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**STRUCTURES AND OPPORTUNITIES TO SUPPLY THE TELECOMMUNICATION SYSTEMS  
IN UNDERGROUND MINES****STRUKTURY I MOŻLIWOŚCI ZASILANIA SYSTEMÓW TELEKOMUNIKACYJNYCH  
W KOPALNIACH PODZIEMNYCH**

Telecommunication systems in underground mines require reliable power supply both of stationary and underground devices. Special problems connected with power supply occur in a case when subscriber devices are located in explosion hazard areas. The paper presents the basic problems connected with power supply of stationary elements of safety systems as well as subscriber devices located in explosion hazard areas that are significantly distant from stationary elements. Acceptable methods of supplying the subscribers devices under technical environment conditions of mine undergrounds have been determined.

**Keywords:** uninterrupted power supply, mining safety systems

Systemy telekomunikacyjne w kopalniach podziemnych wymagają niezawodnego zasilania energią elektryczną zarówno urządzeń stacyjnych jak i dołowych. Szczególne problemy związane z zasilaniem występują w przypadku gdy urządzenia abonenckie znajdują się w strefach zagrożonych wybuchem. W artykule przedstawiono zasadnicze problemy związane z zasilaniem energią elektryczną elementów stacyjnych systemów bezpieczeństwa oraz urządzeń abonenckich znajdujących się w strefach zagrożonych znacznie oddalonych od elementów stacyjnych. Określono możliwe sposoby zasilania urządzeń abonenckich w technicznych warunkach środowiskowych podziemi kopalń.

**Słowa kluczowe:** zasilanie bezprzerwowe, kopalniane systemy bezpieczeństwa

## 1. Introduction

There are a lot of telecommunication systems in underground mines. Stationary devices of these systems are located on the surface mostly in plant dispatch rooms, and subscriber devices

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in headings significantly distant from these devices. From point of view of obligatory regulations the devices (RMG 2002) are to be applied in every mine in Poland:

- Telephone communication devices; with telephone sets located on mine surface as well as in headings (typical capacity of these exchanges is about 2000 NN).
- Alarm and cable broadcasting systems including subscriber devices, determined with compound name as telephone-signalling device, located in permanent operation places as well as on miners escape routes from endangered zones (from 200 up to 800 NN).
- Radio communication systems. These are most frequently the communication systems to mining machines drivers as well as to teams who work in shafts or in cross headings. In these systems, the leaky feeder is most frequently used to transmit radio signals in headings (Miśkiewicz & Wojaczek, 2010).
- Telemetric systems. First of all, these are monitoring systems: of mine atmosphere condition (gasometry), seismic phenomena, (seismoacoustics, microseismology) as well as operation condition of basic machines and mining devices.
- Local telecontrol and loudspeaking communication systems; first of all, on conveyor haulage routes as well as on longwalls. The most of mine subscribers devices have their own accumulator batteries charged using intrinsically safe power supply unit, most frequently the group one.

The majority of these services need usage of cable networks made of copper telecommunication mining cables, leaky feeders or mine fibre optic cables. There is very developed and dissipated telecommunication infrastructure in mines; number of underground subscriber devices included to teletransmission network frequently exceeds 2000 pieces (telephones, telephones-signalling devices, gasometric meters, sensors for monitoring systems of machines and devices, cameras, telecontrol devices. Widespread underground headings, in which there is need to install these subscriber devices in a standard underground mine, significantly exceeds 100 km.

It is worth to mention that all telecommunication devices installed in headings of methane explosion hazard and/or coal dust should be of explosion-proof design.

## 2. Supply of subscriber devices

The advantage of copper cables is, among other, an opportunity to supply remotely the subscriber devices. However, the said power supply in mines is burdened with many limitations connected mostly with widespreadness of headings, the most of which is endangered with explosion of gases.

There is several methods of supplying the subscriber device located in headings. Mostly, this supply may be accomplished remotely, for instance, using a line applied also to transmit the usable signals as well as locally, from power supply unit located near this device.

