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MEASURING INFORMATION SYSTEM FOR THE PUMP STATION CONTROL IN THE FUNCTION OF PREVENTION ENGINEERING

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Abstract. *A measuring information system for the pump system control installed in the pump station "Berilovac", Pirot, is presented in the paper. A special attention is paid to the system protective role, i.e. the system role in the function of prevention engineering. It emphasizes the possibility of applying some protective functions and eliminating any negative influence of the human factor. MIS contribution related to the field of system diagnostics and preventive maintenance are presented too.*

Key Words: *Pump Station, Protection, Preventive Maintenance*

1. INTRODUCTION

Most of the pump stations in Serbia, situated in municipal or industrial systems, are known for their very low level of technical equipment (a small number of reliable measuring instruments, a low level of automation and protection). This situation results in a great number of negative effects, such as ignorance of the actual system characteristics, control errors, errors in redesign, unnecessary increase of production costs, increase of system breakdowns and slowdown in production.

Through a detailed analysis of this problem [2], during completion of a project [1], PS "Berilovac" set an example for reducing pump station (PS) operating costs for more than 50% [3]. The results achieved in PS "Berilovac", Pirot, have led to the realization of another project [4] and installation of measuring information system (MIS) for energy efficiency management in water supply systems [5]. Besides additional reducing of production costs, the MIS application emphasizes its important role in the PS supervision, control and management systems, as well as in protection and preventive maintenance systems.

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2. Description Of MIS

MIS is built according to the methodology for indirect pump system parameters estimation, based on the measured electrical values for the induction machine drive [6]. The methodology has been developed during the project realization [1]. Using the available information, the methodology provides all relevant data on PS behavior [5] (single pump flow, PS total flow, head, power loss, power factor, pumped water amount, etc).

MIS is composed of hardware and software part (Figure 1):

