https://doi.org/10.7494/miag.2021.3.547.31

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The modernization of the main fan station of the “Wilson” shaft in KS “Wieliczka” S.A.

This article discusses the modernization of the “Wilson” shaft’s main fan station in KS “Wieliczka” S.A., which included: the station building, main fans, the 110 kW electric motors to drive the fans, 3/0.4 kV transformers, 3 kV “Wilson” switchgear, 0.4 kV main switchgear and the communication systems used to control the station.

Key words: *mine shaft, main fans, modernization, salt mine*

1. INTRODUCTION

This article covers the issues related to the modernization of the main fan station of the “Wilson” shaft, which included its architectural part: the construction of a new building of the fan station with electrical and social rooms, a decompression building and fan rooms with diffusers and silencers. Sound-absorbing materials were used in the construction of the building to reduce the noise level. The scope of the modernization included the installation of a new dAL16-1100 fan with an electric drive. A new 3 kV MV “Wilson” switchgear, new 3/0.4 kV power transformers and a 0.4 kV RG switchgear were built to supply the fan stations. The switchgear is controlled manually or automatically (remotely) from the operator panel installed in the control room for GSTR 15/3/0.4 kV electrics. In order to ensure the uninterrupted power supply to sensitive receivers, mainly the automation, measurement, control and telecommunication systems, a guaranteed voltage supply system was used. As a part of fan operation parameter analysis, new automatic control and measurement devices were employed. The control and visualization system for the operation of the fan station is implemented by means of programmable industrial controllers (PLC) and PCs. As part of the project, the old main fan station was also removed along with its entire power supply, control and measurement infrastructure. The modernization in question produced a modern facility with an improved communicational safety for tourists and sanatorium users, as well as employees staying in the underground workings of the “Wieliczka” Salt Mine. Thanks to the development of modern devices, the mine meets the requirements of restrictive environmental standards with regard to the permissible noise level.

2. MAIN FAN STATION BUILDING BEFORE MODERNIZATION

Before the modernization, the main fan station building of the KS “Wieliczka” S.A. “Wilson” shaft was located on the same plot as the new building and was 16.88 m long and 6.48 m wide. On the northern side, it had a duty room. It was a one-storey building, with a flat roof covered with tar paper. The facility was made of ceramic bricks, according to traditional technology. In the main building, all the steel windows were single glazed and the door was also made of steel. The floors were made of cement mortar smoothly troweled on a concrete base with a tar paper damp insulation. The entrance to the shaft building was located on the northern side of the building, and to the duty room on the eastern side. In the fan station building there were two main fans (Fig. 1), WOK type – 4duB, each with a capacity of 58.3 m^3/s at nominal speed 490 rpm. They could work in both suction and reversible modes. The change of the operating mode was performed by changing the direction of rotation of the motors. Power supply was provided by electric motors with a power of 200 kW and a voltage of 3 kV [1].

The 3kV MV "Wilson" switchgear (Fig. 2) was built in the building of the main fan station of the "Wilson" shaft. The switchgear consisted of two 3 kV distribution sections built of five distribution bays, RSK6 type. The primary and backup power supply were provided by two independent cable lines from two different sections of the main transformer and switchgear station GSTR 15/3/0.4 kV. The 3 kV MV "Wilson" switchgear supplied the main fans station of the "Wilson" shaft and the 3 kV MV "III East" switchgear on the level III of the mine. Two 6.3 kVA 3/0.4 kV transformers were supplied from the 3 kV MV "Wilson" switchgear, which in turn supplied the auxiliary circuits of the "Wilson" main fan station. The distribution point for 380/220 V loads was the hooded switching station located in the fan room. Essentially, the switchgear worked on one power supply, while the other was a backup that was switched on manually in the event of a power failure. However, during the operation of all heaters (e.g. in winter), the switchgear had to be powered from both transformers. The auxiliary switchgear 380/220 V supplied power to: radiator socket circuits, rotation switch cabinets, AKP measuring cabinet, gate valve power supply circuit, 24 V sockets circuit, as well as external and internal lighting circuits.

The power supply diagram for the old "Wilson" shaft main fan station is shown in Figure 3.

