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Integrated control system of main fans station for deep mines ventilation

The article describes a complete control system of the main fans system with an integrated remote control and monitoring system. A power supply system and communication diagram were presented. Co-operation between particular elements of the system was discussed. Then the author presented a sample user interface to control and monitor the work of the fans station based on a graphic display with a touch panel. Finally, a sample implementation was described.

Key words: mining, fans, ventilation, automatic control.

1. INTRODUCTION

In order to ensure proper air exchange in all working excavations of a mine, one can use a drop of natural air pressure or produce an artificial drop of air pressure. This is achieved thanks to fan systems installed near upcast shafts on the surface [6] and driven by electric motors. These fans belong to the main ventilation system which is responsible for keeping the required air composition and temperature in underground excavations. Mines which exploit combustible minerals apply exhaust ventilation [6]. This ventilation is achieved by creating, with the use of fans, negative pressure which exhausts air from the mine into the atmosphere through diffusers.

According to mining regulations, the main fans should enable to reverse the ventilation, i.e. to change the direction of air flow in the mine. This is done either by using trap doors and latches or by changing the direction of the fan rotations.

Main ventilation systems should be equipped with tools that make online measurements of the following: air velocity in ventilation channels, static negative pressure in front of and behind the latch, and static negative pressure in the cross section of the upcast shaft. The measurements of air velocity and negative pressure in front of the latch should be registered automatically, while other measurements should be documented [6].

Additionally, the regulations require that each upcast shaft should have not only a working main fan or a set of main fans, but also an auxiliary fan which can start working within 10 minutes [6].

Interruptions in the work of the main fan should be automatically reported to the operator, while their duration and causes should be documented [6]. An interruption of at least 20 minutes results in stopping the work and leading the personnel towards intake shafts or to the surface [6]. Thus it is important for the ventilation system to operate efficiently and reliably.

In the fans station, apart from fans with their drives or control and measuring devices of the ventilation system, there are a number of auxiliary devices, such as control systems of oil pumps which are used to grease the bearings of rotating parts or systems for manipulating the trap doors of fans – used to throttle the air flow in a ventilation shaft. In addition there are security devices, such as electric and temperature protection measures of motors or systems for measuring vibrations and electric parameters. When the control process of the ventilation station is automated, i.e. when all executive elements are supervised and controlled by one superior device, it is possible to raise significantly the service quality and to eliminate errors and mistakes of the operating personnel which could be dangerous in the case of a system as crucial as the mining ventilation system.

The integrated system to control the fans station, presented in the article, was developed by JJA Pro-

gress in co-operation with the experts from the Technical University of Silesia. The system fulfils all requirements of mining regulations and is currently exploited in a continuous manner in several Polish mines.

2. FANS STATION SYSTEM

Figure 1 features a diagram of power supply to fans and auxiliary devices of a fans station, implemented in a hard coal mine.