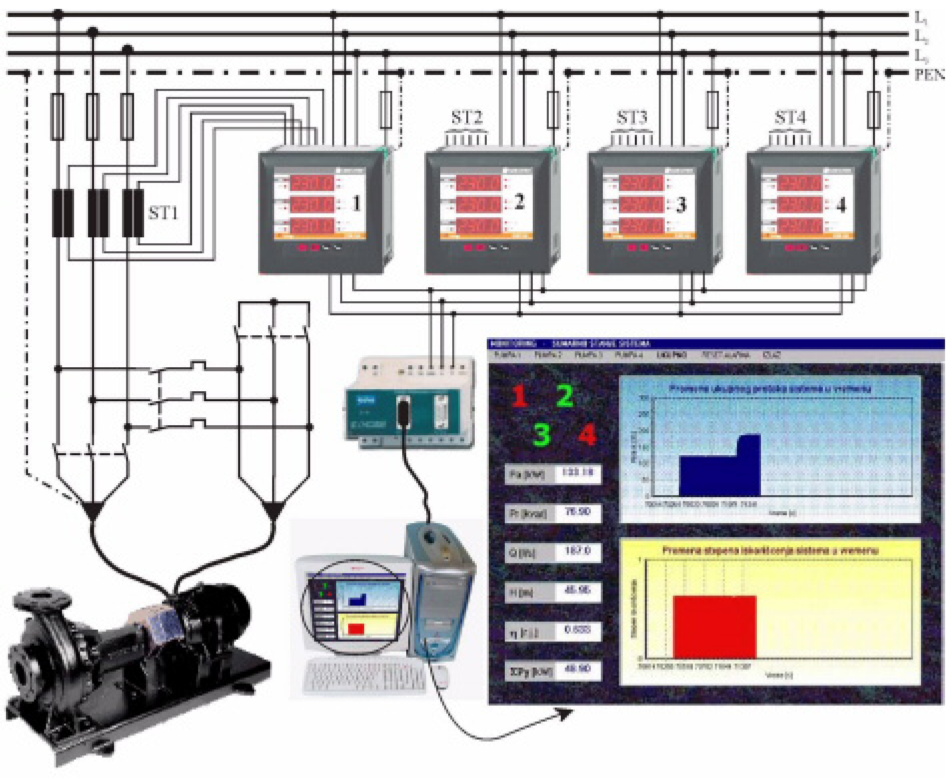

Fig. 1 Functional Model of MIS

For the realization of the hardware part of MIS, 3-phase network analyzers are used. Information about 3-phase voltages that supply driving machine of each pump and motor currents are led into their inputs. In the case of the PS "Berilovac", voltage values are obtained directly from a joint bus bar, which all the pumps are connected to, while current values are obtained indirectly through current transformers (Fig. 1). The data from the network analyzers are led to PC every 4 seconds, through RS 485/RS 232 converters. The PC operates as a work station and it displays, archives and, additionally, process the collected data for full determination of the system parameters [5].

The network analyzer collects information about the following electric values: phase and line voltages, line currents, power factor in each phase, active, reactive and apparent powers, total harmonic distortion factor of voltages and currents. According to these variables, the program detects which pumps are in operation and, using the previously defined functional dependencies, calculates (every 4 seconds) the values of: single pump flow, PS total flow, electric drive efficiency, total efficiency, partial loss of pumps and their electric drives and system total loss. Also, the value of each pump's head is calculated.

Most of the data that could be useful for the system operator are shown on the working station screen, enabling high-quality monitoring of PS operation.

In addition to the evident conveniences in obtaining a partial or summary process parameter, the user receives the suggestions about the optimal combination of pumps regarding the minimal summary power loss.

MIS continuously memorizes parameters of the process, which enables data analysis and processing in order to gain a better insight into the system operation.

A wide range of possibilities of MIS, which includes monitoring, control and management functions of PS operation, also allows for the realization of protective function in order to increase the system's reliability and safety.

3. Protective Requirements

During PS operation several requirements are imposed, regarding reliability and protection from breakdowns that may cause equipment damages, create dangerous situations to personnel, or may lead to financial loss. Concerning numerous dangerous situations during PS exploitation, the ones related to technical and financial aspects are discussed in the paper.

Considering devastating effects of atmospheric discharge to the equipment in PS, especially to the devices containing sensitive electronic components, it is necessary to provide appropriate protective measures against atmospheric discharges.

PSs are large power consumers, containing large electric motors and complex electrical installations, which means that a significant possibility of short circuit emergence exists, with many negative effects. This brings out the necessity of undertaking respective protective measures.

During the PS operation, there is a danger of pump electric motor overload, and in order to avoid such situations there is respective overload protection, usually in the form of bimetal relays.

PSs are usually driven by 3-phase induction motors. Dropping out of any phase or increased asymmetry of phase voltages induces irregularity in operation. Therefore, it is necessary to prevent 2-phase operating mode, as well as asymmetrical mode.

Depending on the PS location and the way of PS power supply realization, the phase voltages may differ from the permitted values range of (0.9- 1.06)U_n, according to the IEC 38 and JUS N.A2.001. Phase voltages greater than 1.06U_n have a much more negative effect on the electric motors of the pumps because they increase magnetizing current of a motor, which may cause overheating. On the other hand, the phase voltages lower than 0.9U_n increase the motor's starting currents. In order to avoid such negative effects protective measures have to be taken.

Pumps may be left without working fluid, during their start, which does not affect electric motors negatively. But, it may lead to mechanical damage of pumps, if it is not stopped in a short period of time. Namely, running without fluid causes the overheating of the pump bearings, with possible negative effects on the electric motors.

Several pumps in PS may be simultaneously turned on. Combinations of pumps working at the same time are usually predefined. But, some combinations of pumps, turned on at the same time, are about to cause negative effects on the system. Several pumps working together may increase production costs and flow and pressure in pipeline and, therefore, may cause damages to the pipeline and filters. All these things bring out the necessity of protection from turning on certain combinations of pump simultaneously.

In order to stabilize the pressure in the water supply system, different types of reservoirs are used. Therefore, the operation of a PS has to be adjusted to water level changes in reservoirs, by applying specific protective measures, especially protection from overflow.

In addition to all the problems mentioned above, other kinds of protection from any impact on the system that could have a negative effect when reliability, stability, security and any other technical parameters are considered, should be applied.