An opportunity of remote power supply may be evaluated considering the diagram shown in Fig. 1. Core resistance of subscriber line causes limitation of power as could be fed to the terminal device. The greatest effective power  $P_u$  is supplied to a receiver in case when the following condition is met:

$$R_s + l \cdot R_k = R_o \quad (1)$$

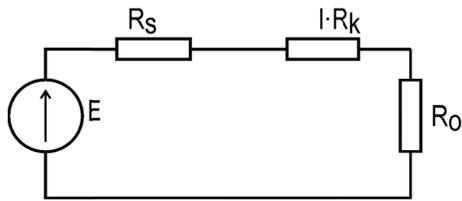


Fig. 1. Simplified diagram of remote power supply of subscriber device;  $E$  – EMF of supply source,  $R_s$  – resistance of inner supply source,  $l$  – length of cable circuit,  $R_k$  – unit resistance of pair in cable,  $R_o$  – resistance of receiver

Effective power  $P_u$  equals:

$$P_u = \frac{E^2}{4 \cdot R_s + l \cdot R_k} \quad (2)$$

Value  $E$  is limited by fire-fighting conditions. Under disadvantageous environmental conditions (in mines) it should not exceed 60 V.

Fig. 2 shows the relation of maximum power that could be supplied by means of transmission line to subscriber device, depending on:

- voltage supplying this line (40 V – break line, or 60 V – full line),
- length  $l$  of symmetric subscriber's line ( $l = 1 - 10$  km).

Unit resistance of mine subscriber's line of core diameter 0,8 mm cannot exceed 75 W/km. Distance from stationary device to subscriber device, reaching frequently 10 km, is the basic parameter that decides about usage the cables of such large core diameters in mines.

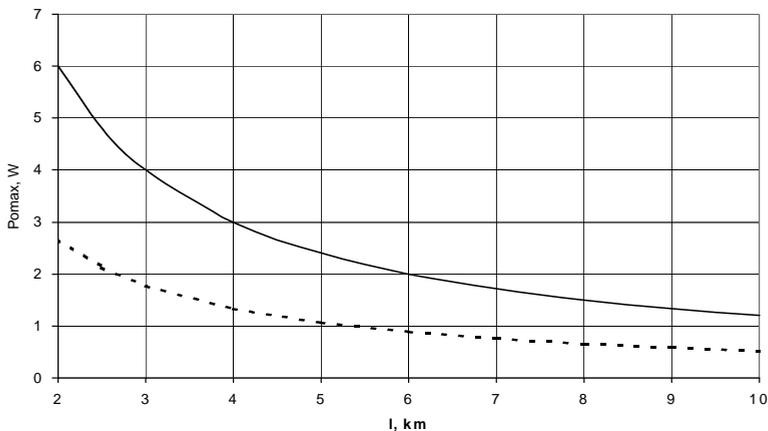


Fig. 2. Relationship of maximum power ( $P_{max}$ ) as could be supplied to a receiver using transmission circuit of determined – versus length ( $l$ ) – for voltage 40 V (bottom line) or 60 V (upper line)

For instance, in case of 10 km long cable and power supply  $E = 60$  V, the maximum power that could be supplied to a subscriber device equals 1,2 W. Double increase of power (up to

2,4 W), for voltage 60 V and 10 km long line) may be achieved using a derived circuit. (Cierpisz et al., 2007).

In case when subscriber device is located in a hazardous zone (methane heading) the remote supply of this device has to be additionally executed using the intrinsically safe method that limits the effective power that could be supplied to a subscriber device by means of non-intrinsically safe circuit of specified length (Fig. 3).

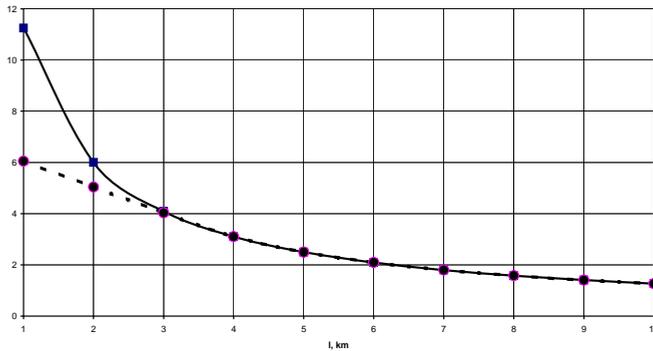


Fig. 3. Relationship of power value  $P_u$  (for non-intrinsically safe circuits – the upper line) as well as  $P_i$  (for intrinsically safe circuits – break line) versus the length  $l$  of subscriber line

In intrinsically safe circuits of remote supply of subscriber devices with symmetric lines the power limitation results mainly from value of ignition current, so called, the resistance circuit (PN-EN 60079-25:2011). For supply voltage equal 60 V the minimum ignition current of resistance circuit equals 0.12 A. Technical execution of intrinsically safe remote supply has to provide the limitation of maximum current of supply source to the value of 0.12 A, which fact limits the intrinsically safe power  $P_i$  (break line in Fig. 3) that could be supplied to a receiver using symmetric lines (of core diameter 0.8 mm). However, differences relate only to symmetric lines shorter than 3 km (Wojaczek, 2014).