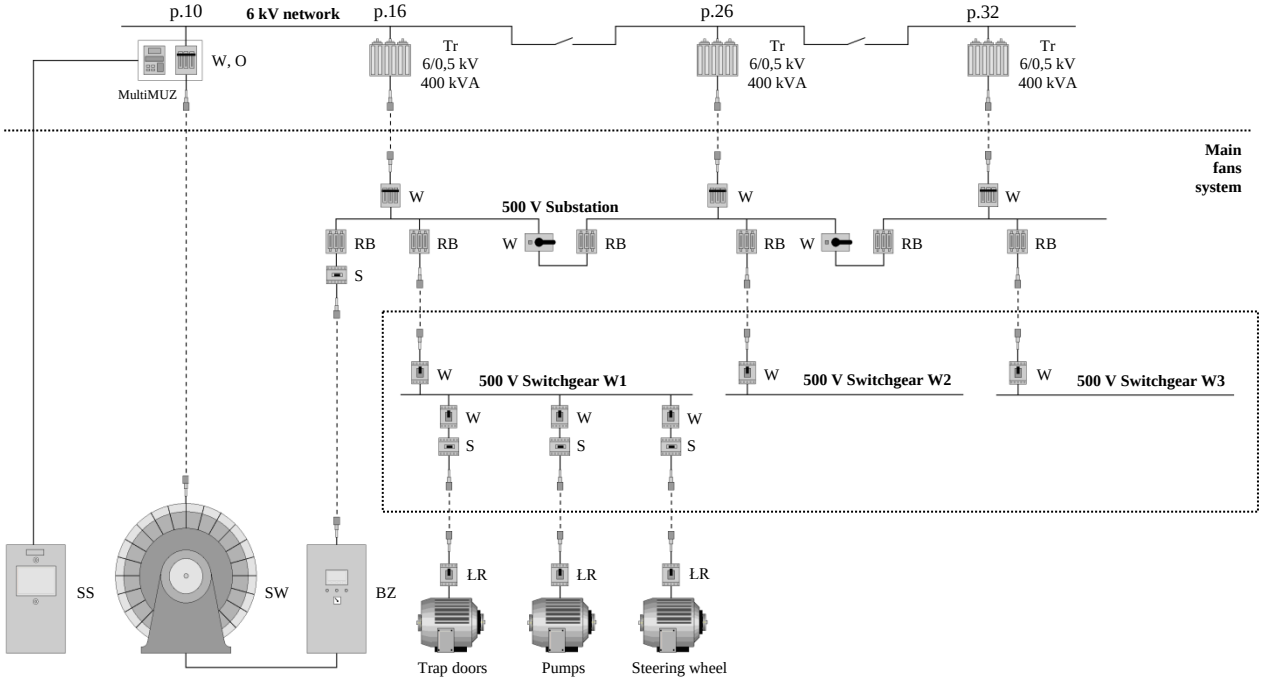

Fig. 1. Power supply of a fan motor and auxiliary devices: SS – control box, SW – fan motor, BZ – power supply block of a synchronous motor, W – switch, O – disconnector, S – contactor, RB – fuse switch, ŁR – repair switch, MultiMUZ – digital protection unit

The presented diagram contains only the elements of a power supply system for electric devices. Apart from that, it is necessary to provide co-operation with mechanical elements of the drive system as such (e.g. mechanical brake on the motor shaft) and with the measuring and control apparatus which measures air parameters in the ventilation shaft.

Thus the control of the fans station is a complex process in which many different devices are monitored and controlled.

In order to integrate the service of all elements from selected stands, it is necessary to construct a system of communication between particular devices. In the presented solution a local Ethernet is used. The communication is maintained by means of the TCP/IP protocol.

Figure 2 presents a diagram of the fans station communication system which can co-operate with external IT systems.

In the fans station there are usually several fans. In the presented solution PLC controllers were used for each of the three fans. The controllers communicate with each other, with the remaining elements of the fans station system, with a remote-control monitoring system, and with the central system of reactive power compensation.

The integration of the control system makes it possible to control and monitor the fans station from the touch panel of the control box of any fan or from controllers installed in another location, e.g. in the 6 kV substation, maintaining independent control and power supply systems of each fan in compliance with the standard requirements [5].

The structure of the system allows to expand it easily with extra functions and to co-operate with any visualization or supervision programs.

The developed control system comprises all kinds of fans, irrespective of their number or synchronous/asynchronous quality of their drives. The presented solution is based on three fans driven by synchronous motors [3, 4].

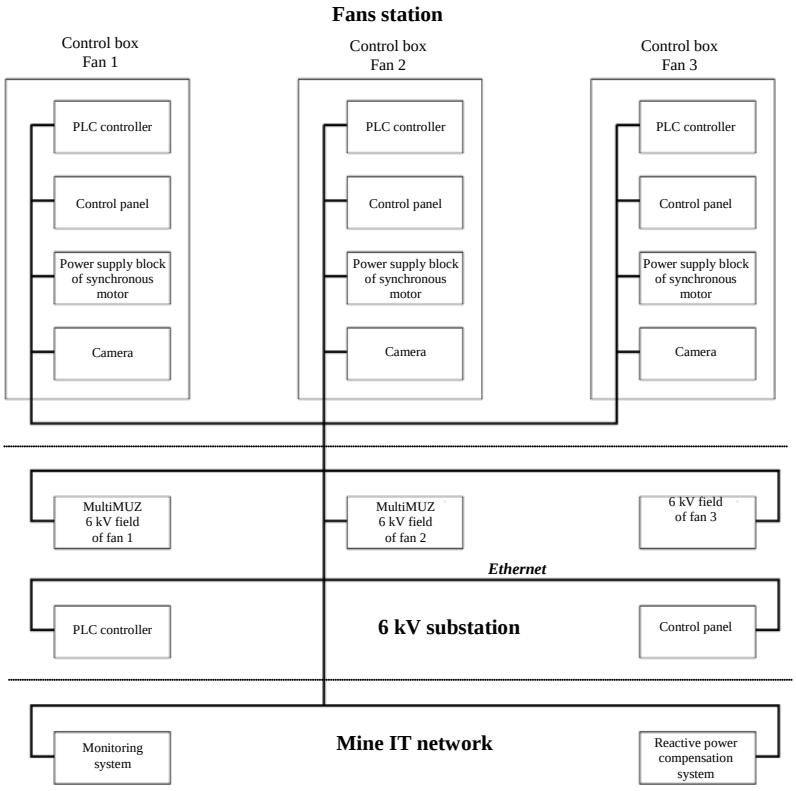

Fig. 2. Communication system

3. CONTROL SYSTEM OF THE FAN

The control system of the fan is based on a PLC controller which co-operates with an industrial computer, equipped with a touch panel, used to visualize the process and service the users' reactions. What is more, it is possible to control the station from panels placed in other locations.