Unfortunately, only basic protective measures for prevention of negative effects of atmospheric discharge, overloading and short circuits, are provided in our pump stations, while the more complex ones are rarely present. Instead, the human factor still has a dominant role in protection.

4. Protective Role of MIS

Since the previously described MIS continuously monitors all the parameters relevant to PS operation, it can play an important role in the PS protective system. In that sense, except protection from atmospheric discharge and short circuit protection, which require a very fast response of the protection system, MIS can take part in all other above-described cases, as is going to be shown in the following examples.

4.1 Protection from Driving Motor Overload

In addition to the standard overload protection, realized by bimetal relays, the protective role of MIS may be performed as follows: every time an overload appears, a signal is given and data is written into the corresponding data base. Only is the authorized user allowed to change technical requirements, regarding overload toleration.

When a tolerable overload occurs, a yellow signal field appears above the serial number of a pump (above number 3, in Figure 2). If the overload is out of the range of tolerance, the field turns red and the sound alarm is given. In the case of full automation of PS, MIS turns off overloaded motor.

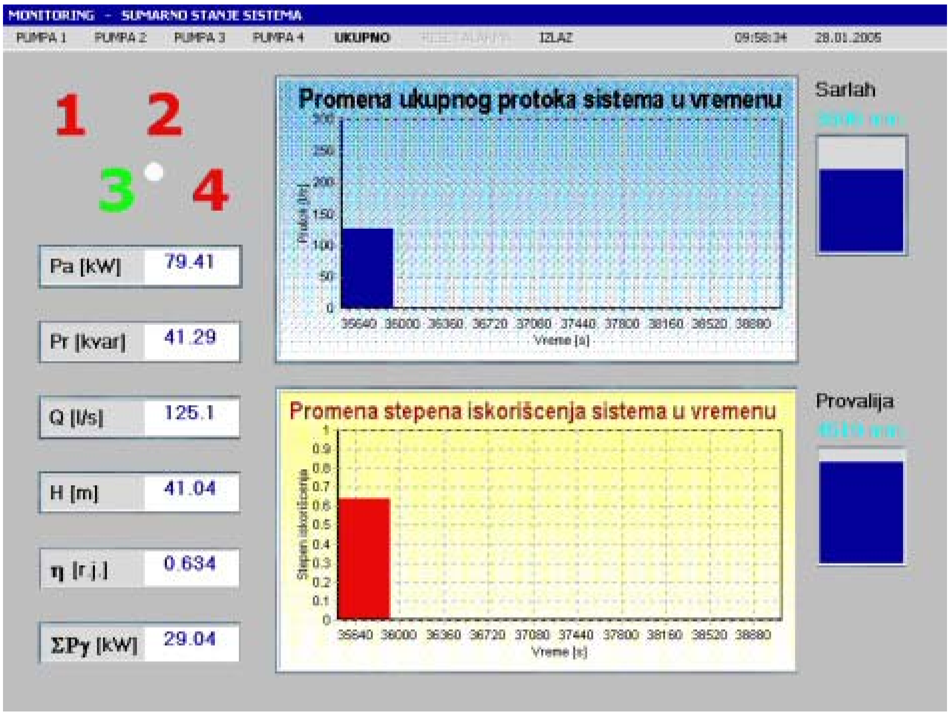

Fig. 2 MIS Screen

4.2 Protection from Unbalance in Power Supply or Phase Drop Out

The line current asymmetry can be calculated as:

$$S = I_1 + I_2 + I_3$$

$$A = \frac{1}{6}(I_1^2 + I_2^2 + I_3^2)$$

$$B = \frac{1}{6}\sqrt{|3 \cdot S \cdot (S - 2 \cdot I_1) \cdot (S - 2 \cdot I_2) \cdot (S - 2 \cdot I_3)|}$$

$$a_I[\%] = \sqrt{\left|\frac{A - B}{A + B}\right|} \cdot 100 \qquad (1)$$

where I_1, I_2 and $I_3$are line current values.

If the asymmetry is greater than predefined, MIS turns off induction motor. In that sense, MIS represents a device protecting from asymmetry or phase drop out. A message about the reason for turning off is shown on the screen. The time and the reason of turning off are written into data base.

