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DECISION MAKING SUPPORT FOR THE CHOICE OF A CONTROLLED PUMP DRIVE IN THE PROJECT OF WATER SUPPLY SYSTEM RENOVATION

LĒMUMU PIENĒMŠANA ATBALSTA SISTĒMAS IZSTRĀDE REGULĒJAMAS SŪKŅU PIEDZIŅAS IZVĒLI ŪDENSAPGĀDES STACIJĀS

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Keywords: water pump station, decision making, decision support system, electrical drives

Introduction

Decision making for water pump stations energy saving problem is described in the article. Rule based multi criteria decision making method for decision support system is developed and described in the article.

The structure of the decision support system for decision making are developed in the article, taking into account that decision support system is an information system, used for supporting decision making used by decision makers, giving system support, without replacing people, system incorporate database and models.

A decision support system for making decisions about control of pumps electric drives installation in renovating process of pump stations are investigated as a sample. The potential decreasing of the consumed electric energy in general motor control is more than 30% [4], using developed rule based multi criteria decision making method for decision support system increasing energy consumption efficiency of pump aggregate if the total payment time does not exceed 5 years.

Problem statement

Electrical energy saving problem in Latvia is actual, because the self sufficiency of electrical energy covers 36,5% of all the consumption, Latvia buys the rest of electric energy from other countries [the calculation of 2005 is based on EUROSTAT data base 6]. Taking into account that pumps, fans and compressors together consume about 50% from the electric energy produced in Latvia then the mass saving of this energy could result in the decreasing of its volume for ¼ part.

Pump station renovation problem is of important in Latvia because the is big potential of energy saving, using new electrodrives control methods. In average the motors are loaded for about 70%. The average efficiency factor is lower than 30%. The registration of the water flow is rough as the measurement devices do not operate or are absent at all.

As an energy saving example a scheme of the consumed power automatic regulation could be considered – frequency converter – induction motor – centrifugal pump. Figure 1 demonstrates the system of consumed power automatic regulation that consists of the following elements:

frequency converter, motor (induction motor in this case), centrifugal pump, water supply network and water pressure or water flow sensor at the control point.

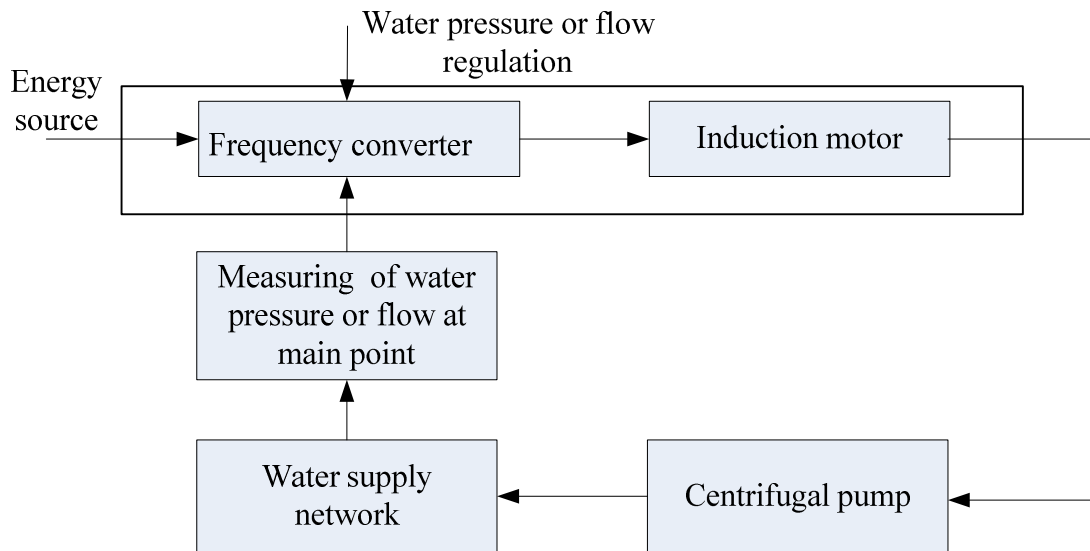


Fig.1 A system of consumed power automatic regulation

The control system realizes a particular supply of water flow according to the data of the water pressure measurements. The main control element is microcontroller. The input information of it is analogue signal proportional to the pressure and a reference command signal as well [1].