The controller monitors all elements of the system by means of digital and analogue inputs/outputs as well as a communication system. In addition, it exercises continuous monitoring of the fan readiness to work, also during stoppages.

The controller co-operates with the measuring apparatus of the shaft as it registers parameters related to the ventilation process.

The basic operating mode is the automatic one in which independent control systems of all fans co-operate with each other. In this kind of control the automation system supervises the whole of the activation process, operations, motor shutdown, as well as opening and closing of trap doors. Emergency switch-off of a working fan results in an automatic, maintenance-free switch-on of an auxiliary fan. The time of the fans switch-over is limited only by the time of achieving proper oil pressure, rearranging the trap doors, activation and synchronization of the motor which drives the fan.

In order to activate the fan to work in the semi-automatic mode it is enough to push one button on the operating panel screen. This results in the activation of the greasing system monitored by an oil pressure sensor connected to the controller. As soon as the required oil pressure level is achieved, an automatic procedure is applied to start up the motor and rearrange the trap doors of the ventilation system.

In the manual mode the greasing system and the 6 kV motor are activated manually from the operating panel. The synchronization of the motor is supervised by the controller. Once the motor is synchronized, it is necessary to rearrange the throttles.

In the emergency work mode it is possible to start a fan outside the IT system, with no involvement of the controller and operating panel, with the use of buttons placed in the control box. The synchronization of the motor is conducted by the microprocessor system of the activation power supply block [1]. In the emergency mode the following protection measures work: measures provided by the multiMUZ protection in the 6 kV field which supplies the fan motor, as well as technological protection measures of the fan (protection of fan bearings vibrations, temperatures of motor and fan bearings, oil pressure in the bearings greasing installation. This mode is used only in the case of a failure of the basic control system.

4. POWER SUPPLY

The stator of the fan motor is supplied from the 6 kV main substation field. The control of the field switches can be carried out locally or automatically from the control box of the fan station. In the field of the fan a MultiMUZ protection unit was installed. It provides the controller with information about the switches location in the 6 kV field, status of protection measures, state of relays, etc.

To control current in the excitation circuit of the fan drive synchronous motor, a power supply block was used with an embedded reactive power regulator [1].

The device has a thyristor transformer and a shift keying system for a starting resistor, both supervised by a microprocessor system. The software of the device allows autonomous control over the motor operations: start up, synchronous work with the possibility to automatically regulate excitation current or reactive power, procedures of excitation current enforcement, process of technological or emergency shutdown. The power supply block of the motor can co-operate under the supervision of a superior system too, here under a PLC controller of the fans station system. Additionally, the device can be connected into a superior reactive power compensation system where it will perform infinitely variable follow-up adjustment of reactive power during the operations of the synchronous motor [2].

The controller which co-operates with the 6 kV field starts the engine (also for the system with a starting choke) and performs the synchronization according to the selected algorithm (time-, current-, speed algorithm). After the synchronization. the trap doors are rearranged and the fan is switched onto the ventilation network. At the same time all security measures are checked. If any security measure in the fans station starts to work, the operations of the switch in the 6 kV field are stopped.

5. CONTROL OF TRAP DOORS AND STEERING WHEEL

The fans efficiency is adjusted to the demand for air, most frequently, by changing the number of simultaneously working motors, choking the air flow or changing the approach angle of the fan blades.

In the presented solution the controller monitors the settings of the trap doors and steering wheel system on the basis of signals coming from these elements. The current state is displayed on the touch panel screen. The following are monitored: power supply system, contactor status, motor protection, control voltages, selection of work type, and location of a repair switch. The drives of steering wheels are equipped with location transducers which enable to monitor the location of the steering wheel blades.

The control of the trap doors is exercised from the touch panel or locally from control boxes placed near the drives. If the motor is started in an automatic or semi-automatic mode, the controller sets the trap doors for start-up. After a successful synchronization of the motor, the controller rearranges the trap doors, i.e. opens them for the fan which takes up the loads and closes them for the fan which takes up the reservation status.

The steering wheel can be controlled by the maintenance personnel any moment during the fan operations to regulate the fan efficiency – the efficiency measurement is available on the control panel screen.

6. CONTROL AND MEASURING APPARATUS IN A SHAFT

In the shaft channels there are Prandtl tubes installed at the ends of which intelligent sensors were placed to measure pressure difference, air velocity and efficiency. Negative pressure sensors were used to measure static negative pressure in front of and behind the latches and to measure pressure drops in the shaft.

The applied sensors co-operate with analogue 4-20 mA modules of the PLC controller, while the whole installation is made as an intrinsically safe one.