Fig. 1. Main ventilation fans for "Wilson" shaft

Fig. 2. Field distribution station type RSK-6 of the 3 kV MV "Wilson" switchgear

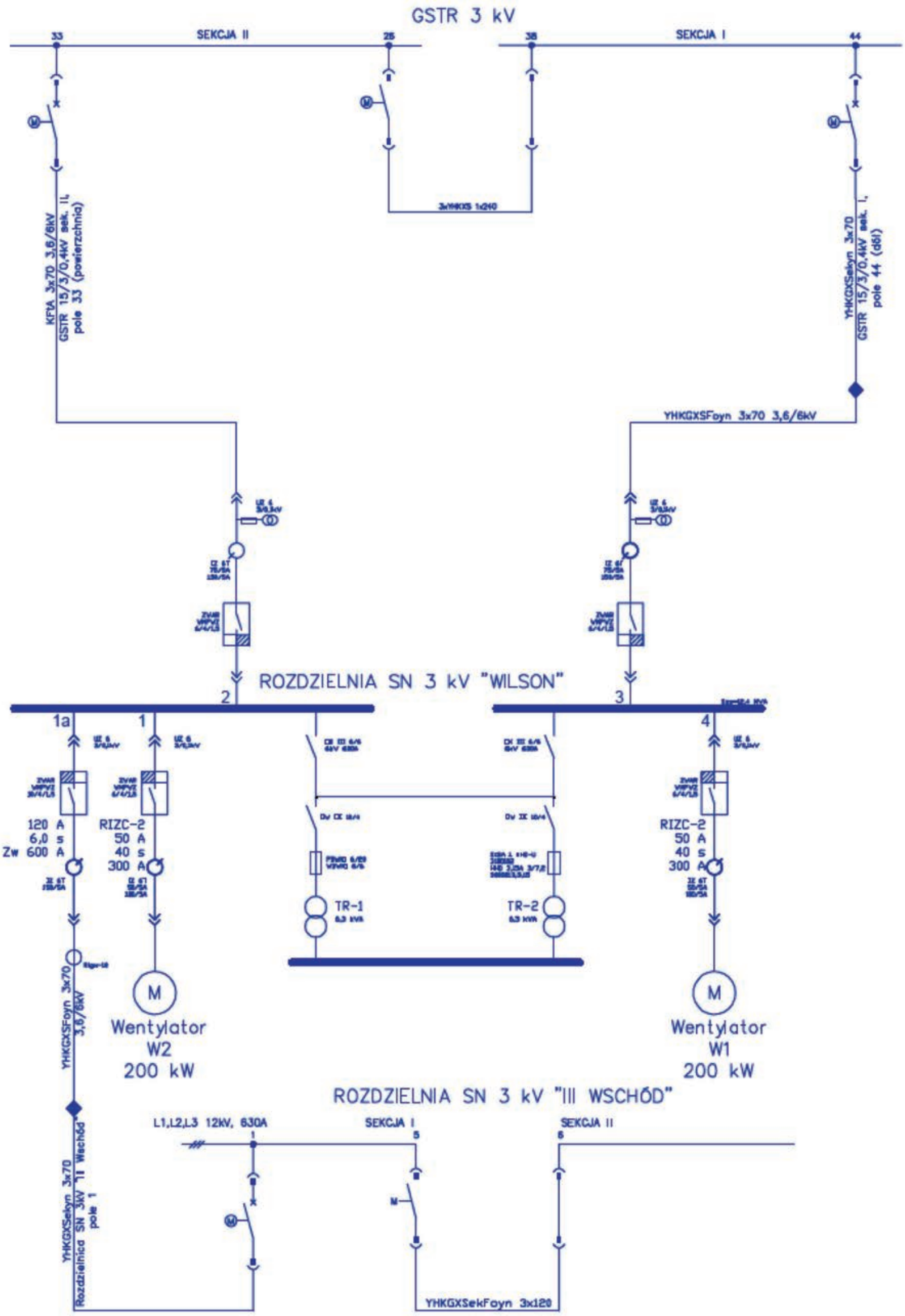

Fig. 3. Structural diagram of the power supply to the “Wilson” shaft main fan station

The control of the 3 kV MV “Wilson” switchgear, the auxiliary switchgear 380/220 V and the activation of the main ventilation fans was operated manually. The flaps were also controlled manually by means of three-phase left-right switches. The supervision and information system for the operation of the fan station was realized by means of the AKP and signalling cabinet connected with the medium voltage bays. The station’s personnel stayed in the rest and refreshment room on the premises of the facility. The AKP cabinet provided information on the parameters of the exhaust air and the temperature of the fan's bearings. Moreover, the exhaust air parameters were transmitted to the mine's main control room by the VAL station and the computer system. Telephone communication was provided by a telephone set of the company-wide telephone communication. In the event of any failures, switching off the fan was signalled by an acoustic signal (a buzzer). The switching on and off of the MV bay of the 3 kV MV "Wilson" switchgear was signalled by signal lamps installed in each bay. In the event of the temperature of the fan bearings being exceeded, this was signalled by an optical signal (signal lamps) and an acoustic signal (bell). The suction or discharge operation of the fan was signalled by signal lamps mounted in the cabinets that change the direction of rotation of each fan.

