Automation System for the well drainage system at Coal Mine "Underlying Seam Suvodol", Mining Power Complex Bitola

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ABSTRACT

Power production in Macedonia is largely dependent on coal. Thereby, discovering new coal resources is not only a state necessity but a crucial ingredient in the process of power production in MPC "Bitola". In that respect, a viable example of system which will provide coal reserves for future exploitation is the Drainage System of 19 wells equipped with submersible pumps and 9 wide-area subterranean water measuring stations located at the coal mine "Suvodol", which is a part of the Mining Power Complex "Bitola".

It has been noticed that the existing remote aspect of such a system has been making difficulties in its continual exploitation and troubleshooting. Therefore, a custom made automation system has been made for remote control and monitoring of the drainage system (SCADA).

In order to fully satisfy the new requirements, a complex electronic system for control and monitoring on each of the well stations has been installed consisting of frequency inverters for variable speed control of the pumps, programmable logic controllers, wireless communication devices and process instrumentation: ultrasonic clamp-on flow-meter, water level transmitter and water quality analyzer.

The technology of lowering the sub-terrain water level imposes applying a cascade PID regulation which provides the needed flow and constant sub-terrain water level for a longer period; by means of constant adaptations of the pump-motor frequency.

The water level monitoring on the whole radius of influence of the well stations is made by 9 piezometer stations equipped with wireless device, PLC and water level transmitters.

All of the important signals which give information for the actual state of well stations and the water level in the surrounding area are being transmitted to the main dispatching center in the coal mine by means of wireless link at a 5 GHz band.

The SCADA system is custom made and purposely developed for the need of this system. The drawings represent the actual geologic profiles depicted in proportion of the terrain which is subject of drainage and its coal layers position underground. The pictures are dynamic and change in real-time. All of the states, as technology events, real-time measurements, warnings and critical alarm states are displayed to operators, which is of a great advantage in the continuous well exploitation.

This system as a whole is of great significance for the future lifespan and exploitation period of the coal mine "Suvodol".

KEYWORDS

SCADA, Wireless, Wi-Fi, PLC, frequency, inverter, well, ultrasonic, PID, regulation, flow, level, PH, O2, pump, coal, mine, power, plant, SIEMENS, SIMATIC, S7, SISKON

1. Introduction

The location of the underlying coal series is in MPC Bitola and as coal mine it is of great significance for electricity generation in Thermal power plants 1, 2 and 3 with installed capacity of 233 MW, each. Thermal power plants in MPC Bitola operate with full capacity and participate in total electricity generation in Republic of Macedonia with 70-80%.

Surface mine Suvodol is situated 15 km east of Bitola and it spreads on area of 9 км2. Exploitation of mine Suvodol has started in 1977 with excavation of waste and coal excavation has started during the middle of 1982. Mine Suvodol is opened according to accomplished research works in 1972-1974 and accomplished "Elaborate for coal reserves" from 1975 which determined and verified geological reserves of cca 175.000.000 tones and use of 95% of mineral raw materials respectively 5% losses, exploitation reserves of 161.000.000 tones are calculated with average proportion of coal and waste 1:3,9. Coal layer has average thickness of 19,8 meters and it is situated at depth of 30-100 meters.

The area of the deposit is situated under the main production layer of exploitation field of mine Suvodol and it spreads over approximately 3 km2. Main mining design for opening and exploitation of this coal reserve was elaborated and geological reserves of 55.000.000 tons of coal were determined out of which there are exploitable reserves of 50.000.000 tons of coal with overburden coefficient 1:4,7 cubic meters for ton. The exploitation technology of the Under-stratum series Suvodol consists of continuous ETS systems.

Planned annual capacity of around 6,5 million tons of coal, which are necessary for operation of the three units in TPP Bitola, should be obtained with combined excavation and homogenization of coal on three sites: Main coal seam in SM Suvodol, SM Brod Gneotino and SM Deep underlying coal seam. This is, first of all, due to decrease of coal reserves in SM Suvodol and necessity for their completion with coal from other sites respectively coal mines.

Through analysis and interpretation of performed investigations and research for the underlying coal series, only two coal seams are selected as economically interesting: underlying coal seam I and underlying coal seam II, respectively, located under Major productive coal seam.

