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EXAMPLE FOR ELECTRICAL ENERGY SAVINGS WITH THE PUMP ADUSTABLE ELECTRIC DRIVE

Slobodan MIRCEVSKI, Zdravko ANDONOV, Fahrudin SARACEVIC, Darko MICESKI, Aleksandar BUCKOSKI
Faculty of Electrical Engineering - Skopje

Abstract

Most used method of flow regulation is by throttling the pipeline. Development of power electronic gives opportunity for induction motor pump drives speed control. The common ways of pump flow control are throttling, reducing the working circle, usage of forecircle shovels rotating, by pass and pump speed control. Only pump speed control is the most suitable for the energy possibilities. Intensive development of power electronic gives opportunity to create devices - power converters, which can change the speed of induction motor.For that improvement the energy savings the measurements of power consumption with throttling and speed control have been made. Also, the MATLAB-SIMULINK model of the measured system has been made.The economic effects of saving energy using adjustable speed drives are analyzed for the measured values. The analysis shows that the money payback period of speed controller investment is short compared with the drive lifetime (20 years).

Куса содржина

Во трудот се обработува пример за заштеда на електрична енергија кај погон на пумпа со променлива брзина на вртење. Експериментот е направен во Лабораторијата за електромоторни погони на Електротехничкиот факултет во Скопје. За задвижување на пумпата тип KCP 25-3 од M3T - Скопје е употребен асинхрон мотор тип 4AZ 100L-2 од Раде Кончар - Хрватска, напојуван од преобразувач на фреквенција со директно управување на моментот ACS 601 od ABB - Финска. Цели на експериментот е да се установи количеството на заштедена електрична енергија во однос на класичен начин на пригушување на протокот и да се види кое е времето на исплатување на инвестицијата во преобразувачот на фреквенција. Исто така, како можност за генерилизирање на резултатите од експериментот, направен е модел на системот во MATLAB-SIMULINK. Се покажува дека заштедите на електрична енергија се значајни. Времето на враќање на инвестицијата е кратко во споредба со експлоатационот век на погонот (20 години).

1. Introduction

Pumps are the most common types of working machine. They are wasting 20% of whole produced electric energy. The power of the pumps starts from few watts and expanse to tenth thousand kilowatts. Their use is most common in the systems for communal and industrial water supply and irrigation.

Dominant in the pump drive is the use of induction electric motor, so in this text are elaborated only that kind of solutions.

For flow change of pumps throttling, by pass, turning the shovels and regulation of speed are the used. Technically best way for the change flow is speed control. That is impossible in classical solutions. Intensive development of power electronic gives opportunity to create devices - power converters (controllers), which can change the induction motor speed [3], [5].

In this text are analyzed conditions that are required by the pump as working mechanism to electric drive. Also are analyzed economical effects by saving energy using adjustable drives.

2. Flow regulation of pumps

The flow regulation is understood as changing the pipeline or of the pump curve, to get the needed flow. By regulation is changing the place of the working point that is found in the section between H-Q curve of the pump and Hc-Q curve of the pipeline, which causes changing pump effort and flow as shown in Fig. 1.

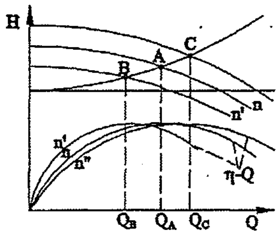

Fig. 1 Pump working curves for the different speeds

2.1 Classical ways of regulation

2.1.1 Flow regulation by throttling the pipe line

In exploitation of turbopumps often is required change of the flow. For this purpose usually is used valve which is installed right after the pump on the suppressed pipeline. By opening or closing the valve, hydraulic losses are getting higher or lower. The working point is changing its position and the flow is reduced. This way of regulation is wide used, although is uneconomical and efficiency may be reduced. The flow can be changed in wide range between completely open and completely closed valve. Pipeline throttling is very simple, and it has wide use especially on places where quick flow changes are needed.

2.1.2 Regulation by reducing the working circle

During the pump exploitation often is needed reducing of the flow and the effort, i.e. to reduce the pump power. If speed can't be changed by drive, than working feature is realized by reducing the working circle at its exterior diameter. By reducing the exterior diameter of the working circle, the fluid speed at the exit of working circle is reduced, so the effort is reduced too. According to that, by reducing the working circle the efforts feature is moving down and at some value of its exterior diameter is getting the wanted parameters.

2.1.3 Regulation by using forecircle

Turbopump forecircle can be radial or axial. By changing the exit angle of the forecircle shovels, entrance perimeter component of the working fluid absolute speed at the entrance in the shovel space of working circle changes and also effort changes.