Fluorescent and incandescent fittings with 220 V, 50 Hz power supply were used, in order to illuminate the room. There were also four 60 W incandescent fittings for emergency lighting, which were supplied with 24 V voltage from a 4 × 6 V battery bank. The batteries were powered by a BZB 24/25 rectifier from a 220 V, 50 Hz mains. The outdoor area was illuminated with 250 W mercury lamps.

The 3 kV MV "Wilson" switchgear was equipped with locks in the form of bolts, installed in each bay of the switchgear. Activation of the lock resulted in switching off the medium voltage bay. Moreover, in the S-1 and S-2 cabinets that changed the direction of the rotation of the fan, limit switches were installed at the door of each cabinet, which eliminated the possibility of fan activation in the state of opened door of the cabinet that changed the direction of the rotation of the fan. The motor bays of the 3 kV MV "Wilson" switchgear had overload and short-circuit protection with the use of RIZc2 relays. In the bays supplying the fans, undervoltage protections were installed to switch off the bay in the event of 3 kV voltage failure. The outgoing bay supplying the 3 kV MV "III East" switchgear was protected by VIP-40 overload and short-circuit protection. This bay also had an earth-fault protection. Within the 3 kV medium voltage network, electric shock protection was provided by protective earthing of medium voltage devices. Within the low-voltage network, the electric shock protection was implemented as a quick disconnection of the power supply with the use of installation fuses and S-type fuse switches. Additionally, in the low-voltage circuits, residual current circuit breakers with a differential current of 30 mA were used as supplementary protection.

3. A MODERNIZED BUILDING FOR THE "WILSON" SHAFT MAIN FAN STATION

3.1. Main building

The new building of the "Wilson" shaft main fan station has a simple form, consisting of several adjoining blocks that are functionally connected to each other and form a compact whole. On the north-west side, there are facilities with electrical rooms and a rest and refreshment room. The rooms are accessible from the outside. On the eastern side, there is a fan room with a diffuser and silencer. Entrance gates with wicket doors lead to the fan room from the outside. The whole building is a single-storey structure, covered with a flat roof with a slope angle of at least 2% or 3%. During the construction of the building, sound-absorbing materials were used to limit the level of the noise generated, and which could affect the neighbouring areas of single-family houses. The aim was to ensure that it does not exceed 40dB at night and 50dB during the day, in accordance with the regulations and the decision of the Wieliczka Starost [2].

3.2. Main fans

Axial fans dAL16-1100 (Fig. 4) are intended for the ventilation of underground mine workings and are single-rotor fans with an electric drive. They have a capacity of 42.8 m^3/s and can operate with 1250 rpm. In order to meet the stringent noise standards, the fans were additionally placed in special housings equipped with damping elements. The fan shaft is mounted on rolling bearings and the fans were equipped with diagnostic systems. Temperature sensors are installed in sockets located in fan bearing housings, while vibration sensors are installed on each of the bearing housings and one sensor is installed on the fan housing. Signals from transducers are collected for visualization purposes and displayed continuously on the monitor screen in the station room and at the control room. Each fan is powered from the frequency converter cabinet, ensuring smooth adjustment of the efficiency and pressure of the sucked air by changing the rotational speed of the motor with a power of 110 kW and voltage of 400 V. It is possible to reverse the operation of the fans by changing the direction of rotation of the engine. The fan efficiency when working in the reverse mode is up to 27.0 m^3/ s, which is about 70% of its nominal capacity when working in the suction mode. The fans are connected to the ventilation duct leading to the "Wilson" shaft and to the diffuser [3]. The ventilation duct system enables two-way air flow, depending on the needs of the mine's ventilation. The fans are equipped with dampers, which are made as multi-blade (horizontal) with an AUMA drive equipped with limit switches with an additional manual drive. It is possible to adjust the position of the flaps and the transition time to the extreme positions.