### 3. Supply methods of subscriber devices

Supply of intrinsically safe underground terminal telecommunication devices (UK) could be executed using the method as follows (Wojaczek, 2014):

- remotely from stationary device (US) presented in Fig. 4a,
- remotely from stationary device with opportunity to charge the local battery located in terminal device UK; this battery constitutes an additional supply source in case of instantaneous power consumption by device UK (Fig. 4b),
- locally from underground power supply unit ZS of explosion-proof design; power supply unit ZS has no battery support (Fig. 5a),
- locally, using the arrangement as above, but explosion-proof power supply unit ZSB is buffered with accumulator battery (Fig. 5b).

### 3.1. Remote power supply

The remote power supply of device UK, with additional opportunity to charge the local battery located in this device is accomplished from stationary device US using the common transmission line. In case of rooms endangered with explosion the terminal device should be marked I M1 Ex ia I (operation possible at any methane concentration). Such method of central power supply relates to majority of mine communication, alarm and gasometry systems. In this case, stationary device should be equipped with additional teletransmission elements that provide intrinsic safety of subscriber's line, called mostly the intrinsically safe barriers.

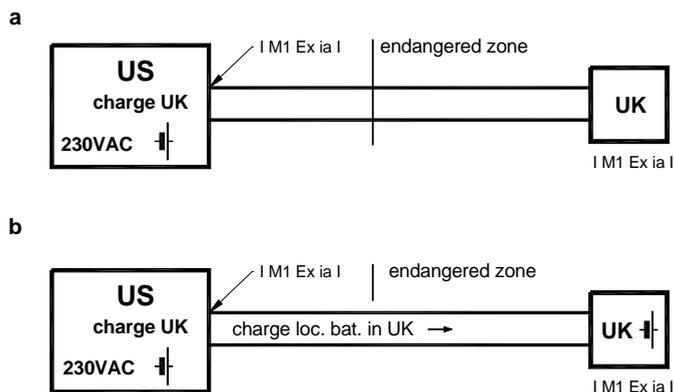


Fig. 4. Power supply scheme to final device UK (a) as well as UK device equipped with local battery that is located in endangered zone (b) from stationary device US

In intrinsically safe telecommunication systems these devices fulfil many import functions in subscriber's line such as: they separate the non-intrinsically safe portion of subscriber's line from its intrinsically safe part, they process and transmit the serviceable signals to both directions, they supply the UK device with intrinsically safe power including galvanic separation in power supply system as well (DC/DC converters in every subscriber's line), they detect and process the signalling applied in teletransmission lines.

In many cases the terminal device, in some operation conditions, consumes the larger instantaneous power than it could be supplied by means of intrinsically safe subscriber line. In UK, accumulator battery is installed then charged remotely by transmission line (Fig. 4b). This kind of solution is commonly used in alarm communication and in gasometry. In signalling phones the battery is, for instance, used to supply the power amplifier while alarm messages are broadcasted.

### 3.2. Local supply from explosion-proof power supply units

In case when there is no opportunity for central power supply of device UK using the line from the surface, the local supply from electric power supply units (ZS, ZSB) should be applied (Fig. 5).

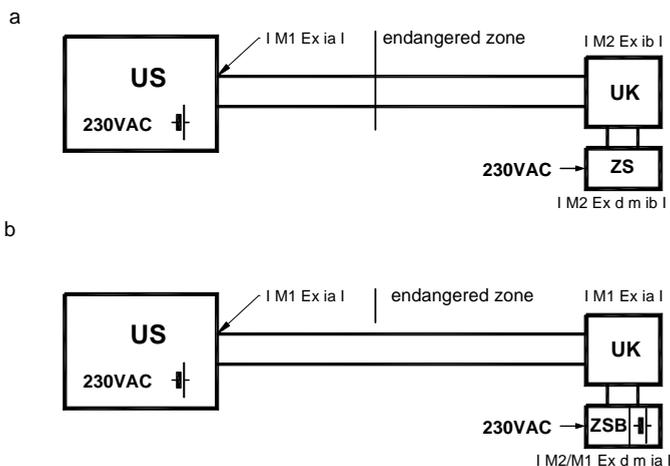


Fig. 5. Power supply scheme of the final device UK from local power supply unit; (a) the case when network power supply unit ZS has no battery support, (b) network power supply unit ZSB with battery support