2.1.4 Regulation by rotating the shovels of the working circle

This way of flow regulation is used for large axial pumps with moving shovels of the working circle. In this kind of pumps the shovels can be rotated in different angles. In each shovel angle responds another working curve and also another working point. In this way the optimal value of the efficiency is reducing insignificantly because during the new working regime shovels won't be best surrounded by streaming flow.

2.1.5 By-pass regulation

This kind of flow regulation is realized by turning back the part of the working fluid from the suppressed to the absorb line by using by-pass line (Fig. 2) which contains valve 2. By changing the valve's resistance is changing the flow of the working fluid through the by-pass line and above to the users. The stream energy of the working fluid which streams through by-pass line is loosing i.e. is converting in to heat. According to that by-pass regulation is uneconomical. [1], [4].

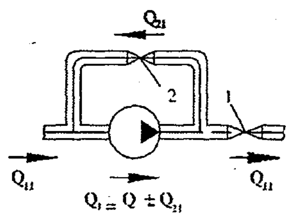

Fig. 2 By-pass regulation

2.2 Usage of power converters

2.2.1 Flow regulation by adjustable speed drives

Working curve of the pump H-Q is changing by changing the pump speed, and also is changed the working regime. Working regime is determinate by the working point, which is situated in the section of the H-Q and Hc-Q curves by given speed. For example if the speed is reduced from n to n' the pump feature parallel is getting down (Fig. 1). In this case section point A is moving to B so the flow is reducing from Qa to Qb. During the increasing of the speed from n to n" the H-Q is moving parallel up and the flow is rising from Qa to Qc.

2.2.2 Solutions with power converters

Power rate of low - voltage induction motors usually is up to 250 kW, sometimes to 400 kW. Today's power electronics development enables realization of voltage/frequency converters with wide output range. Voltage and frequency power converters can be direct and indirect. Because direct converters are complex, expensive with low output frequency they are not suitable for pump drives.

The indirect frequency and voltage converters are usually used for pump drives with induction motors. At indirect voltage and frequency converters (IVFC) electric power with supply frequency first is converted in to DC. There are voltage or current IVFC depending on constant DC link value.

Principle scheme of IVFC is shown on the Fig. 3 a); and the output signal is shown on the Fig. 3 b).

At single-motor drives with high power is used current inverter. At multi-motor and lower single-motor drives are used voltage inverters.

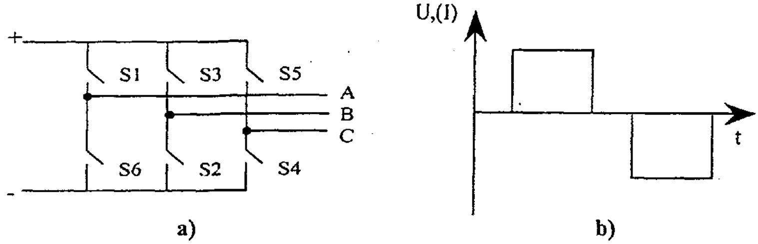

Fig. 3 a) Principle scheme of inverter; b) Output waveform in one phase

This solution is suitable for drives with induction and synchronous motors. For wound rotor induction motors drives undersynhronous cascade can be used.

3. Practical measurements

The aim of this article is measurement of electrical energy consumption for different ways of flow regulation and to check feasibility of the speed-regulation. For that purpose these measurements have been made in the laboratory of electric drive at the Faculty of Electrical Engineering in Skopje. For that purpose we use this equipment: electric motor, centrifugal pump, speed-controller, two tanks and system of pipes and valves. This equipment enables to working and measure with the real system.

3.1 System description

System (Fig. 4) has pump driven by induction motor (IM). By intake pipe water is pumping form lower tank and by lifting pipe it transports to higher tank. From higher to lower tank water goes by by-pass pipe. Flow control in is done by valve V1.

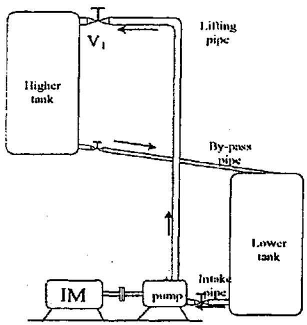

Fig. 4 Principle scheme of measured system

3.1.1 Motor characteristics

For the driving we use induction motor 4AZ 100L-2 made by Rade Koncar Croatia. Its nominal data are: Pn = 3000 W; In = 6,4 A; nn = 2860 min^{-1}; hn = 83 %; $cos\varphi_n$ = 0,86; Mp = 2,4 Mn; Mk = 2,6 Mn; f = 50 Hz; J = 0,0043 kgm^2; connection Y.