The first underlying coal seam is characterized with relatively small thickness of 4.5 meters and lies directly beneath the area of the Major productive seam in Suvodol, which is already excavated or is in progress of excavating, (nearing its end of coal reserves) and is located atdepths between 2.5÷35.0 metersfrom the surface.The second coal seam (the major coal seam of the underlying coal series) is located at 50÷100 meters from the surface, separated from the first seam with series of dusty sands. The main difference here is is that this one has continuous extension, with variable thickness and in certain locations is subdivided in several thinner seams.

Major challenge before the excavation of the coal is successful dewatering of the sub-terrain waters. The first step was appropriate positioning of the wells in order to achieve efficient dewatering of the area affected.

In the first phase of this major investment there were drilled 19 wells and 9 piezometers with different depths according to the major geological and mining project. There are installed

19 submersible pumps in each of the wells with different power on different depths, according to the tests and effectiveness estimations.

Positioning of the wells is in two lines:

First line: consisting 12 wells, well 1 to well 12 and 5 piesometer stations

Figure 1: First well line

Second line: consisting 7 wells, well 13 to well 19 and 2 piesometer stations

Figure 2: Second well line

The piezometers are positioned in such a manner to give relevant information on the sub-terrain water level in the whole area imposed by the influence of the well system.

Due to the nature of the dewatering process and expected radius of underground dewatering, and solidity and structural integrity of the well construction, there have been imposed technological constraints of pump work.

2. Automation System

Each pump has asynchronous 3-phase motor. The power of the motors in different pumps and wells varies among 5.5 KW to 18.5 KW on 400 VAC. Each motor has a nominal frequency of 50 Hz.

The preconditions of a successful functioning of monitoring and control systems are:
– adequate hydrogeological observation, and
– properly configured optimized system consisting executive, process instrumentation and communications equipment

Each well station has installed:

1. PLC SIEMENS Simatic S7-1200 with Profibus DP communication module
2. Frequency inverter SIEMENS Micromaster 430 with Profibus DP communication module
3. Operator panel SIEMENS Simatic KP300
4. Wireless communication device SIEMENS Scalance IWLAN W700
5. Directional antenna with strong directional efficiency on 5GHz SIEMENS IWLAN
6. Electrical energy analyzer SIEMENS Simeas P50 with Profibus DP communication module
7. UPS System PHOENIX CONTACT Quint with 12Ah battery
8. Surge and lightning protection PHOENIX CONTACT Trabtech
9. Current transformers PHOENIX CONTACT
10. Inverter protection SIEMENS Sirius 3RV
11. Enclosure RITTAL CM, IP54 protection
12. Transmitter for water level measurement SIEMENS SITRANS P MPS
13. Ultrasonic clamp-on flow meter SIEMENS SITRANS FST 020
14. Water quality analyzer SEKO 502

Each piesometer station has installed:

1. PLC SIEMENS Simatic S7-1200
2. Operator panel SIEMENS Simatic KP300
3. Wireless communication device SIEMENS Scalance IWLAN W700
4. Directional antenna with strong directional efficiency on 5GHz SIEMENS IWLAN
5. UPS System PHOENIX CONTACT TRIO with 7.2 Ah battery
6. Enclosure RITTAL AE, IP66 protection
7. Transmitter for water level measurement SIEMENS SITRANS P MPS

2.1 Pump regulation

The desired effect of dewatering is equal and steady lowering of the sub-terrain water level in the whole area affected by the well system. In this manner the pump should be able not to empty the well in a short period of time, in contrary, the water should be pumped out in a slow fashion, achieving the desired underground level and to be able to maintain that level.

These technology demands impose the application of the pump speed regulation which is conditioned by few factors:

- Underground water level – maintaining the level
- Pumped water flow – maintaining constraint flow for moderate emptying of the wells

- Underground water input < Pumped water output as a condition for lowering the level

Another constraint is the pump vendor recommendation of speed regulation range of the submersible pump which is, in this case, from 30 Hz to 50 Hz in order to avoid mechanical stress and damage of the pump.

Considering these technological issues, there has been designed an integrated, custom made, automation system for a pump regulation, supervisory control and data acquisition.