In case of local supply we may use the power supply unit of category M2. It has usually the intrinsically safe output, provided to supply the intrinsically safe terminal devices, whereas power connection to this supply must be executed in explosion-proof flame-proof chamber (designation with letter “d” according to PN-EN 60079-1:2010). In such a case, occurrence of methane concentration in a heading where it has been installed above admissible value shall cause switching off the power supply on supply connection (230 V). Output of this power supply unit has, indeed, the intrinsically safe feature (with protection level ib) but, one way or the other, it shall not supply the device UK due to lack of supply from power grid (Fig. 5a and 6a) as well as due to lack of support source of electric power in this power supply unit.

An example of so executed teleinformatic system using the local power supply unit (without battery support) is the commonly used monitoring the electric machines and devices. When machines and mine devices have no supply, their monitoring does not operate. Such power supply unit design may have, for instance, explosion-proof feature of designation I M2 Ex d m ib I (Fig. 5). In the designation the letter “m” also occurs that means that this power supply unit has also some elements air-tight sealed with appropriate filling compound which fact is commonly used in local power supply units. Output circuit from device US has to be – in this case – the intrinsically safe one having protection level “ia” (designation I M1 Ex ia I in Fig. 5), because there is no possibility to switch it off while methane concentration increases above the determined threshold settings.

Local supply make the telecommunication system independent of limitations connected with length and resistance of subscriber’s line.

Local supply with battery support ZSB (Fig. 5) is used when we wish that the system operation is independent of power grid condition. Power supply unit, operating with battery, should have the intrinsically safe direct current output circuit with protection level “ia” (Fig. 5b). The important limitation is maximum battery capacity of local power supply unit ZSB that still preserves intrinsically safe conditions (PN-EN 60079-11:2012). This is a basic coefficient that decides about autonomous operation time of device UK for battery operation. The intrinsically

safe power supply unit with battery support manufactured at present have, at output voltage 12-15 V, the available capacity of 3-7 Ah; for instance, power supply unit ZIG15/06/11. At output voltage 15 V, it makes possible the current consumption of 1,1 A during 6 hours, power supply unit ZBI-1 at output voltage 15 V makes possible current consumption of 0,7 A during 5 hours (Miśkiewicz & Wojacek, 2010).

### 3.3. Supply of underground telecommunication optical fiber devices

Using fiber-optical cable in teleinformatic networks the local supply with battery support is only possible (Fig. 6b) or without the said support.

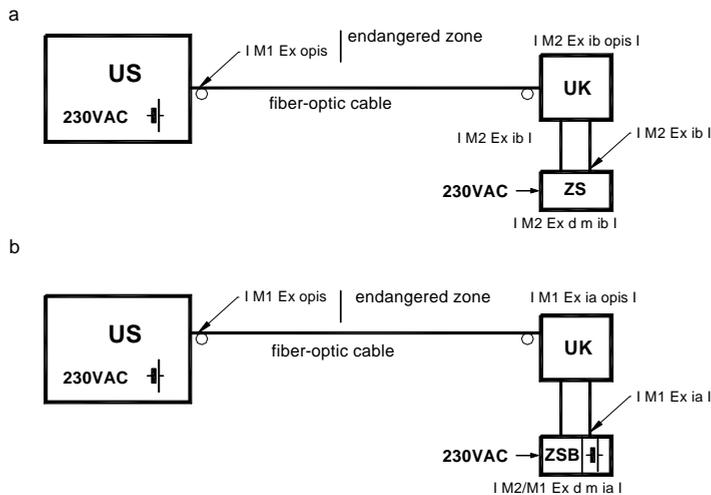


Fig. 6. Power supply scheme of final device UK, connected to US device by fibre optic circuit: (a) from intrinsically safe power supply unit ZS, (b) from intrinsically safe power supply unit equipped with local battery

At present, obtaining the broadband transmission at the range of 10 km and at power limitations connected with explosion-proofness of optoelectronic elements cooperating with optical fiber does not constitute a problem (PN-EN 60079-28:2010).