The measurements of shaft parameters of each fan are transmitted to each controller installed in the station where, according to the regulations, they are recorded and archived [6]. This way the shaft parameters are recorded in several independent devices. A damage of any device does not make it impossible to register the data.

The system to control and supervise the station enables to communicate to the personnel any case when the set ranges of ventilation parameters are exceeded.

7. USER INTERFACE

The user interface was made with the use of touch-panel industrial computers which co-operate with the PLC controllers of the fans.

The touch panel allows to respond to the users' commands and is used to present current and archived data about the system operations. In addition, it enables clear presentation of all devices that work in the station and are controlled by the controllers.

The software of the industrial computer with a control panel makes it possible to conduct different analyses, such as the analysis of registered parameters of the ventilation system operations, electric parameters of the fan motor drive, changing work state of the ventilation station and particular devices, alarms and damages. These data can be presented as text or by means of time diagrams.

In addition, the registered data can be exported to an external data storage medium in order to be analyzed in other IT systems.

Figure 3 features a sample view of the operating panel screen.

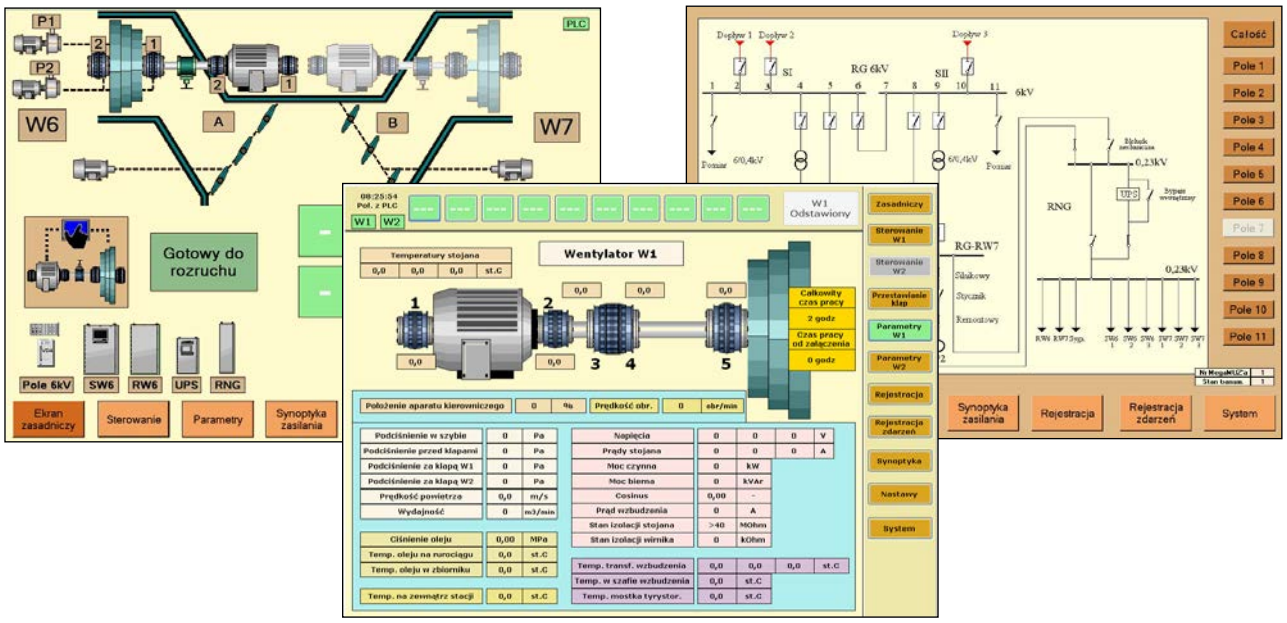

Fig.3. Sample view of operating panel screen [materials from JJA Progress]

Fig.4. Integrated system to control the fans station [materials from JJA Progress]

8. IMPLEMENTATION

Figure 4 features sample implementation of the integrated system to control the fans station, worked out and developed by JJA Progress in co-operation with the author.

The presented solution, with different modifications according to the users' requirements, was implemented in several hard coal mines and is exploited without any failures in the continuous work mode.

9. CONCLUSIONS

The presented integrated system to control the main fans station enables complex monitoring of the station and centralized control of all executive elements.

The operations of all elements of the station under the control of PLC controllers allow an auxiliary fan to take over the ventilation process automatically. This is particularly important due to time criteria stipulated by regulations [6].

The user-friendly interface, based on a graphic screen with a touch panel, enables to work intuitively, to visualize the current state of the system and to browse through the archived data.

The communication system allows to co-operate with external devices or SCADA software on the basis of the Ethernet.

The implementation of the system ensures safe and convenient exploitation in compliance with all mining standards and regulations.

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The article was reviewed by two independent reviewers.