To transform the analogue signal into a digital one an analogue-digital converter is supplied. The output signals of the microcontroller control the transistors of the frequency converter. The inverter contains six power transistors, and one transistor is a part of DC voltage regulator. The microcontroller realises functions of a frequency converter, for example pulse-width modulation (PWM) or pulse-amplitude modulation. The frequency converter can realize control of the induction motor and centrifugal pump. The applied control algorithm gives a possibility to change the speed of the pump drive according to the water consumption in a building. The operational speed of the induction motor is controlled in the way that the pressure at the work point is not lower than the reference level (for example 1,5 m).

The actual problem of decision making about choosing of pump electric drives control for water pump stations renovation is described.

Research method

The choosing of pump electro drives control for water pump station renovation can be divided into two parts – choosing technical solution and financial evaluation.

The technical solution could be chosen, taking into account the method of calculation of difference of expenses for electric energy in the pump drive, comparing the control of valve in pump pressure cable with frequency converter speed control. The calculation is the following [5] :

The nominal power of the pump is calculated:

$$P_{sn} = D * Q_n * H_n * 0,981 / \eta_{k_{sn}} .$$

The Q - H characteristic of the pump is described with the following expression:

$$H_{si} = H_{max} - (Q_i/Q_n)^2 * (H_{max} - H_n),$$

where Q_n – the rated supply of the pump [m^3/h] ($1l/s = 3,6 m^3/h$),

Q_i – the calculated supply of the pump [m^3/h],

H_n – the nominal head of the pump [m],

H_{max} – the pump maximum head [m],

lk_{sn} – nominal efficiency factor of the pump [%],

0,981 - coefficient of pressure conversion into bar units.

Characteristic of the system: $H_{si} = H_{st} + (Q_i/Q_n)^2 * (H_n - H_v - H_{st})$,

where H_{st} – the static head of the system [m],

H_v - decreasing of the pressure for open valve [m].

Necessary power for the pump drive with the frequency converter:

$$P_{fpi} = \frac{D * Q_i * H_{si} * 98,1}{(lk_{sn} * lk_{mn} * lk_{mi} * lk_{fpi})},$$

where the efficiency factor of the motor

D - the liquid density of the water = $1,0 kg/dm^3$,

$lk_{mi} = (Q_i/Q_n)^{(0,2 - 0,2 * H_{st}/H_n)}$,

lk_{mn} - efficiency factor of the motor [%],

lk_{fpi} - nominal efficiency factor of the frequency converter [%].

Power that is necessary for the pump drive controlling supply with a valve in pump pressure cable:

$$P_{ari} = \frac{D * Q_i * H_{si} * 98,1}{(lk_{sn} * lk_{si} * lk_{mn})},$$

where the pump efficiency factor:

$$lk_{si} = Q_i * (2,4 - 1,44 * (Q_i/Q_n)) / Q_n.$$

The energy consumed per year for the pump drive with frequency converter is

calculated as $A_{fp} = \Sigma(T_{ki} * P_{fpi})$,

But for the pump drive with valve in pump pressure cable: $A_{ar} = \Sigma(T_{ki} * P_{ari})$;

where T_{ki} - total operating time of the pump drive per year [h].

Electric energy saved per year: $A_s = A_{ar} - A_{fp}$ [kWh].

Expenses saved per year with the use of frequency converter:

$$E = A_s * (\text{price for one kWh}) \quad [Ls].$$

Time of payment of the investments:

$$t_a = \text{FP price of the equipment} / E \quad [\text{years}].$$

The payment of the investments contains the price of the chosen frequency converter only. The additional expenses of the frequency converter purchasing are returned within the further two years. With the changing of pump aggregates the investments are increased and the time of money returning is increased as well but the new pump aggregate will have higher efficiency factor and totally the payment time will not exceed 5 years.