### 3.4. Supply of bus telecommunication systems

There are also telecommunication systems in which several subscriber devices are connected to the common cable line. Subscriber devices may be supplied in parallel or in series (Fig. 7). This method of supplying (parallel supply) is used, for instance, in (Miśkiewicz i Wojacek, 2010):

- system of multiple transmission of binary or analog signals of FOD-900 type,
- radio communication system with leaky feeder, where several elements are supplied from one power supply unit.

Gasometric system MICON 2PS (Cierpisz 2007), in which series supply of several gasometric meters is used constitutes an example of telemetric system in which the supply has the structure presented in Fig. 7a.

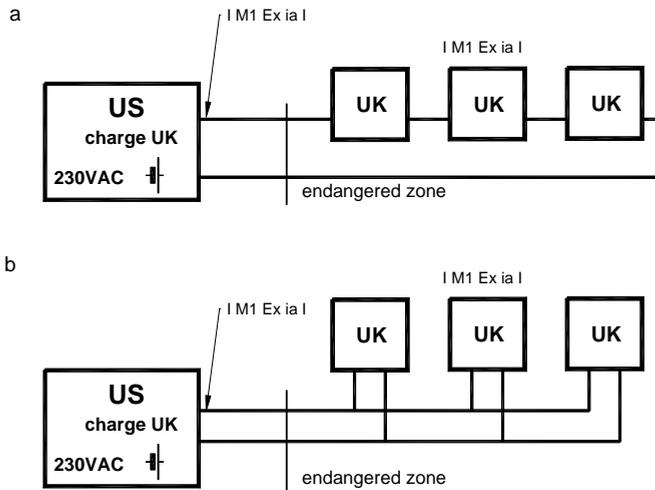


Fig. 7. Remote supply diagram of bus devices in mines; (a) connected in series, (b) connected parallel

In case of telecommunication systems of local feature (for instance, loudspeaking communication systems) the group power supply units are most frequently applied, in which local power supply unit supplies several telecommunication devices (UA). In group supply systems the battery support is applied of two available arrangements:

- the group power supply unit is furnished with local battery (Fig. 8); this type of supply is applied, among other, in radio communication systems with leaky feeder to supply the line repeaters in system MULTICOM (Miśkiewicz et al, 2010) as well as in system ImPact for group supply of intrinsically safe access devices that provide radio communication with utilisation of protocols 802.11,

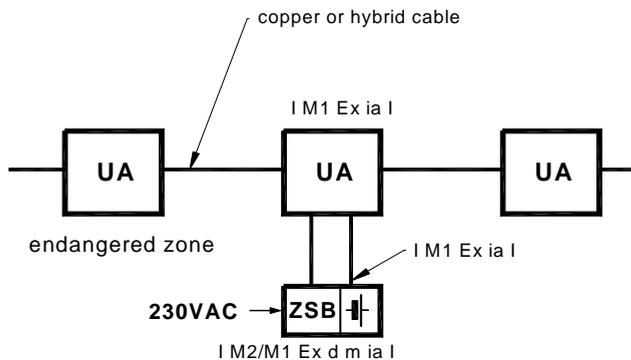


Fig. 8. Group supply including battery support in power supply unit ZSB

- group power supply unit has no battery support; the device supplied from this power supply unit have their inner batteries (Fig. 9); this is so called distributed battery support;

this type of supply is used, among other, in loudspeaking communication systems as well as in radio communication system with leaky feeder of MCA 1000 type (Miśkiewicz & Wojaczek, 2010).

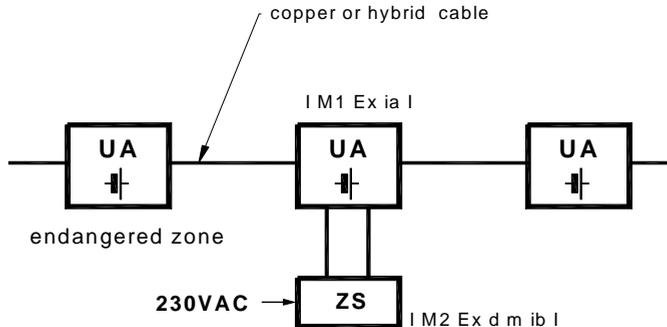


Fig. 9. Group supply with distributed battery support

Distribution of supply in group supply systems may be accomplished by means of:

- multicore copper cable, frequently of special design, in which cores for supply have greater cross-section than cores provided for transmission of signals.
- leaky feeder in radio communication systems; supply and signals are laid in the same coaxial cable.
- hybrid cable with copper cores for supply and optical fibre for transmission of signals (for instance in ImPact teletransmission system (Fig. 9).