The speed regulation of the pump is done by a variable speed drive. The frequency which is applied to the motor, by the frequency inverter of the manufacturer SIEMENS type MICROMASTER 430, is calculated on a programmable logic controller (PLC type SIEMENS SIMATIC S7-1200) and transferred as a set-point to the inverter by means of PROFIBUS DP industrial serial communication protocol.

Frequency calculation demands a regulation technique of two cascade PID controllers - which is executed on the PLC. The output of this algorithm gives the frequency of the pump which will satisfy the constraints and desired values of the underground water level and desired flow.

This concept requires two feedback signals. One signal is from the water level measuring transmitter – SIEMENS SITRANS P MPS, which works on the principle of hydrostatic pressure, and the second one is the flow signal which is calculated from the ultrasonic clamp-on flow meter – SIEMENS SITRANS FST 020.

The first PID controller is master controller for the closed loop system. The set-point in the master controller is the desired level of underground water which is given by a geology engineer from the operator panel locally or from the SCADA interface in the dispatching center. Feedback is a current signal of 4-20 mA from the transmitter for water level.

The second PID controller is slave controller and inner control loop from the cascade PID controllers. Set-point for this controller is the desired flow – also given by the geology engineer from the operator panel locally or from the SCADA interface in the dispatching center.

Feedback for the inner loop is a current signal of 4-20 mA from the ultrasonic clamp-on flow meter. The output of the regulation structure gives the set-point frequency to the variable speed drive which is transferred by means of industrial serial bus protocol.

There is a situation when the frequency of the pump is low as 30 Hz, and because of the low underground water input the pump is still emptying the well below the desired set-point level. In this point the regulation transits from cascade PID to hysteresis control. When the water level is high enough above the desired level set-point, the pump again starts with continual regulation, and so on.

Regulation algorithm is described with the following control structure:

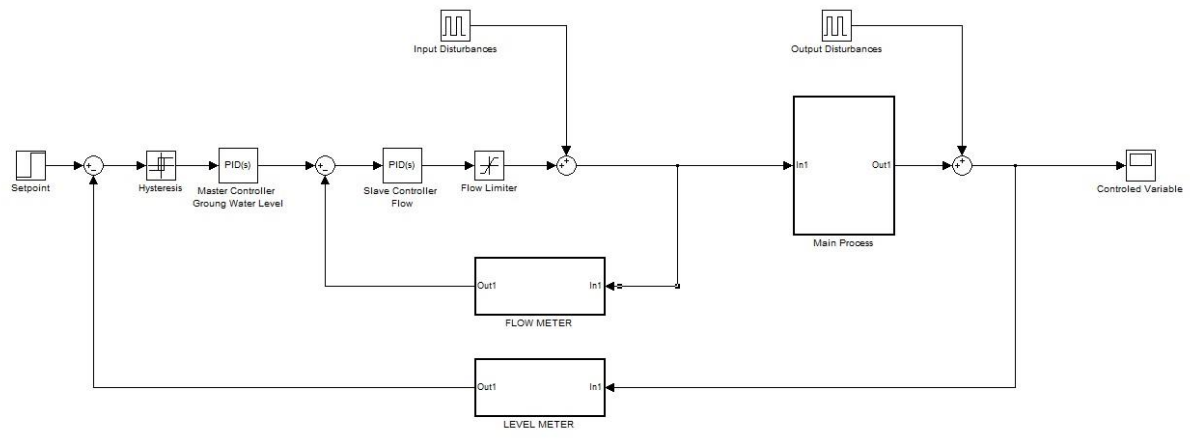

Figure 3: Control structure of pump regulation

2.2 SCADA

To provide functions of remote control, monitoring the operation and management of dewatering system, it is necessary to secure, in real time, the signalization and acquisition of measuring data:

- visualization of the ground profiles displayed with appropriate ratio,
- geometry of current field that changes with the progress of mining works,
- piesometric levels of ground waters – real-time dynamic change,
- flows – l/s and total cubic meters,
- ground water quality (temperature, ph value, dissolved oxygen),
- consumption of electric power (U, I, cosφ, active and reactive power, total power)
- temperature of pump and frequency inverter and
- online trends and archiving for the continual values
- warning and alarm of the minimum water level in the well,
- transmitters malfunction detection
- signal system of pump engine in operation, status and alarm messages of the frequency inverter
- UPS alarm, voltage failure detection
- wireless and wired connection status
- protection of dry work is ensured by the water level measurement – the pump stops when minimum level level is reached, with a capacitive probe for empty pipe detection and with monitoring of the pump temperature and monitoring the pump torque.