4.3 Over or Undervoltage Protection of Induction Motor

MIS continuously monitors voltage on the joint bus bar (Fig. 3), which enables protection from operation when voltage is out of range of tolerance.

Fig. 3 Diagram of Voltage Changes on Induction Motor Connectors

The authorized user has an ability to change the range of voltage tolerance, and MIS automatically disables induction motor every time the voltage value leaves the range of tolerance. Besides, showing an appropriate message on the screen and writing corresponding data into data base, MIS does not allow turning on until the normal voltage conditions are established.

4.4 Protection from Operating without Fluid

MIS enables us to detect the absence of fluid in the pump impeller in a simple way. In such cases, the power which the pump induction motor takes from the supply network is substantially smaller than the minimal power which would be taken if the pump operated with the normal amount of fluid and with the fully closed tap in the pipeline. The minimal power consumed in the normal operation can always be exactly determined for every system pump-induction motor. Measuring the power taken from the network and comparing it to the calculated value of the power consumed when the amount of fluid in the pump is normal can be used as a condition for protective device reaction and for turning the motor off.

4.5 Protection from Water Overflow in Reservoirs

In the case of PS "Berilovac", MIS is connected to the water level monitoring system in "Sarlah" and "Provalija" reservoirs, and it measures water levels every 15 minutes (Fig.

2). Depending on the momentary water levels, MIS determines optimal combinations of pumps in PS, which enables filling both of the reservoirs without water overflow. When the upper limit is reached, MIS automatically turns the pump off.

4.6 Protection from Operating with Too Many Pumps

In order to insure water supply, PS is composed of several pumps. These pumps are never turned on all at the same time. Some of them are left in reserve. PS energetic efficiency depends on combination of working pumps. Therefore, certain pump combinations may be predefined for certain working conditions. Also, certain combinations may be permanently forbidden, regardless of any working conditions. According to the preset requirements, MIS is able to forbid turning on of any combination of pumps in order to avoid unnecessary loss.

4.7 MIS as a Part of Preventive Maintenance System

During the exploitation of the MIS installed in PS "Berilovac", MIS turned out to be an important part of the prevention maintenance system. Through the analysis of all data gathered by MIS, it became clear that it is possible to define appropriate methods for estimating the state of shaft bearings of pumps and driving induction motors. Not only that the bearings in poor conditions increase loss, they also provoke additional changes of motor load. A diagram of active power change for four pumps in different combinations is shown in Figure 4.

Fig. 4 Active Power Change Diagram for 4 Pumps

It is difficult to obtain the information about state of bearings only from analysis of diagram of active power taken from the network. However, when the pump head is calculated, taking into account the measured electric values of driving induction motor parameters according to the proposed methodology [6], a great difference between diagrams in Figure 5 becomes prominent. Due to the poor state of bearings, switching on of the pump SPS 7/B is forbidden. Pump SPS 88 is operating much longer than relatively new pumps NK 150-400/380 and NK 150-400/379. These facts, combined with the analysis of the diagrams in Figure 5, lead to conclusion that oscillations in diagrams in Figure 5 contained information about state of bearings. In that sense, the greatest oscillations are found in the diagram of the SPS 7/B pump, the pump with bearings in a very poor state (1 and 2, in Figure 5). New pumps, NK 150- 400/380 and NK 150- 400/379, which have been working for less than a year, have negligible oscillations in their diagrams of active power change (5 and 6, in Figure 5).