The indispensable and important function in case of usage the local power supply unit furnished with battery support is transmission of information, for instance, to dispatch room about power supply units operating in battery mode. Lack of supply from power grid shall allow technical service for reaction connected with need to restore network supply of group power supply unit (Dmowski & Dzik, 2004).

#### 4. Guaranteed supply of stationary devices of telecommunication systems in underground mines

Every telecommunication system in underground mine need continuous (uninterrupted or guaranteed) electric power supply. Stationary devices of these systems are supplied with:

- direct voltage 48 VDC, (communication and alarm systems),
- alternating voltage 230 VAC (computers, dispatch rooms).

Correct structures of supply systems of stationary devices are presented in Fig. 10 and Fig. 11 (Cierpisz et al., 2007).

#### 4.1. AC and DC module telecommunication power stations

At present, the module rectifier systems are used in telecommunication DC power stations.

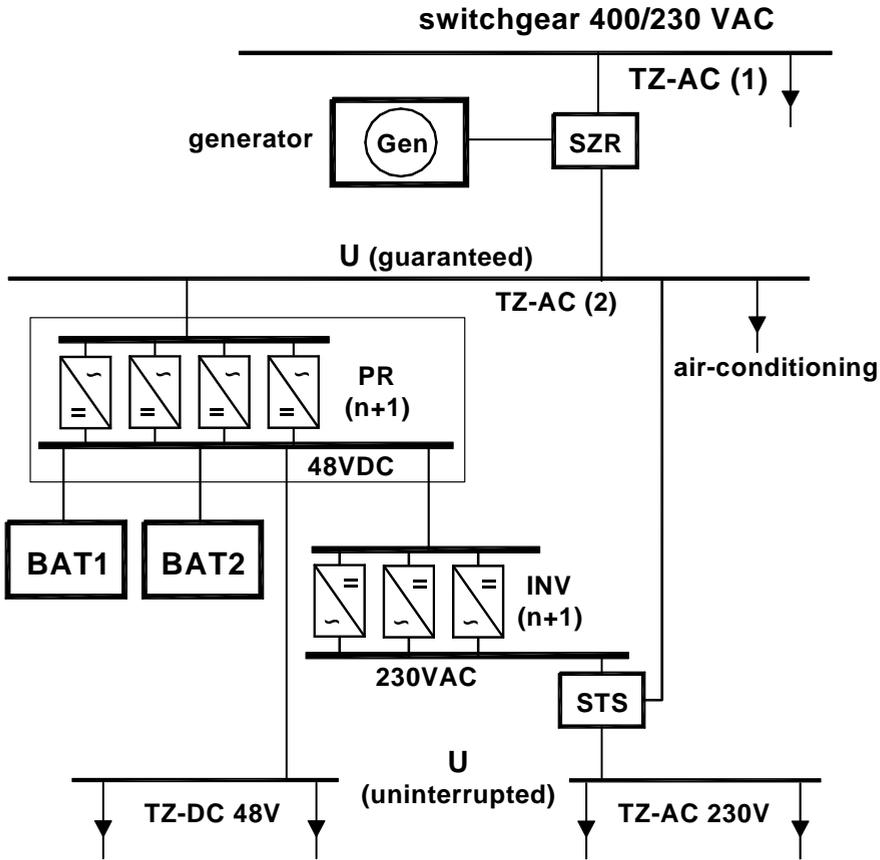


Fig. 10. Block diagram of power supply of dispatcher devices by rectifier with battery and inverter

AC power supply system for telecommunication devices should also include inverter modules INV (Fig. 10), also in quantity  $n + 1$ <sup>1</sup>. Such integrated telecommunication power station uses common accumulator batteries, as presented in Fig. 10.

Attention should be paid that every modular inverter power station should be equipped with power supply static throw-over switch (STS), which makes possible emergency supplying the devices that require the guaranteed supply 230 VAC directly from power grid, omitting inverter modules (Heinloth K., 2006).

<sup>1</sup>  $n$  – denotes quantity of required from calculations the rectifier modules under design, or inverter ones in telecommunication power plants that supply the systems with uninterrupted voltage.

