporcionālā spiediena vadības metode salīdzinājumā ar tradicionālo konstanta spiediena vadības metodi otrā pacēluma sūkņu stacijās sabiedriskajās ūdensapgādes sistēmās.
Centrbēdzes sūkņu analīzes gaitā tika iegūts attiecīgs regresijas vienādojums, ar kuru palīdzību ir iespējams novērtēt enerģijas patēriņa samazinājuma potenciālu sabiedriskajos ūdensapgādes tīklos. Bez tam tika iegūts arī regresijas vienādojums, kas apraksta ūdens zudumu samazinājuma potenciālu attiecībā pret esošiem ūdens zudumiem ūdensapgādes tīklā.
Elektroenerģijas patēriņa samazinājuma potenciāls tiek novērtēts, ja celšanas augstuma vērtībai ir dažādas novirzes no noteikta darba punkta vērtības pie nulles patēriņa, tādā veidā realizējot proporcionālā spiediena vadības metodi. Proporcionālā spiediena centrbēdzes sūkņu vadības metode tika realizēta salīdzinājumā ar konstanta spiediena sūkņu vadības metodes pielietojumu, ja darba punkts un slodzes profils paliek nemainīgs. Pētījuma gaitā tika veikti vairāki patērētās elektroenerģijas aprēķini pie attiecīgā slodzes profila dažādas konstrukcijas centrbēdzes sūkņiem. Visiem aprēķiniem tika izmantots „Zila Eņģeļa" slodzes profils

(Blue Angel Profile). Tika konstatēts, ka palielinoties celšanas augstuma vērtības novirzēm no noteikta darba punkta vērtības pie nulles patēriņa realizējot proporcionālā spiediena sūkņu vadību, palielinās arī energoefektivitātes uzlabošanas potenciāls otrā pacēluma sūkņu stacijās.
Pētot ūdens zudumu samazinājuma potenciālu attiecībā pret esošiem ūdens zudumiem ūdensapgādes tīklā, līdzīgi kā energopatēriņa samazinājuma potenciāla izpētes gadījumā, tika ņemti vērā dažādas celšanas augstuma novirzes no noteikta darba punkta vērtības pie nulles patēriņa.

Денис Пильщиков, Эгилс Дзелзитис. Повышение энергоэффективности, используя метод управления пропорционального давления на насосных станциях второго подъема в системах общественного водоснабжения

Целью публикации является оценка потенциала улучшения энергоэффективности при использовании метода управления пропорционального давления в сравнении с традиционным методом управления константного давления на насосных станциях второго подъема в системах общественного водоснабжения.
В процессе анализа центробежных насосов было получено соответствующее регрессивное уравнение, с помощью которого можно оценить потенциал понижения потребления электроэнергии в общественных сетях водоснабжения. Кроме того, было получено регрессивное уравнение, которое описывает потенциал понижения утечки воды по отношению к существующим утечкам воды в сети водоснабжения.
Потенциал понижения потребления электроэнергии был оценен при различных отклонениях величины напора по отношению к определенной рабочей точке при нулевом расходе, таким образом реализуя метод управления пропорционального давления. Метод управления пропорционального давления центробежных насосов сравнивался с применением метода управления константного давления, если значение рабочей точки, а также профиль нагрузки являются неизменными. В процессе исследования было выполнено множество расчетов потребления электроэнергии при соответствующем профиле нагрузки для центробежных насосов различной конструкции. Для всех расчетов был использован профиль нагрузки „Blue Angel Profile”. Была определена тенденция, при которой повышаясь отклонениям величины напора по отношению к определенной рабочей точке при нулевом расходе реализуя метод управления пропорционального давления, увеличивается и потенциал улучшения энергоэффективности на насосных станциях второго подъема.
Исследуя потенциал понижения утечки воды по отношению к существующим утечкам воды в сети водоснабжения, также как и в случае исследования потенциала понижения потребления электроэнергии, были приняты во внимания различные отклонения величины напора по отношению к определенной рабочей точке при нулевом расходе.