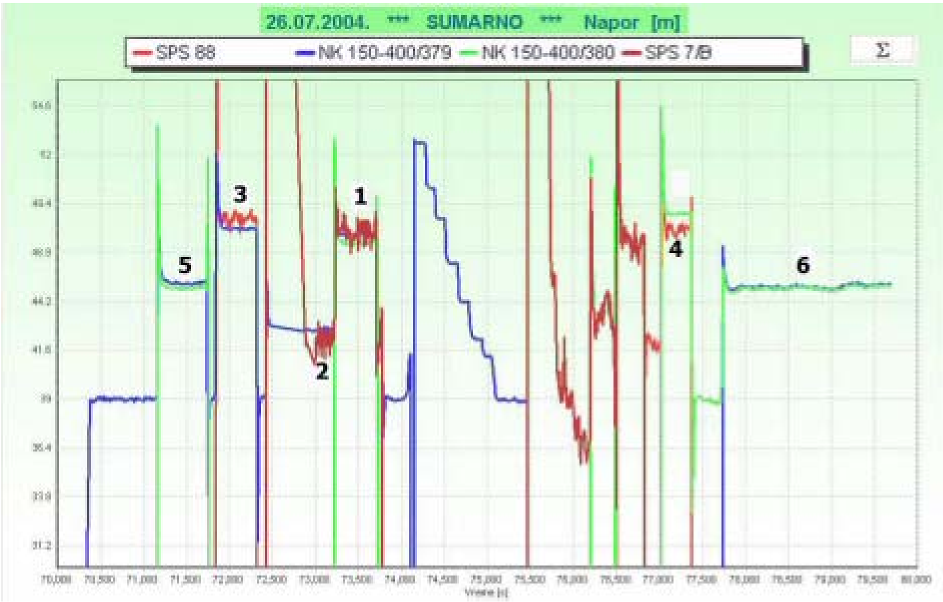

Fig. 5 Head Change Diagram for 4 Pumps

The events described above may be used for the creation of methodology for determination of pump shaft bearings condition, which makes the data obtained by MIS very useful in preventive maintenance system.

5. Conclusion

Technical possibilities for applying of MIS as a part of the prevention engineering system are analyzed in this paper. The example of MIS installed in PS "Berilovac", Pirot, shows that, in addition to its basic functions (monitoring, control and management of PS), it also enables performing of different protective functions.

Protective functions of MIS may be applied individually or together with predefined protective functions, which leads to a higher levels of reliability and safety in the whole system.

MIS also significantly contributes to diagnostics of electric drives and prevention engineering. It enables full automation of PS and centralized management of the complete water supply system.

REFERENCES

1. "Peak electric load managing in communal systems", Project from National program of energetic efficiency, evidence number NP EE413-118A.
2. Z. P. Stajić, N. Radovanović, D. Nikolić, "Analysis of energetic efficiency of PS "Berilovac" electrical drive and technical possibilities for it's increse", Project analysis No. 1/0-05-057/02-5, Faculty of Electronic Engineering, Niš, august, 2002.
3. Z. P. Stajić, N. Radovanović, D. Nikolić, "Analysis of pump station "Berilovac" energetic efficiency - experimental verification", Symposium proceeding "Modern electromachinery gear in water supply and sewage systems", Vrnjačka Banja 6.-8. october 2004.
4. "Information system for managing of urban communal systems", Project from national program of water regulation, protection and utilization, evidence number: NPV-19.B.
5. Z. P. Stajić, Z. Golubović, V. Pešić, "An information system for managing of energy and work efficiency of water supply systems", Symposium proceeding "Modern electromachinery gear in water supply and sewage systems", Vrnjačka Banja 6.-8. october 2004
6. Z. P. Stajić, S. Radosavljević, N. Radovanović, "An indirect method for pump stations pipeline characeristics determination", "Preventive engineering" (YU ISBN 0354-3811), 2/2003, 2003.

MERNO INFORMACIONI SISTEM ZA UPRAVLJANJE PUMPNIM STANICAMA U FUNKCIJI PREVENTIVNOG INŽENJERSTVA

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U radu je prikazan merno informacioni sistem za upravljanje pumpnim sistemima koji je instaliran u PS "Berilovac", Pirot. Posebna pažnja je posvećena zaštitnoj ulozi ovog sistema, odnosno njegovoj ulozi u funkciji preventivnog inženjerstva. Ukazano je na mogućnost primene pojedinih zaštitnih mera i eliminacije negativnog uticaja ljudskog faktora. Istaknut je doprinos MIS na poljima dijagnostike stanja i preventivnog održavanja.

Ključne reči: *pumpne stanice, zaštita, preventivno održavanje*