## 4.2. Systems with UPS power supply units

Supplying the telecommunication devices is also possible from emergency power supply units of UPS type (5) furnished with their own accumulator battery, provided that two UPS (UPS1+BAT3, UPS2+BAT4 from Fig. 11) devices shall be applied being switched over with power supply static throw-over switch (STS), whereas every of them is able to supply the receivers that need AC guaranteed supply. Every UPS device (on-line type) has to be equipped with electronic inner by-pass connector (not shown in Fig. 11) and external by-pass connector (POS1a, POS1b, POS2a, POS2b).

Stationary devices of safety systems of underground mine works should not be supplied from UPS emergency power supply units of off-line-type or line-interactive AVR. (Wojda, 2004).

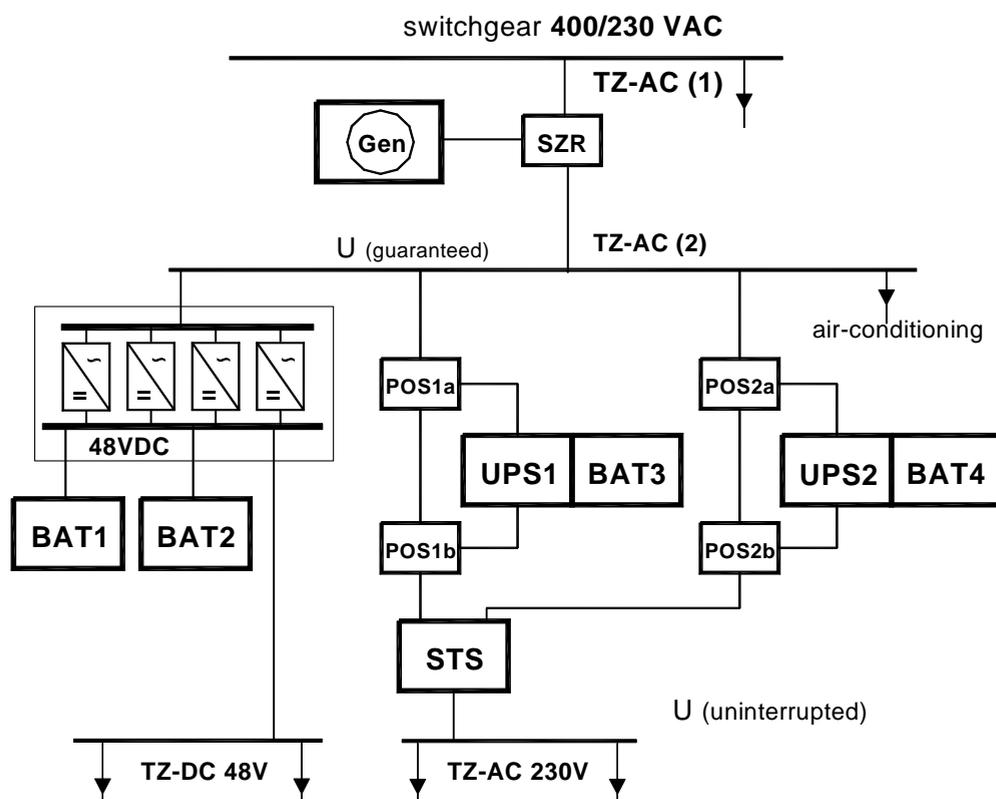


Fig. 11. Block diagram of power supply with UPS

Important dispatcher devices should not be supplied from single UPS power supply units. Lack of redundancy or internal electronic by-pass connector in guaranteed power supply system, especially in emergency or service cases should not be tolerated (Muhammad, 2007). It is also inadmissible that UPS power supply units were not equipped with external, service by-pass connectors (POS).

## 5. Summary

Within the scope of guaranteed power supply all dispatcher telecommunication systems of mines subject in principle to several important limitations. Stationary devices, due to common usage in Polish mines of central power supply, should use the module telecommunication power stations. Distributed elements of safety systems (for instance, dispatcher panels) are to be taken into account in power supply structures.

Explosion-proof design of telecommunication system requires usage of special intrinsically safe line systems in underground subscriber circuit that provide the galvanic separation also in central power supply systems, with separate cable lines, in which only intrinsically safe circuits run.

Correct operation of underground telecommunication devices, needed first of all intrinsically safe power supply. In case of supplying the subscriber devices, verifying the appropriate power supply requires not only calculation of voltage drops in supply line but also checking the consistence of intrinsically safety conditions of devices connected together as well as taking into account the electric parameters of transmission line.

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