Fig. 4. Fan type dAL16-1100 manufactured by Korfmann

3.3. 3 kV "Wilson" switchgear and 0.4 kV main switchgear with a 3/0.4 kV transformer station

As part of the modernization of the RSK6 type bay of the 3 kV "Wilson" switchgear, the bay was replaced with e^2ALPHA (Fig. 5) bay with e^2TANGO-800 safety devices and e^2BRAVO circuit breakers. They were built in the new main fan station building. The switchgear has 2 sections with 5 bays each [3]. It is characterized by a compartment structure which is air-insulated.

Fig. 5. e^2ALPHA distribution cells of the 3 kV MV "Wilson" switchgear

The switchgear is supplied from the GSTR-15/3/0.4 kV surface switchgear which is located in the KS "Wieliczka", with the voltage of 3 kV in the IT system, through the existing two cable lines 3.6/6 kV 3 × 70 mm^2, which power the existing fan station at the "Wilson" shaft. One of these lines is guided above the surface, and the other runs through the underground mine workings and the "Wilson" shaft. The line on the surface on the plot of the "Wilson" shaft was cut and connected through a coupler to a new section of the cable, which was introduced to Section I of the designed RSN 3 kV "Wilson" switchgear. The line guided through the underground mine workings was cut at level III near the "Wilson" shaft and, by means of a coupler, connected to a new section of cable running through the "Wilson" shaft, which was introduced into Section II of the designed 3 kV MV "Wilson" switchgear. The new fans and gate valves are supplied from the RG 0.4 kV "Wilson" switchgear, while the lighting, plug-in sockets, ventilation and heating systems are supplied from the RPW auxiliary switchboard. These switchgears are located in the designed electrical part of the fan station building. The fan station is supplied exclusively from the internal power grid of KS "Wieliczka". The power supply diagram of the new fan station is shown in Figure 6.