It is necessary to install one speed regulator at each pump station in order to improve quality of the supplied water and decrease expenses for electric energy. Pump aggregate with speed regulator allows significant decreasing of the expenses for the consumed electric energy. Figure 2 demonstrates diagrams of the supplied power changes depending on pump supply for two cases. In the first case the regulation of the water supply is realized with the change of valve position in pump pressure cable. It is clear from the diagram that with the valve fully closed ($Q = 0$), the

power supplied to the motor is only 10% less that under the rated condition ($Q = 100\%$). In this case during the control process the most part of the electric power is consumed for the overcoming of the pump pressure cable resistance.

In the second case the control of the water supply in the centrifugal pump is realized changing its rotational frequency. In this case frequency converter is connected to the supplying part of the drive induction motor, that allows a smooth control of the supplied voltage and frequency. The control of the pump aggregate is realized by an operator of the pump station, computer programm or there is an automatic control system, and the speed is controlled to keep the necessary supply or pressure at the output of the pump station or a distanced point.

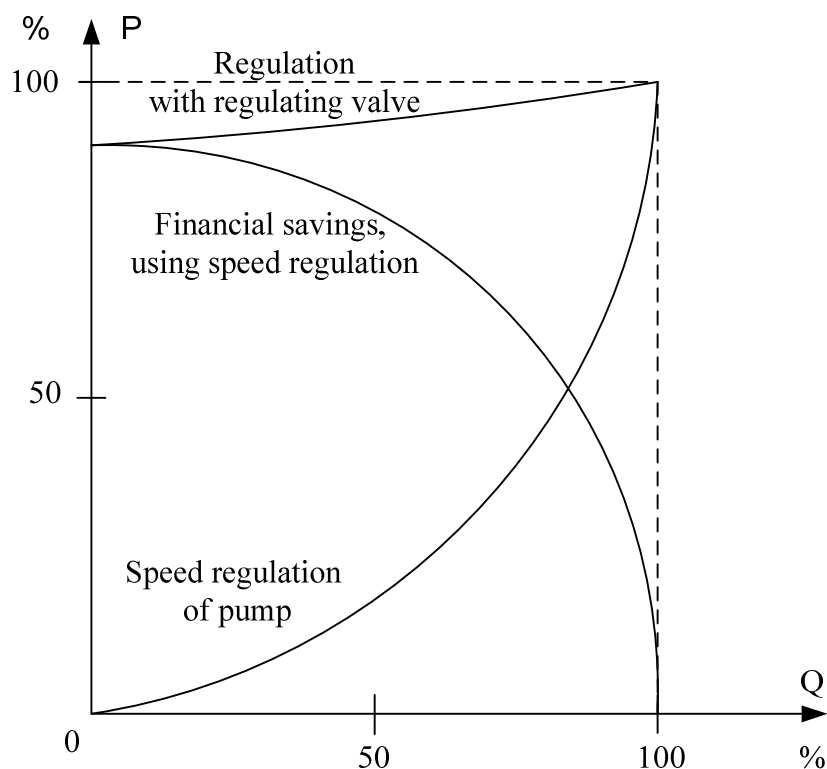


Fig. 2. Q - H diagramm of the pump

The financial evaluation choosing of pump electro drives control for water pump station renovation can be realized, using decision support system.

Decision support system design task formulation

The problem of choosing controlled pump drives for water pump station could be solved, using decision support system, based on expert system, adding human interface. The controlled pump drives choosing could be formalised by expert experience and alternative evaluation for the defined

system parameters and consumer's request. The using of modern information technology helps to choose the optimal drive in innovation study of pump station exploitation.

The actual problem of decision making in choosing pump electro drives control in water pump station renovation is described.

The structure of decision support system is analysed in the article (figure 3).