Each of the well and piesometric stations are equipped with a wireless communication devices –SIEMENS SCALANCE Industrial WLAN, type W700. The wireless communication is according to IEEE 802.11h standard for industrial applications on the free frequency band of 5 GHz. This type of wireless communication ensures fast and reliable mean of data transfer with bandwidth of 20 Mbit/s average.

For the wireless signal to travel distances of 1 km and more, there has been installed an antenna tower which acts as a main node for the successful wireless data transmission to the main dispatching center in the Coal Mine Suvodol.

The data is accepted by the SCADA server. There has been developed a visualization, control, monitoring, reporting and alarm logging application for the purpose of this system in SIEMENS Simatic WinCC SCADA software.

SCADA visualization is made user friendly as simple as one – mouse click functionality and intuitive command and monitoring for the operators is possible without special knowledge on the technology thanks to the fully automated operation and design of the displayed screens.

Monitoring, alarm and event notifications are of enormous help to the maintenance personnel for prompt and easy fault detection and continuous work of the system.

There has been made extensive report generating functionality. The reports are daily; weekly and annual information of the most important parameters for the monitoring and analysis of the well drainage system. Reports give the geology and mining engineers concrete data for the behavior, dynamic and static characteristics of the sub-terrain waters which are basis for decision making in further excavation, as well as general acknowledgment and picture of the behavior of the sub-terrain water useful for the future activities in the coal mine.

SCADA Figures:

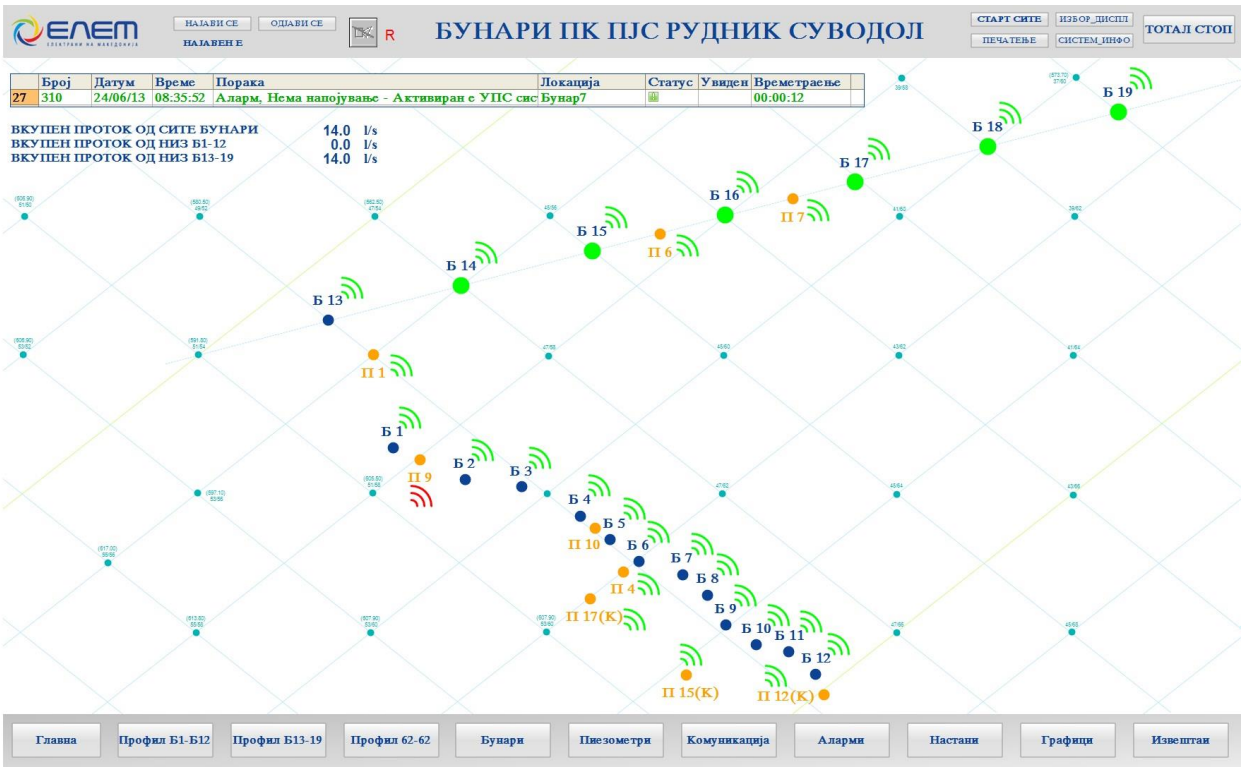

Figure 4: SCADA Main Display 1 – System Overview

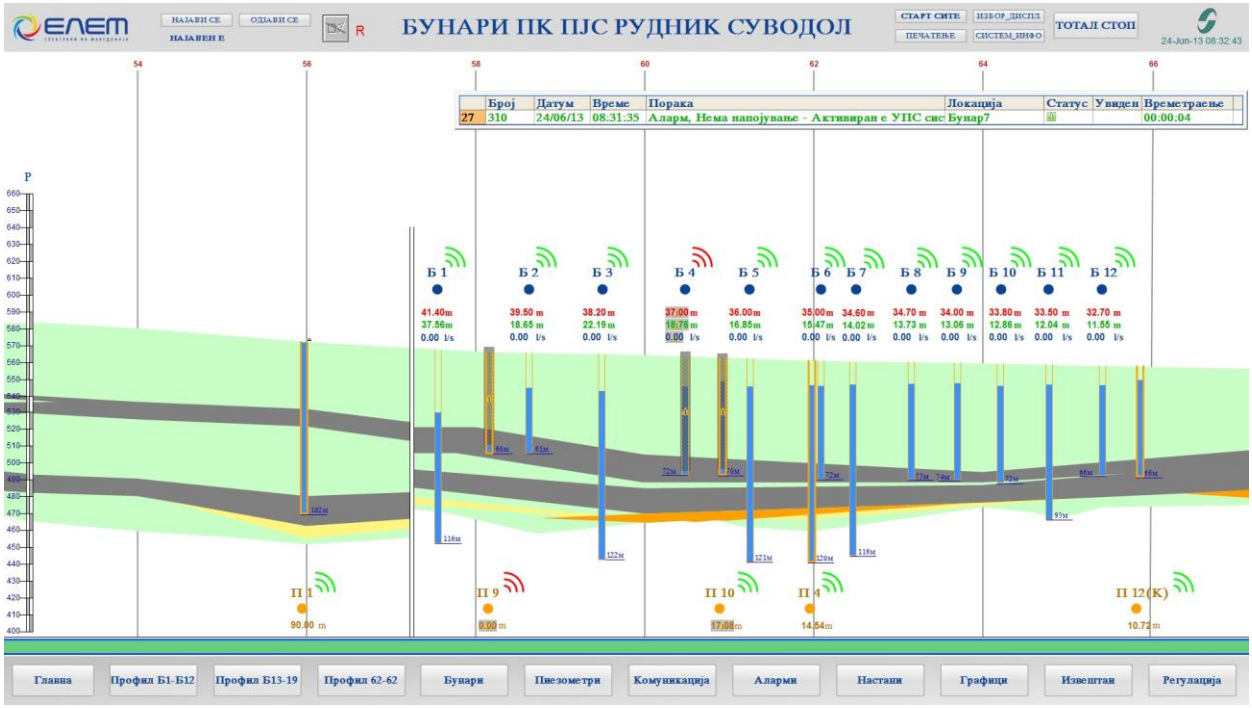

Figure 5: SCADA Main Display 2 – Profile Line Well 1 – Well 12

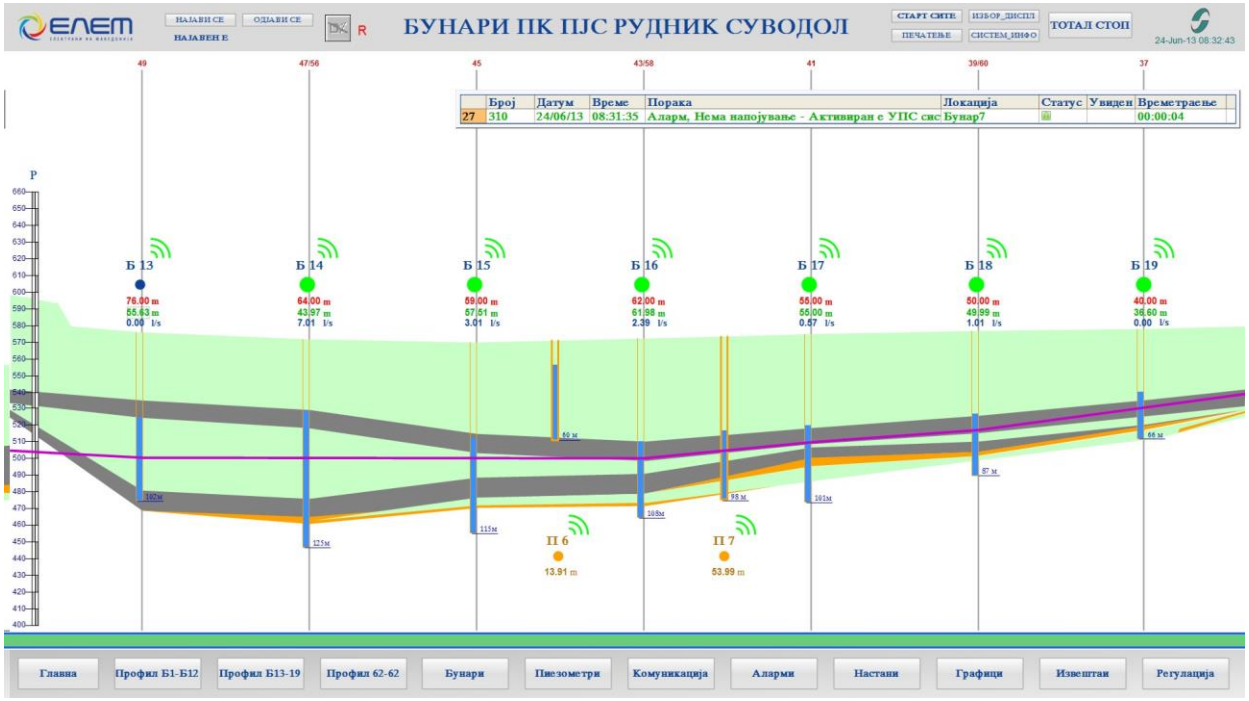

Figure 6: SCADA Display – Profile Line Well 13 – Well 19

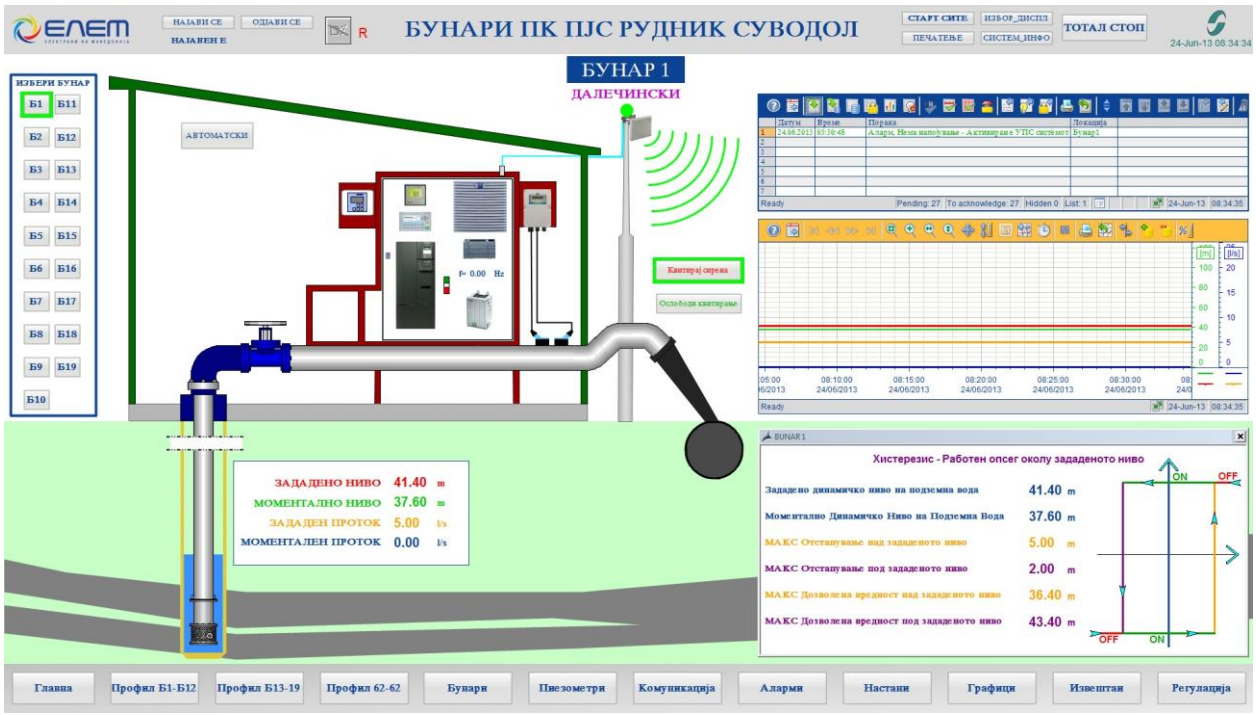

Figure 7: SCADA Display 1 – Well Station Selection, Command and Monitoring

3. RESULTS

Based on the experience gathered so far, a series of useful effects have been accomplished:

- Continual regulation and maintaining of steady state underground water level
- Lowering the energy consumption with the use of frequency regulation and increase in energy efficiency;
- reliability and safety of system work;
- efficient monitoring, diagnostics and lowering downtimes in system operation and decrease of operational costs;

- Surveillance of equipment, prevention of faults and damage of equipment which prolongs its exploitation life, malfunctions and maintenance derived to minimum, prevention of limit line situations;
- Efficiency of the technological process (technological process guided at the assigned level and work regime;