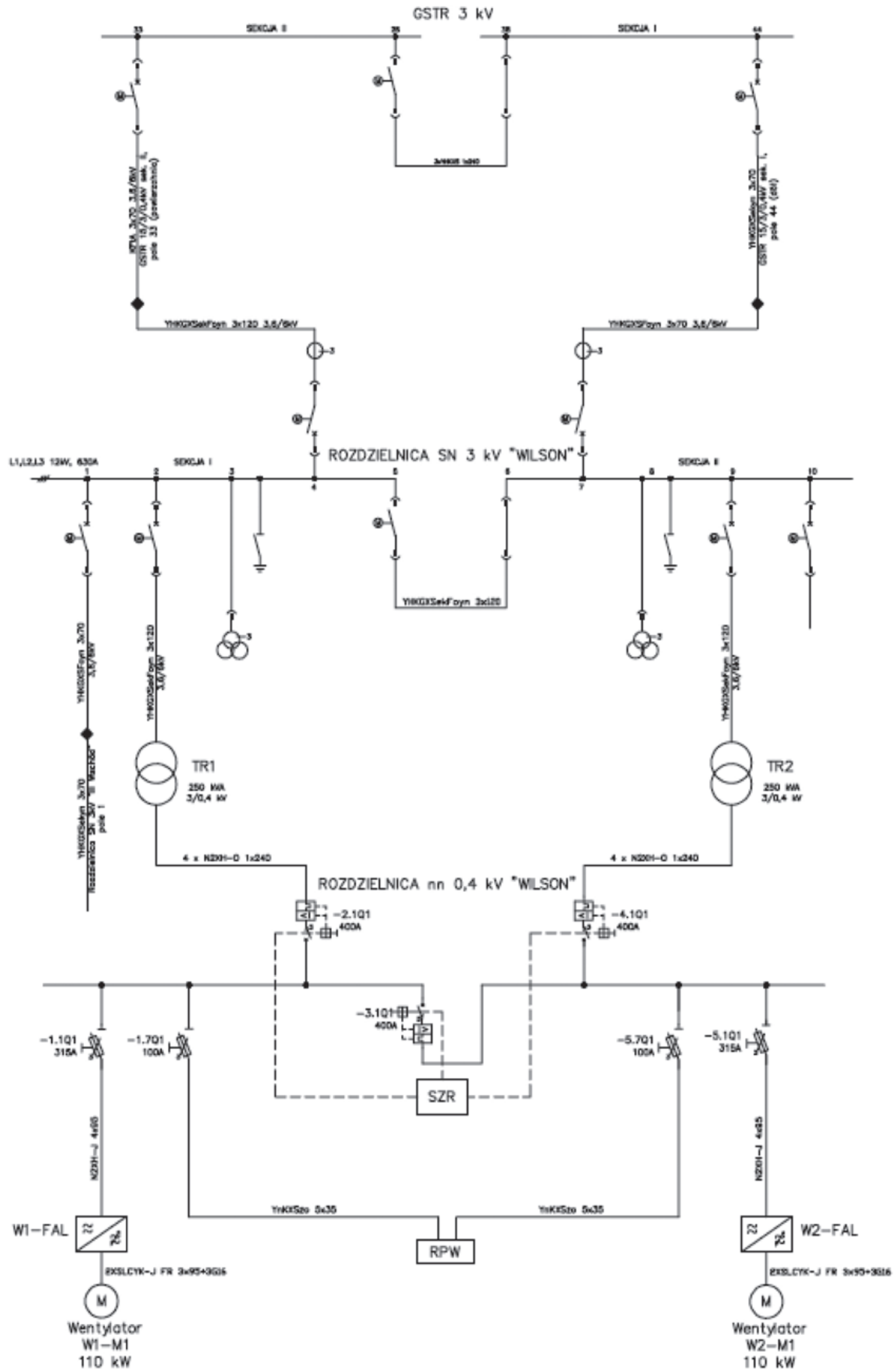

Fig. 6. Structural diagram of power supply to the "Wilson" shaft main fan station

The switchgear is controlled manually, but also automatically or remotely from the operator panel installed in the control room and in the operator’s room in the main fan station building. The communication network at the “Wilson” main fan station is mainly based on the Ethernet interface. The station is connected to the plant’s control room by means of two fibre optic lines. In order to increase the level of communication reliability, the fibre optic lines were configured as a ring enabling uninterrupted operation in the event of the failure of one of them.

The basic aspect of the safe use of the e^2ALPHA switchgear is on-going information on the state and position of switches installed in the switchgear bay. This information may come from two sources: from LED indicators placed on the bay mimic diagram (on the front of the LV compartment door) or from the bay controller mounted on the front of the LV compartment door. Additionally, it is possible to visually check the condition or position of the switches through the sight glasses installed in the door of the equipment and cable compartments.

The main fans station has a low voltage auxiliary switchgear, which is designed to distribute electricity in three-phase alternating current networks with a frequency of 50 Hz and rated voltage up to 690 V, as well as control and protection of receiving devices against the effects of short-circuits and overloads. The switchgear is made as a cabinet, indoor, stationary, with a uniform structure. The building also has an RG 0.4 kV “Wilson” switchgear, designed to supply devices related to the main ventilation fans, auxiliary needs of the fan station, transformer station, lighting, heating, and ventilation. It is powered by two normal transformers, TZEa 250/3.3/0.4 kV type, with a capacity of 250 kVA.

3.4. Measurement systems

In order to monitor the correct operation of the main fan station, measuring devices were installed (Fig. 7) which are connected directly to the PLC controller in the TPA cabinet. All technological measuring devices are approved for operation in explosion hazard zones in category I M1 and are resistant to chloride corrosion. To ensure the highest accuracy and eliminate the need to drain the impulse lines, the pressure measuring transducers were installed as close as possible to the pressure sampling point, and the impulse lines were arranged with a slope towards the ventilation ducts. The pressure transmitters are equipped with manometric valves enabling periodic control of device indications and calibration. The measurement of the air flow velocity in the ventilation duct is carried out by means of a Pitot (Prandtl) tube and a differential pressure transducer. The transducer is equipped with a three-way block for periodic control of device indications and calibration. Additional measuring fittings have been designed for the purpose of the periodic inspections of devices. The earthing terminals on the housing of the measuring transducers are connected to the local equalizing bars.

Fig. 7. Control and measurement equipment of the “Venturon” system

As part of the modernization, the existing control system for safety parameters was moved to the building and employed. This was done together with a microprocessor-based, intrinsically safe, programmable controller which is designed to collect signals from analogue and two-state sensors type VAL-101, and the sensors installed in the shaft area. The transfer of the VAL station was performed after the new main fan station was activated and the existing one was stopped, so as to ensure the shortest possible interruption in monitoring safety parameters. The VAL station, together with the power supply and junction box, was installed in the fan hall. The measuring transducers are placed next to the station's technological transducers, and the pressure is taken through a tee at the connection of the technological transducer.