The short circuit and no load tests were made for determination of motor parameters. Resistance of stator coils was determined by U-I method. The estimated resistance are: stator and rotor resistance Rs=1.76 Ω; R'r=1.34 Ω; stator, rotor and magnetizing inductance Xs=2.85 Ω; X'r=3.85 Ω; Xm=115.98 Ω.

3.1.2 Speed-controller characteristics

Controller type ACS 601 is made by ABB, Finland. In ACS 600 group belongs family of products with nominal powers between 2,2 and 315 kW. Nominal data for the used one are: nominal voltage 400V; output current 11A; power 4 kVA; output frequency to 300 Hz.

Controller is made as voltage inverter with constant voltage in DC circuit. Controller works on pulse wave modulation with modulating frequency between 1.7 and 3.5 kHz. In controller exists programmable analogue and digital outputs. Through that outputs we can measured necessary values: currents, voltage, motor speed, torque.

In this controller there are protections for drive overload, phase unbalance, over-current, and over frequency. It has possibility of DC breaking current. Principle of direct torque control enables optimal motor work. DTC can be used only for single motor drives. For multi motor drive can be applied only scalar regulation. Controller has possibility to control some technologic value, by implemented PID controller.

3.1.3 Pump characteristics

For this research we used horizontal centrifugal pump with three degrees made by MZT from Skopje type KCP 25-3 with following characteristics: Nominal flow Q_v=1.25 x10^{-3} m^3/s; effort Y=600 J/kg; nominal speed of rotation n=2900 min^{-1}; lifting height H=60 m.

3.1.4 Pipeline characteristics

Pipeline is made from polyethylene pipes with nominal diameter 1" connected with thermofusion. For closing the pipeline we used the ball valves for the simple flow regulation. There are three valves, one before the pump, one after the pump and the third one is in the by-pass pipe.

3.2 Measurement results

In this experiment we measured flow, power that motor takes from the supply and electric energy spent for two ways of flow regulation: by throttling the pipeline and by speed-regulation.

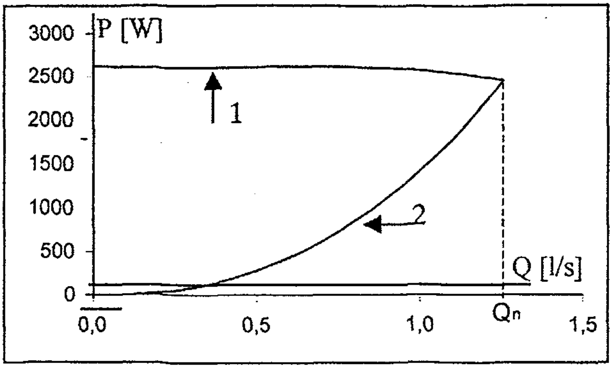

Fig. 5 Change of power by changing the flow 1-by throttling, 2-by speed control

When pipeline throttling makes the flow regulation, motor speed was kept constant, and changing regulation valve position made the flow regulation.

The measured power vs. flow characteristics is show on

Fig. 5, curve 1. In the second case flow change is made by the motor speed. On **Fig. 5 curve 2** is shown power vs. flow when the motor speed is changed.

On Fig. 5 we can note that with the same flow and different way of regulation, motor from supply take different power. Area between two curves on

Fig. 5 is possible saved energy. It's obvious that the higher savings are possible when the flow is smaller.

4. Mathematical simulation

Mathematical simulation of this system work is made in the MATLAB SIMULINK. The models were made of the controller, motor and pump with pipeline as is shown on Fig. 6.

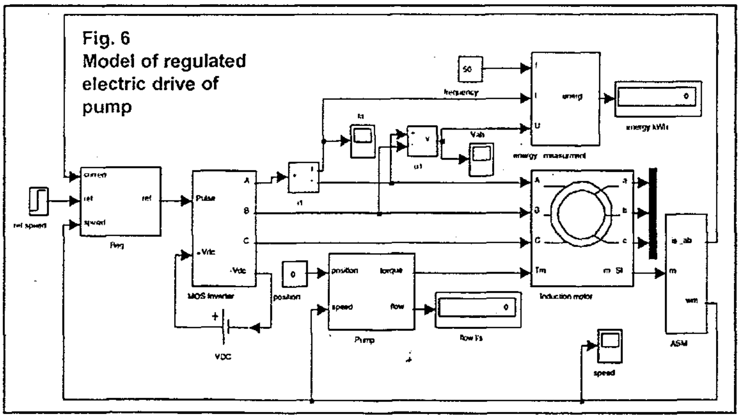

Fig. 6
Model of regulated electric drive of pump

Model of inverter is made with the MOS transistors. The DC circuit is presented with ideal DC voltage source. The motor speed and valve position are inputs in the model pump. The torque and flow are outputs. There are six valve possible positions. Consumption of electric energy is calculating in the block energy measurement. The current values of flow and spend energy are shown on displays. The other values can be shown if they are necessary. Results obtained by simulation are very close to results obtained by practical measurements. For that reason in the futher analysis practical measurement results are used.

