ISSN 1846-6168
UDK 621.65.05-531.3:519.876.5

UNAPRIJEĐENA SIMULACIJA NIVOA VODE ZA PROTOTIPNU AUTOMATIZIRANU CRPNU STANICU

ADVANCED SIMULATION OF WATER LEVEL FOR PROTOTYPE AUTOMATED PUMPING STATION

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Stručni rad

Sažetak: *U ovom članku opisan je proces analize i unaprjeđenja prototipnog modela crpne stanice koji se koristi za izradu, provjeru i unaprjeđenje programskog koda, te vizualizacije sustava (SCADA sustav). Originalno rješenje je bilo iznimno dobro za analizu rada upravljačkog sustava, no mehaničke komponente modela nisu dovoljno dobro obrađene. U obrađenim unaprjeđenjima prvenstveno se osvrtalo na mehaničke odnose dotoka i odtoka vode, te promjene u nivou vode, što je u originalnom rješenju riješeno ručno. Novo rješenje mehatronički je naprednije i bolje jer obuhvaća realniju sliku dinamičkog stanja crpne stanice. Uz to, novo rješenje automatizirano provodi simulaciju nivoa vode direktno iz istog PLC uređaja koji provodi regulaciju rada pumpi, pa je s te strane sustav dobro integriran.*

Ključne riječi: *Automatizacija, crpna stanica, PLC, SCADA, TIA Portal*

Professional paper

Abstract: *In this paper the process of analysis and improvement of a prototype model of a pumping station is described, which is used to build, validate and improve the programming and visualization of the system (SCADA system). The original solution was extremely good for the analysis of the control system, but mechanical components of the model were not sufficiently processed. In described improvements the main issue was mechanical relations of incoming and outgoing water flow, and result differences in water level, which were provided manually in the original solution. The new solution is more advanced and better from the point of view of Mechatronics, since it can give a more real image of a dynamical state in the pumping station. Furthermore, the new solution conducts automated simulation of water level directly from the same PLC device which controls the operation of the pumps, so from that point of view the system is well integrated.*
Key words: *Automation, pumping station, PLC, SCADA, TIA Portal*

1 INTRODUCTION

The existing prototype automated pumping station, with details described in [1], is a faithful replica of a real pumping station drive concerning the integration of digital automation. The automation was implemented using a Siemens Simatic S7-1200 PLC device, with characteristics available in [2], and the visualisation was implemented using a WinCC application in the TIA Portal V11 SP1, with characteristics available in [3]. The communication between the PLC device and a SCADA application is achieved using a Profinet communication protocol described in [4]. The prototype automated pumping station was used to test the operation of real pumping stations and to improve the solution programme of a pump control.

The paper presents the analysis of the drawbacks of the mechanical part of the station, according to [5] and gives solution to the identified problems, according to [6]. Improvements were found for every identified problem, as well as a repeated evaluation of the new solution, according to [7]. The new system must give a more realistic display of the way a real pumping station works.

In order to create a new solution, the existing PLC device was used, as well as the communication channel and the upgraded SCADA application.

2 ANALYSIS OF THE EXISTING PROTOTYPE MODEL OF A PUMPING STATION

The existing prototype model of a pumping station consists of components which can be found in a real pumping station. The result of water level movement is simulated manually. A water level measurement in real pumping stations is replaced by three limit switches which show the state of water level as “higher” or “lower” than their level. The levels of the belonging KPs are marked as “low”, “medium” and “high”. Two DC engines in the model replace real pumps. The model is controlled by the PLC S7-1200 with the SCADA support. Figure 1 shows the existing prototype model of a pumping station. The existing model components which are important for the paper are the mechanical parts for water level simulation:
1 a panel for manual water level simulation

2 limit switches for water level simulation

The limit switches are connected as digital inputs and they can show four different states:
1 a level lower than “low“
2 a level higher than “low“ and lower than “medium“
3 a level higher than “medium“ and lower than “high“
4 a level higher than “high“