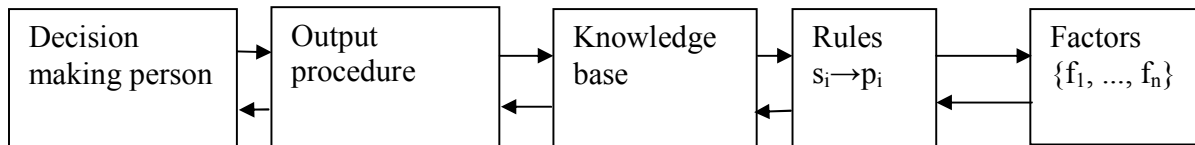


Fig. 3. The structure of production decision support system

The decision making person and system collaboration gives the informational based on solution decision support system. Output procedure [2] is often as rules interpretation by planning. Decisions rules are interpretation as if s_i , then p_i .

The s_i , then p_i could curtain from factors f_i , in a complicated way. The output procedure could be defined in the different ways, the main idea is to define set of factors: $F = \{f_1, \dots, f_n\}$,

It is important to know, that the new facts can not be achieved as results of system functioning. The main aim of e system is to define relations for real situation facts.

The two existing set F subsets will be defined in the article F_0, F_1

$$F = F_0 \cup F_1, F_0 \cap F_1 = \emptyset$$

The subset S_1 will be named as subset of marked (known) facts, but subset F_0 – the subset of unmarked facts. The subset F_1 , sometimes could be considered as a working field of decision support system. In the beginning of the work the system has some facts, for example: $F_1 = \{f_1, f_2, f_3\}$.

The subset F_1 fulfilment could be made by moving elements from F_0 subset. The rules interpretation could be described as $s_i \rightarrow p_i$ with facts from F_1 , if the rule is subset F_1 will be fulfilment from facts, which are true in right side of production P_i . The choosing best decision from $S_1 = \{s_1(p_1(f_1)), s_2(p_2(f_2)), s_3(p_3(f_3))\}$ is the decision maker function, the best alternative we described as $S'_1 \supset S_1$.

Decision making procedure

The decision making procedure structure for pump electrical drives choosing problem for pump stations in innovation process included such elements [3]: decision maker DM, administrator A, decision maker interface I(DM), reactor of knowledge base R(KB), general knowledge base (KB), the particular cases (KBp) (figure 4.). The user interface could be developed as questionnaire, menu, and native language or table of symbols.

The decision maker goal (figure 4) is with the use of decision support system to get maximal ROI (rate of investments (minimal costs)) of operation of pump station.

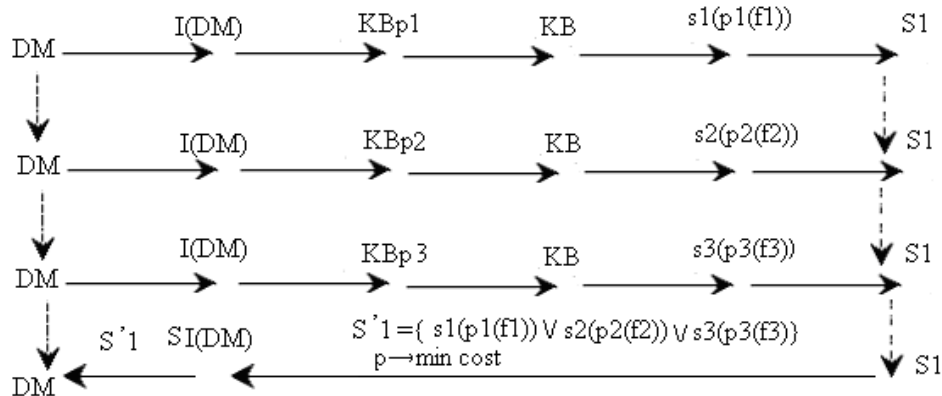


Fig. 4. Interaction between decision maker and decision support system

Numerical example

There is an experimental checking procedure example for the control of water supply with the use of frequency converter in comparison with the changing of valve in pressure cable [5].

Zolitūde pump station. Local authority company "Rīgas ūdens" pump M3 (300 D 70) table 1.

Table 1.

