BUFFER RECTIFIERS

A pulse buffer rectifier converts alternating current (AC) to direct current (DC), and constitutes a basic element of guaranteed power supply systems. These industrial direct current power supply system meet high requirements in terms of functionality, technical parameters, and reliability.

Rectifiers are intended for supplying direct current loads and charging accumulator batteries of rated current 24 V, 48V, 60 V, 110 V, 220 V, 400 V, 700 V or other compliant with the device's specification.

Direct current loads power supply may be carried out in cooperation with a buffer battery or directly from a rectifier. The autonomy of the system is ensured by direct connection of the DC bus with the accumulator battery.

THE PBI TYPE BUFFER RECTIFIER CHARACTERISTICS:

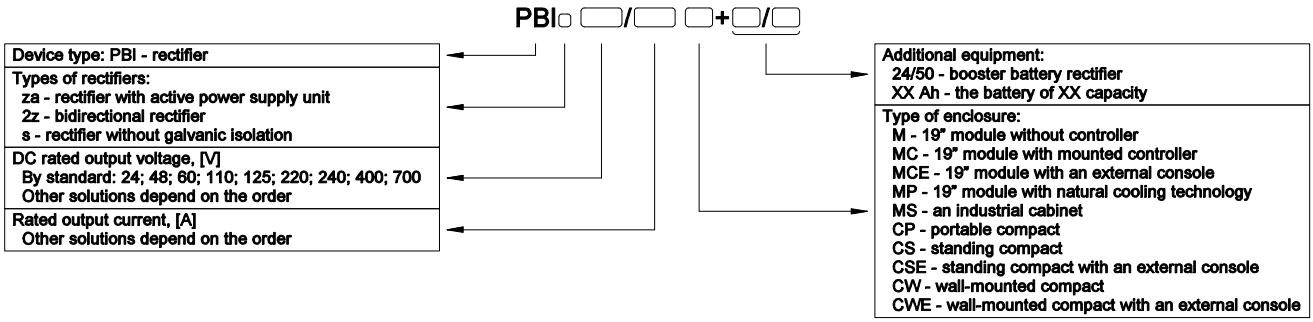
- IGBT technology with a DSP microprocessor controller;
- three operation modes (buffer, automatic, manual);
- high stability of voltages and output currents;
- charging algorithm (as per DIN 41773), accordant with the recommendations of EUROBAT for various types of batteries;
- very low current ripple and output voltage;
- control and limitation of the battery's current;
- battery temperature control;
- battery voltage temperature compensation;
- integrated communication RS485, USB interfaces;
- wide selection of external communication protocols: Modbus RTU, Modbus TCP, IEC 60870-5-103, IEC 61850, SNMP, APS6000, other;
- electromagnetic compatibility (EMI filters);
- parallel operation of the rectifiers with automatic equalisation of currents in all modules;
- galvanic isolation from the mains;
- archiving of events and operating states (SD card);
- modular design;
- silent operation;
- high efficiency;
- monitoring of the ground isolation status of both poles;
- internal overload protection of power systems (limits the output current without removing voltage from the output circuits);
- protection against short-circuit (electronic and fuse type);
- over-current protection.

Views of the rectifier compacts

Views of the rectifier module

Views of the rectifier cabinet

METHOD OF DESIGNATION OF THE PBI TYPE RECTIFIERS



KEY OF THE ABBREVIATIONS USED IN THE DIAGRAMS IN THE CHAPTER

BAT – battery	PBI – rectifier
I – current measurement	T – temperature measurement
IN – power supply	VAC – alternating current (AC)
com – communication	VDC – direct current (DC)
OUT – output	