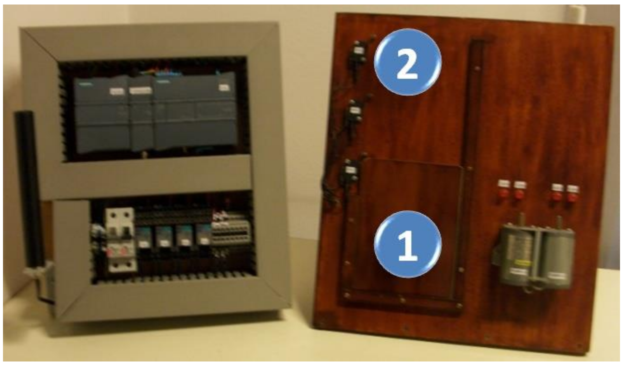

Figure 1 The exisiting prototype model of an automated pumping station

In real pumping stations the incoming water level, which the regulation is based on, is performed using an analogue signal. The pump operation is based on a regulation according to default levels which are entered by an operator. Digital inputs are performed using level switches and they also serve as a security system which takes the main regulating function if, for some reason, a level sensor falls out of the system, i.e., makes an error. Standard procedure for industrial equipment is using voltage analogue signals 0-10 V, i.e., current analogue signals 4-20 mA. Such uniformly chosen signals enable compatibility of all the equipment used in the operation. Standard procedure for input / output digital signals in industrial application is normally 24VDC, while internal intermediate circuits of a PLC device (galavanically separated from input / output connectors, inaccessible to a user) are performed on a 5VDC level.

The pump regulation is based on a “main/auxiliary“ regime, where the pumps exchange their main and auxiliary statuses in each iteration. The controller is performed in such a way that it holds water level within a certain range which is determined by an operator. In the case of the existing model the flexibility of the system is very small considering the fact that there is a difference between only four band levels instead of an exact amount of water level.

It has been established that the main drawback of the existing prototype automated pumping station is the way the water level is simulated in the station. Namely, the existing solution performs a simulation based on recognition of discrete water levels. This kind of simulation is good enough concerning the simulation of working conditions of the control system, but it is not good enough in showing the real relationship between mechanical phenomena and the actions determined by actuators, in this case water pumps. The water level is changed manually according to the rise or fall of water level with discrete levels which are precisely defined by limit switches. They also serve as a replacement for real level switches. It is necessary to create such a way of water level simulation which will continuously change the existing discrete water levels from 0 to 100 %. In this paper we devised a way which still demands a manual simulation of water level.

Two DC engines, which represent the operation of two pumps, make the power section of the existing model. In order to be able to show the possibility of using the PLC, both DC engines were reversed. A solution programme was used to solve the inhibition of energisation of both rotation directions of DC engines.

3 IMPROVEMENT OF THE PROTOTYPE MODEL OF A PUMPING STATION

The components for water level simulation were taken as finished circuits from a scanner and a printer and they were connected to a rheostat. Figure 2 shows the system for water level simulation and it consists of the following components, which are marked with a number:
1 a rounded board made of acrylic glass
2 limit switches
3 a drive motor and a spur wheel with a slider
4 a rheostat