- Efficient utilization of resources available (operation deployment depending on operation conditions);
- Minimization of subjective role of human factor, particularly in condition of sudden and critical disturbances in equipment and plant operation;
- The gathered results from the extensive reporting system are of main significance in future planning and the dewatering systems analysis for the coal mine Suvodol.

4. REFERENCES

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[2] B. Vujic S., Adaptive Computer Supported Surveillance-Management Model of dewatering system at coal open pit mine, Original scientific paper, 2006, pp 33-42

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[4] SISKON company profile

SISKON is an engineering company, founded in 1995, in field of integrated automation systems and complete automation of electrical - energy systems used for control of processes in industry, power plants, mining, substations etc. Ever since, the company is being successfuly developing on principles of knowledge, quality, promptness and fairness.

SISKON provides a multidiscipline engineering projects and consulting in the field of process control and realization of systems on " turn- key" principle.

Starting from computer aided design made in EPLAN and project benefits analysis, advices for choice of brand name electrical equipment, such as SIEMENS, RITTAL, PHOENIX CONTACT, LAPP KABEL and KLAUKE , to assure long uninterrupted working life, SISKON is also source for systems upgrade and spare parts provider, quality assembly stuff and providing of test assembly reports, factory and site acceptance tests. Ending with quick response time within and after the warranty period, SISKON has proven itself through many projects for the biggest and most significant companies in Macedonia. One can rely on technical support, programming end fault analysis made by experienced and proven engineers.

SISKON's reference list of successful projects includes: substation automation with SIPROTEC devices and applied SICAM PAS and PAS CC software in energy sector; dozing, weighing and transport systems as well as control and regulation applications with SIMATIC and WINCC in industry sector etc.

On the Macedonian market, SISKON is also a distributor of the forementioned foreign companies, thus enabling the projects to be realized quickly, efficiently and cost effective.