Output data

Liquid density (water = 1)	D (kg/m ³)	1,0		
Pump nominal flow (1 l/s = 3,6 m ³ /h)	Q _n (m ³ /h)	788	219 l/s	
Nominal head of the pump	H _n (m)	25		
Pump maximum head (at zero flow)	H _{max} (m)	30		
Static head of the system	H _{st} (m)	15		
Nominal efficiency of the pump	lk _{sn} (%)	70		
Decreasing of the pressure for open valve	H _v (m)	3		
Rated power of motor (max. 500 kW)	P _l (kW)	100	Pi=85 kW	
Nominal efficiency of the motor	lk _{mn} (%)	93		
Nominal efficiency of freq. converters	lk _{fpn} (%)	98		
Total operating time per year	T _k (h)	8760		
Price of energy (per kWh)	Ls /kWh	0,05026		
	Flow D (kg/m ³)	Time (%)	Hours	
Operating time in different flow rates as a percentage of the total operating time	30%	236.4	0	0
	40%	315.2	0	0
	50%	394	0	0
	60%	472.8	30	2628
	70%	551.6	20	1752
	80%	630.4	35	3066
	90%	709.2	10	876
	100%	788	5	438
The sum must be = 100%	Sum	4097,6	100	8760

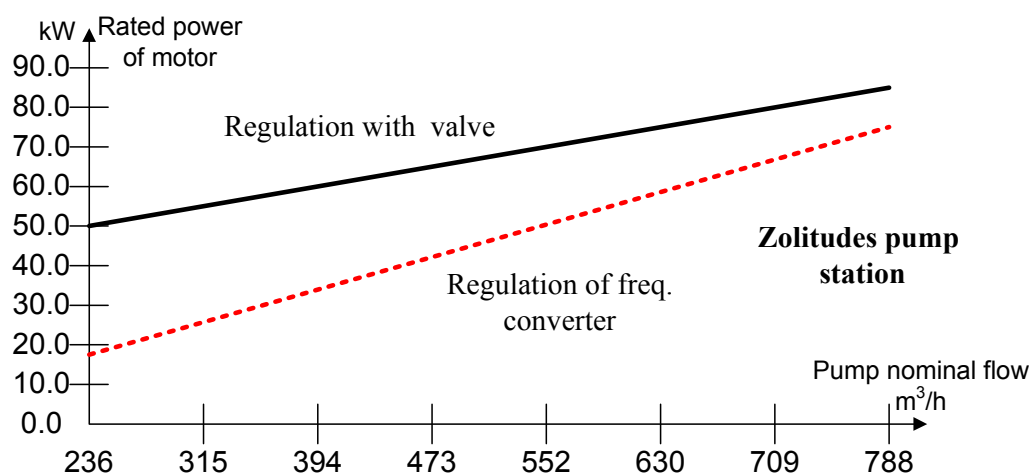


Fig. 5. Diagramm of the pump drive power changes

Results of calculations:

Calculated energy/ hydraulic control	Aar	596 233	kWh
Calculated energy/ freq. conv. control	Afp	427 577	kWh
Total energy savings / year	As	168 656	kWh
Total energy cost savings / year	E	8476,65	Ls
Investment costs (can be given)		12 000	Ls
Direct payback time	Ta	1,42	years

Commentary: using motor M28CM6 and frequency converter ACS 503-140-3.

The data have been obtained from the data base of the water supply pump station.

Conclusions

Decision making problem for pump electric drives control choosing for water pump stations innovation, by long term energy saving are analyzed in the article. Electric energy saving problem in Latvia is actual, because the production of electrical energy covers just approximately 30% of consumption, the rest of electric energy Latvia buy from other countries. For this problem solving the development of decision support system, taking in account structure of technical problem, the user requirements of water supply, the additional costs of control system installation and other parameters are used. The rule based method, based on analysis of costs of tree alternative decision in five middle and long term period. The solution of energy saving problem in water pump station could achieve a potential decreasing of the consumed electric energy in motor control that could be more than 30%.

The structure of decision support system for decision making is developed in the article, taking into account that decision support system is an information system, used for supporting decision making used by decision makers, giving system support, not replacing people, system incorporate database and models.

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Galkina A., Ribickis L., Kuņicina N. Čaiko J., Lēmumu pieņemšana atbalsta sistēmas izstrāde regulējamās sūkņu pieslēgšanas izvēli ūdens apgādes stacijās.