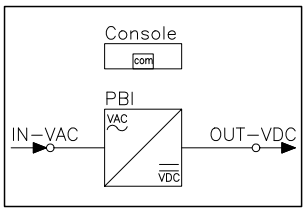


Fig. 1. General block diagram of the rectifier system

THE PBI TYPE BUFFER RECTIFIERS – TECHNICAL CHARACTERISTICS – STANDARD PARAMETERS

PARAMETER		VALUE
AC INPUT*		
Input voltage:	single-phase	220 / 230 / 240 V
	three-phase	380 / 400 / 415 V
Input voltage tolerance		-15 % to +10 % (±15 % for 380 V)
Frequency of input voltage		50 / 60 Hz
Input voltage frequency tolerance		±10 %
DC OUTPUT		
Output voltage		24 / 48 / 60 / 110 / 220 / 400 / 700 V
Output voltage stability**		±0.6 %
Output voltage ripple****		±0.6 %
Range of correction of the buffer charging voltage		between -10 and +50 °C
Temperature compensation of the buffer charging voltage**		0 to 10 mV/°C/cell
Rated output current		10 to 1,500 A
Overload capacity		1.1×In for 3 sec
Output current stability***		±1 %
Output current ripple***		±1 %
Battery charging characteristics		IU as per DIN 41773
Total efficiency		>92 %
Available menu language versions		PL | EN | CZ | RU
OPERATING ENVIRONMENT		
Operating temperature (EN 50178 class 3k3)		+5 to +40 °C*
Storage temperature (EN 50178 class 1k4)		-25 to +55 °C*
Humidity (EN 50178 class 3k3)		5 to 85 % (non-condensing)*
Access to the device		operation and maintenance from the front*
Cable entry		from the bottom / from the top****
Maximum height above the sea level without change of the rated parameters		1,000 m ASL

* – it is possible to design different parameters upon agreement with the manufacturer;
** – buffer operation, voltage regulator;
*** – battery charging, current regulator;
**** – at resistance load;
***** – only for installation in an industrial cabinet (MS enclosure type).

PBI RECTIFIERS TECHNOLOGY

Three-phase or single-phase power supply voltage is converted in the three-stage converter system.

- mains rectifier,
- high-frequency converter,
- high-frequency rectifier.

The PBI rectifier is equipped with a microprocessor DSP (Digital Signal Processor) control system which controls the operation of the converter and monitors the state of the battery.

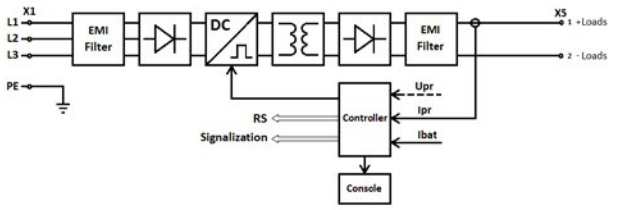


Fig. 2. Conceptual design of the PBI rectifier

The Pulse Width Modulation (PWM) converter ensures adaptation of the input voltage value to the needs of the loads and the battery. The high-frequency ferrite transformer provides a galvanic insulation for the input and output circuits.

Devices are cooled down with a forced air circulation with regulation depending on the temperature of the heat sinks. Operation of the device is monitored by the controller. It also enables communication between the device and the user or master monitoring and control systems.

View of the PBI rectifier power block

PBI RECTIFIER OPERATION MODES

Buffer operation

In this state, the device supplies the battery and/or loads with direct current of high degree of stability and required value (usually 2.23 V/cell). The buffering voltage is compensated thermally by a thermal probe (which must be positioned in the vicinity of the supplied battery) present in the standard equipment. Thanks to this, the output voltage of the power supply is always adapted to the needs of the battery, and maintenance of its fully charged state and readiness for operation in the case of a power supply failure is ensured. During buffer operation, the continuity of the battery's circuit is cyclically checked.

Automatic charging

This function is used in the case of partial or complete discharge of the battery (e.g., as a result of power supply failure), when the battery must be charged as quickly as possible to prepare it for a possible failure. In this case, the power supply will automatically charge the battery to Umax voltage.

Supervised charging

This mode is used in the case of cooperation with open acid batteries, when there is a need to carry out additional equalising charging to 2.7 V/cell. This charging process must be carried out strictly according to the guidelines of the manufacturer of the battery and always in the presence of the operating personnel.