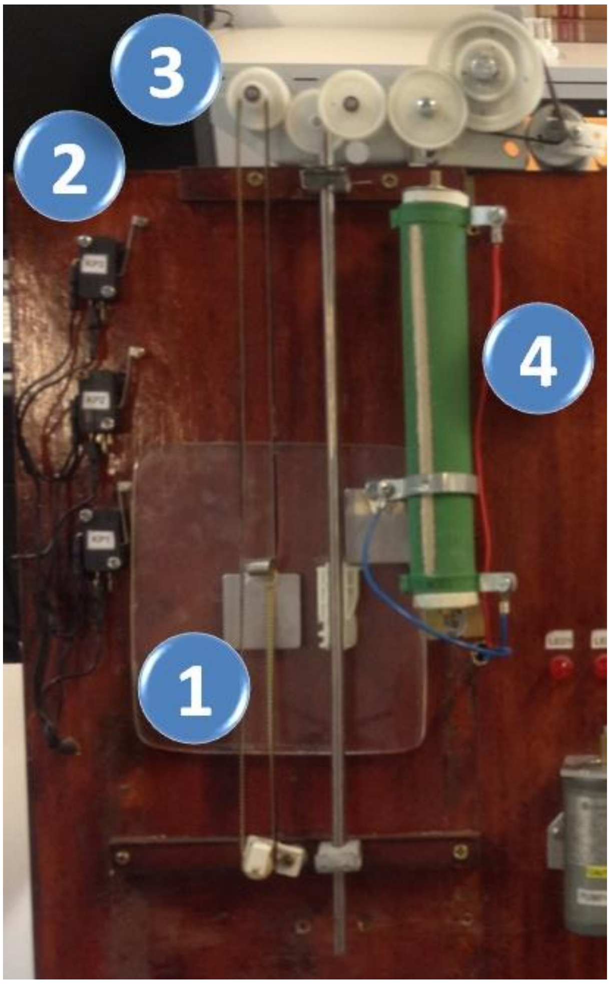

Figure 2 The improved prototype model of a pumping station

The drive part for the movement of the water level simulation system is a DC engine and the feedback is achieved using a sensor which is designed as a rheostat and it shows water level in the shaft. Considering the fact that these are the main components of the designed system, it is necessary to know well their characteristics. These data are necessary for the pairing of the system with a control panel. The drive motor data are given for the nominal voltage value of 12 VDC and they amount to 8170 r/min and 0,89 A with developed power of 6,74 W. The rheostat data are adjusted to the signalling mode which the system is expected to work in. A linear rheostat was chosen with total resistance of 1 kΩ with ± 5 % tolerance and rated power of 100 W.

The existing wiring of the prototype model of a pumping station was upgraded with new cables and conductors. The characteristics of the wiring (group appliances, colour, sectional views) from the existing condition were preserved and used for the newly installed equipment. The cables and conductors were fixedly connected to the control panel and disconnection can be completely done on the mechanical part of the prototype model of a pumping station, as it is shown in Figure 3. The final version of the mechanical part of the prototype model of a pumping station is shown in Figure 4.

Figure 3 Wiring of the prototype model of a pumping station

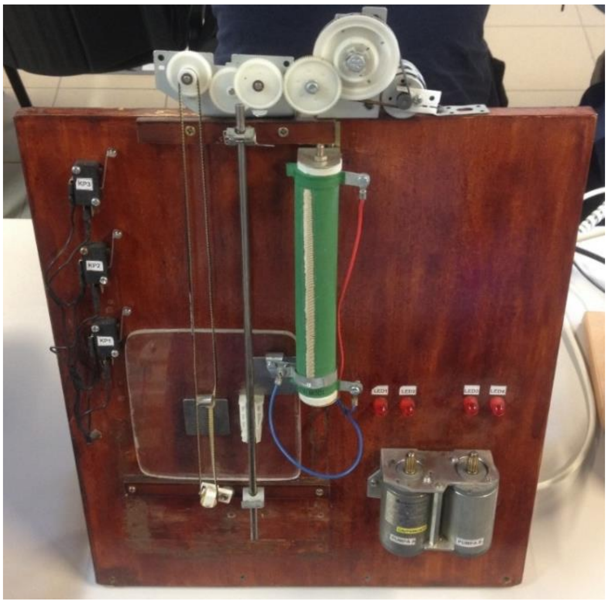

Figure 4 The final version of the prototype model of a pumping station

The power section of the DC motor supply requires reconstruction so that another reversible DC motor can be capacitated. For that reason the pump operation is rearranged in such a way that they work in one direction only, which is actually correct, and the other two relays are used for two directions of the DC drive motor for water level simulation. Minimal changes in wiring resulted in full functionality of the power section of the prototype model of a pumping station.

4 RESULTS OF THE IMPROVED PUMPING STATION MODEL IN OPERATION

The existing solution, in response to manual water level simulation using limit switches, defined four discrete levels, which were described in previous chapters. The values of water level were defined as: 5% for a level lower than "low", 15% for a level higher than "low" and lower than "medium", 55% for a level higher than "medium" and lower than "high" and 95% for a level higher than "high". Uniform lifting of the water level simulation panel in the existing solution resulted in the response to the SCADA, as it is shown in Figure 5. It is evident that the state changes at the moment when the state of the limit switches changes. It is a significant change and in one case it is 10% and in the other two cases even 40%. This kind of feedback resolution is not satisfactory.