Elektropiedziņas sūkņu staciju renovācija Latvijā ir aktuāla problēma, tādēļ ka lielo ūdenssūkņu staciju darbība Rīgas pilsētas ūdensapgādes sistēmas ir neekonomiska. Ūdensapgādes staciju renovācija ir laika un resursu ietilpīgs projekts, kā rezultāti būs novērojami ilgtermiņā, tādēļ, ir aktuāli izvēlēties tādu sūkņa regulēšanas veidu, kas būs ekonomiski efektīvs ilgtermiņā, ņemot vērā ne tikai tā kapitālās izmaksas, bet arī uzturēšanas izmaksas. Rakstā tika aprakstīta lēmumu pieņemšanas atbalsta sistēmas izstrāde regulējamās sūkņu piedziņas izvēlei ūdensapgādes staciju renovācijas projektam. Rakstā tika formulēta elektroenerģijas lietošanas efektivitātes paaugstināšanas procedūra sistēmā frekvences pārveidotājs - asinhronais dzinējs - centrālās sūkņa. Parādīta elektroenerģijas izmaksu starpības aprēķina metode sūkņu piedziņā, salīdzinot aizbīdņa regulēšanu spiedvadā ar ātruma regulēšanu, izmantojot frekvences pārveidotāju, kas ļauj plūstoši regulēt pievadītā sprieguma lielumu un frekvenci, tādējādi izsaucot sūkņa

ātruma un ūdens piegādes daudzumu maiņu. Aprēķina rezultāti ir atspoguļoti arī diagrammās. Aprēķina piemērs tika izstrādāts Zolitūdes sūkņu stacijai, lietojot izstrādātu lēmumu pieņemšanas procedūru, kura ļauj, zinot, sūkņa parametrus iegūt ekonomisko salīdzinājumu vidējā termiņā un ilgtermiņā.

Galkina A., Ribickis L., Kunicina N. Caiko Y., Decision making support for the choice of a controlled pump drive in the project of water supply system renovation.

The problem of renovation of the electric drive pump stations is highly actual in Latvia. In particular, in Riga the operation of major pump stations is economically unprofitable. The renovation is a long-term project, whose results will be seen in the future. Therefore, it is of importance to choose such a type of the pump regulation that will be effective in perspective, taking into account the capital and maintenance expenses. The paper describes a decision making procedure for the choice of a controlled pump drive in the project of water supply system renovation. The procedure involves improvement of the efficiency of electric energy use within the system. The authors propose a method for calculation of the electric energy consumption by pump drives in the cases of valve regulation of a drive as compared with the speed regulation using a frequency converter, which allows a smooth control of voltage and frequency thus changing the water feed. The results are demonstrated in the diagrams. For calculation, the Zolitude (Riga) pump station was taken. The results of calculation can be used for elaboration of the procedure of decision making on the choice of a water pump station based on the economic comparison in medium- and long-terms.

Галкина А., Рыбицкий Л., Куницына Н., Чайко Е. Системы поддержки принятия решения выбора водонапорных станций путём регулирования электропривода.

Реновация электроприводных насосных станций в Латвии является актуальной проблемой, потому что реновация системы водоснабжения это долгосрочный проект, результаты которого будут заметны в продолжительный период. Актуально выбрать такой вид регулирования насоса, который будет экономически приемлем, не только с точки зрения капитальных затрат, но и затрат эксплуатации. В статье предлагается процедура принятия решения выбора насосов в системах управляемого привода водонапорных станций для реновационного проекта. Анализируется повышение эффективности систем применяя частотный преобразователь и заслонку. Показан расчет затрат электроэнергии используемой приводом насосов, сравнивая метод регулирования заслонки с методом регулирования, используя частотный преобразователь, который позволяет свободно регулировать величину напряжения и частоту, таким образом меняя частоту подачи воды. Как пример рассматривается насосная станция Золитуде, для расчета используя процедуру, которая позволяет, введя параметры насоса, получить экономическое сравнение в долгосрочном режиме.