This model enables analysis of regulated electric drives of pumps independently from their installed power. For that purpose we must change motor and used pump system parameters. In this way is possible techno-economical analysis without measurements. [2], [6].

5. Techno-economical analisys

5.1 Basic suppositions

This analysis was made to determine possible energy saving by using the inverter instead of pipeline throttling. Possible indirect savings as extending pump and pipeline lifetime, reduced maintenance costs etc, are not mentioned in this analysis.

For determination of inverter pay off period installing in the pump drive its necessary to know the pipeline daily working diagram.

Basic analysis was made with supposed daily working diagram as shown on Fig. 7. A real daily diagram contains more flow changes. Supposed price of electric energy is 0.03 $/kWh, and the price of the used inverter is approximately 1200 $.According to these facts is possible to determine the daily saving of electric energy and pay off time of controller.

Daily saving diagram of is shown on Fig. 8. Daily saving curves are obtained from supposed daily diagram, for a constant full flow working time flow has been changed from 0 to nominal value.

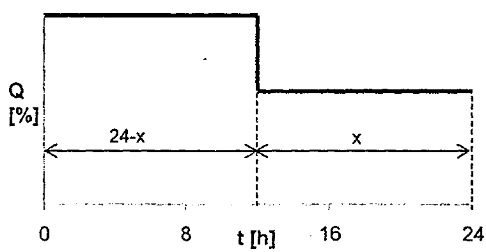

Fig. 7 Supposed daily working diagram of pump

In the Fig. 8 are shown five daily savings curves (curves 1 to 5 on Fig. 8) for 4, 8, 12, 16 and 24 hours work with flow lower than nominal. The curve 6 is shown the controller payment time in days. Daily saving for certain flow is determined by suitable curve by the working time of the pump with certain flow. We can determine the payment time by pay off period curve.

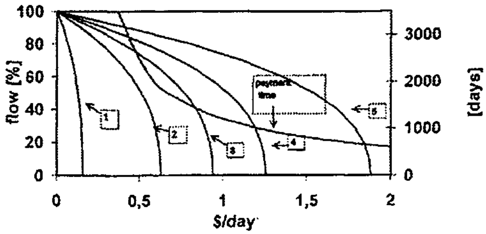

Fig. 8 Diagram of daily savings and pay off period

Expected daily saving is limited by curve 5 (pump works 24 hours with flow different then nominal), and y-axis (pump works 24 hours with nominal flow).

5.1.1 Examples

On Table 1 are shown some examples, which have daily, working diagrams like swown on Fig. 7.

Table 1 Examples

Example	Flow Q [%]	Working time [h]	Daily saving [$]	Pay off period [days]
1	50	12	0.77	1558
2	80	8	0.54	4444
3	30	16	1.19	1008

The Fig. 8 can be used for controller installation pay off period determination even if the working diagram is more complex (as shown in the Fig. 9)

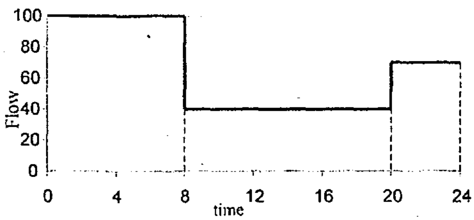

Fig. 9 Complex pump daily work diagram

According to the fact that the saving is possible only with flow smaller then nominal, then we can split the diagram on two parts. In the first part pump works 12 hours with 40 % of nominal flow and 12 hours with nominal flow, and in the second part pump works 4 hours with 70 % of nominal flow and 20 hours with nominal flow. Daily saving from first part is 0.84$ (curve 3), and from second part is 0.19$ (curve 1). Complete daily saving is the sum of this two savings and its 1.03$/per day. The payment time amounts to 1165 days.

6 Conclusion

Basic problems in area of energetic today are result of needs of rational energy usage. Performances that enable controllers with new control methods and possibilities of turning back energy in to the supply enables to favor this kind of solutions.

From this article we can see that the installing of speed controller in pump's drive, only by saving energy, is worthwhile in less years then drive's life.

Results are obtained for 3 kW motor's drive. For bigger drives energy savings are rising taster instead of the drive price of. According to that the payment time is reducing. Thus controller can be installed in the older drives too.

Instead of electric energy saving we not mention indirect savings made by increasing the pump life, pipeline and on the motor too.

Also drinking water saving and fuel saving for electric energy production today presents big gain in ecological aspect.

7 References

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