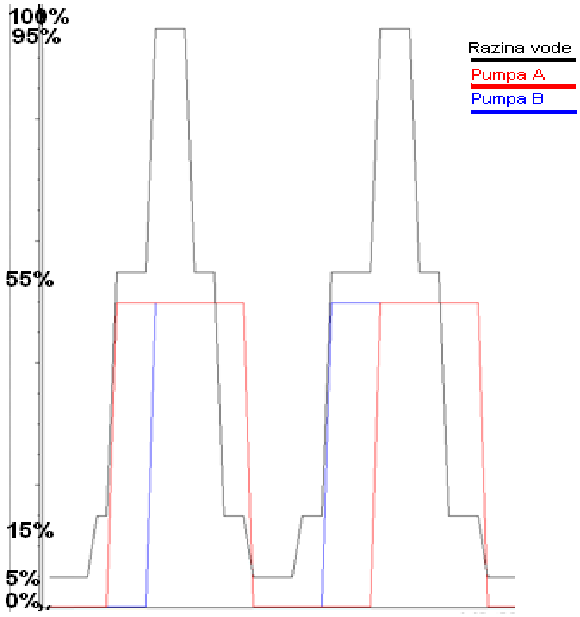

Figure 5 A graphical representation of the operation of two cycles of the existing state - high level [1]

The programme which was made for the redesigned model included a regulation of water level using pumps, a visualisation and a control of water level simulation in the pumping station. A visualisation screen which serves for the pump control and the water level simulation is shown in Figure 6 during the testing run. It is evident that the improvement had a good result and that is a continuous water level simulation. In this case the water level above the limit switch is "medium" and below the limit switch is "high", but this time the amount is not assumed to be 55%, as it is in the old solution, but in this case its actual value is measured and for the shown example it is 77%. A system operation has been recorded for the same typical scenarios as in [1]. In the first scenario there is an incoming water flow and it is assumed that one pump is enough to pump out water. After that, a scenario is recorded in which there is an incoming water flow, but a single pump operation is not enough to reduce the water flow. Then two pumps operate together, which creates an outgoing water flow high enough to reduce the water level. Responses in Figure 7 show primarily that the water flow changes continuously, which were demanded. The testing of the scenario shows that the regulation of functionality did not change according to the old solution which faithfully described a real controller which is used in pumping stations.

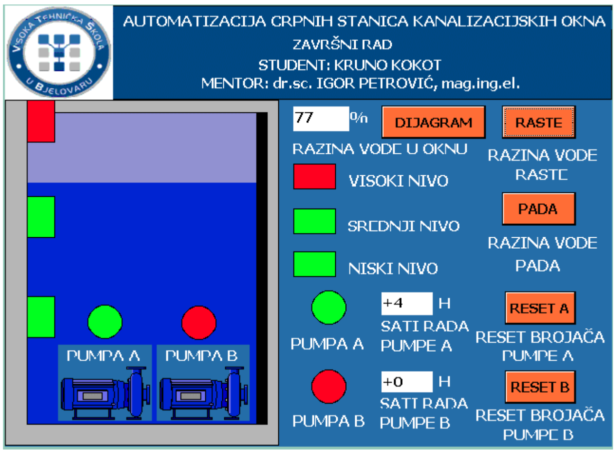

Figure 6 A SCADA screen for water level regulation

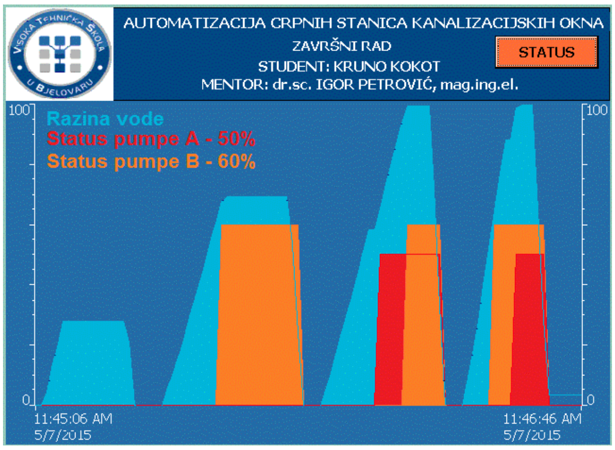

Figure 7 A graphical representation of the responses to operation scenarios of the pumping station

5 CONCLUSION

A discrete water level simulation in the pumping station, which was shown in the original prototype model of a pumping station, was good enough from the point of view of performance and testing the control programme operation and communication with SCADA.

In this paper more attention was paid to the analysis of drawbacks of the mechanical part of the prototype model and improvements were suggested and implemented. The quality of simulation of water level measurement was improved. Incorporation of new active and passive components enabled an automated rise and fall of the simulated water level and at the same time a continuous feedback to the PLC was achieved.

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