3.5. Uninterrupted power supply

In order to ensure uninterrupted power supply to sensitive receivers, mainly the automation, measurement, control and telecommunication systems, a guaranteed voltage supply system was used:
- 110 V DC, nominal current 60 A (two systems A and B),
- 230 V AC, 1.5 kVA (+1.5 kVA – redundancy),

and accumulator batteries (Fig. 8) to maintain the power of 6 kW (+6 kW – redundancy) for 2 hours.

3.6. Protection

e^2ALPHA switchgear bay has a number of anti-shock protections. The basic means of protection (against direct contact with elements with high voltage potential) is provided by covers made of sheet steel which are 2 and 3 mm thick (protection class IP4X, acc. to [3]). All conductive elements of the switchgear which are not a part of the electric circuit were in turn connected to the protective cable. This component is made of a flat copper bar with a cross-section of 30 mm × 5 mm, selected for the thermal and dynamic impact of short-circuit currents. All of the main track components have an earthing terminal connected to the main earthing bar. Each of the e^2ALPHA switchgear distribution bays is equipped with external terminals for connecting the main earthing bus to the earth electrode located in the switchgear building. The control circuits in the switchgear are made at 110 V DC, and are supplied from a DC power plant equipped with a monitoring system for the condition of continuous insulation. The doors of the high-voltage compartments and the covers of the control circuit compartment containing the apparatus with a rated voltage of not more than 1 kV are connected to the protective conductor with a copper cable having a cross-section of no less than 6 mm^2.

Fig. 8. Accumulator batteries

The places of earthing connection are marked with an appropriate symbol. The earthing of the removable unit in relation to the switchgear was made by means of a sliding connection with a constant pressure, with the use of an e^2BRAVO switch. The contact elements are the following: a copper strip screwed to the bottom of the movable unit trolley and a specially profiled rail located on the sub-switch partition.

Protection against induced and switching overvoltages for the MV switchgear is provided by surge arresters installed in the cable compartment of the 3EK4 3.6 kV switchgear. The integrated 1+2 type surge arresters (SPD) are used for the main switchgear RG 0.4 kV.

Due to the fact that fire hazards may occur in the building of the fan station, there is a built-in fire switch that cuts off the voltage. It is located at the entrance to the corridor of the transformer station. Additionally, all cables passing through potential fire zones are fire-proof.

3.7. Fan station control

The control and visualization of the fan station operation is carried out by means of programmable industrial controllers (PLC) and PCs with implemented control and visualization applications (Fig. 9). Control and measurement signals from: measuring sensors, converters, frequency converters and other control and executive elements are connected to the PLC controllers. The PLC controller supervises the operation of the fans on the basis of signals from measuring sensors, including: air flow velocity and static negative pressure, and the control algorithm stored in the memory. The system is equipped with control stations in the fan service room and in the plant’s control room.

Data transmission between the controllers and the workstation in the plant’s control room is based on a fibre optic bus. To ensure security, the data is transferred via two independent routes, with the use of underground workings. The main technological controller supervising the operation of fans is located in the transmission and measurement cabinet of TPA automatics, in the room of the nN RG 0.4 kV main switchgear. The TPA cabinet is powered by two 110 V DC lines, from both RPS uninterrupted voltage power supply systems. The flaps upstream and downstream the fans as well as measuring devices controlling the pressure in the shaft upstream and downstream the dampers, as well as air flow speed and temperature, are directly connected to the controller. Monitoring measurements for temperature and vibration are connected to dedicated control modules in local fan control cabinets, which can also be used to control the fan if necessary [4].

Fig. 9. The control panel of the fan station

4. SUMMARY

The described modernization of the main fan station of the "Wilson" shaft provided a modern facility that improves the safety of tourist and sanatorium traffic as well as the safety of employees and other people in the underground workings of KS "Wieliczka". Thanks to the development of modern devices, the mine also meets the requirements from regulations, including restrictive environmental standards with regard to permissible noise level [5]. When it comes to the modernization of the main fan stations, devices with lower electricity consumption were used, thus reducing the amount of electricity bills. Another solution that reduces costs is the use of automated devices, a move which will completely eliminate the need for the position of device maintenance employee in the long-term.

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