Operation modes parameters

Operation mode	Factory settings		Possible regulation range
	Lead-acid batteries	Ni-Cd batteries	
Buffer mode (Float mode)	2.23 V/cell	1.41V/cell	0.8 – 2.4 V/cell
Automatic charging (Boost mode)	2.40 V/cell	1.50 V/cell	0.8 – 2.7 V/cell
Supervised charging (Equalising mode)	2.70 V/cell	1.80 V/cell	0.8 – 2.7 V/cell

Three-stage I_1 U_1 U_2 battery charging technique

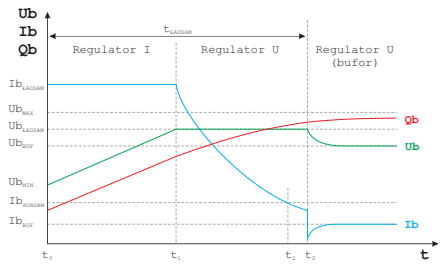
In the case of discharge of the battery, the PBI rectifier will automatically activate the quick charging mode (optionally, this mode may be activated manually). The charging parameters are configured in the memory of the rectifier in accordance with the requirements of the producer of the battery of a given type. The charging has three stages:

1st phase – direct current charging I_1 (the first limit parameter): this is a current-limited charging. The rectifier gradually increases the battery voltage to not exceed the recommended charging current (most often, limitation at the level of current I_1 = 5÷10-hour charging (I_{C10}) is used);

2nd phase – direct current charging U_1 (the second limit parameter): the battery is partially charged after the first phase of charging, there is no risk that the increase of the charging voltage will exceed the set battery current I_1, the second limit parameter works, the allowed (maximum voltage at the DC bus due to loads or due to the battery) voltage U_1. Completion of the 2nd phase of charging depends on the adopted algorithm. APS Energia SA uses the DBC method.

3rd phase – direct current charging U_2; the system has completed quick charging, and the rectifier switches to voltage U_2 = Ubuf buffer voltage.

Charging characteristics DBC (Dynamic Charge Characteristic) model



Configurable parameters:

- charging current – Ib_{C10}
- maximum voltage – Ub_{MAX},
- recharge current – Ib_{DOL},
- time of automatic charging – T_2,

In accordance with the recommendations of EUROBAT.As per DIN 41773.

DBC charging method

The DBC is a charging method developed by APS Energia SA based on the experience in production of buffer rectifiers and in strict cooperation with the manufacturers and users of batteries. The Dynamic Battery Charging (DBC) is a method which controls all charging parameters, and thus ensures quick replenishment of the battery's electric charge according to all recommendations of the producer of a given type of cell. The method consists in charging the battery with voltage U_1 in the second phase until the two following criteria are met at the same time:

- criterion no. 1 – achievement of the set value (e.g., 0.2×I_{C10}) by the dropping charging current – a configurable parameter;
- criterion no. 2 – charging of the battery after the criterion no. 1 has been met for 30 minutes – a configurable parameter;

As an option of the DBC method, an additional criterion of completion of the quick completion phase is assumed, i.e., the length and the depth of the battery's discharge.

PBI RECTIFIER FUNCTION DESCRIPTION	
Battery current measurement	This system measures the battery circuit current using a transducer. The transducer may be located inside the power supply (internal current measurement) or outside the power supply (external current measurement), e.g., in the user's distribution board or at the battery itself, on any pole.
Battery circuit continuity test	In the buffer operation state, the rectifier cyclically tests the continuity of the battery's circuit. The process is carried out by way of appropriate regulation of voltage and current measurements. After a positive test result, the rectifier's voltage goes back to the buffer voltage level. The test parameters are set in the rectifier's menu.
Charging interlock	Switching the rectifier into the "charging interlock" mode limits the current flowing to the battery at the 100-hour current level. This function is tripped by applying voltage to the binary input. The charging interlock limits the current during the automatic charging and supervised charging. This function is most often used with another system, e.g., a battery room's ventilation system. Failure of the ventilation generates a signal to the "charging interlock" to limit the charging current, and thus protect the battery against potential overheating, increased aeration of the electrolyte, etc.
Rectifier operation interlock	In this mode, the rectifier does not transfer energy from the mains to the loads and the battery, and only remains in the standby mode. The rectifier will start automatically after the "rectifier interlock" signal has been removed. This function is tripped by applying voltage to the binary input. This function is necessary if the rectifier must be controlled remotely.
Over-voltage protection of the load	When a voltage dangerous to loads is present for a time longer than 500 ms at the power supply's output, an overcurrent protection is activated to turn the rectifier off. This voltage is preset appropriately to the rated voltage of the power supply. After the excessively high voltage at the input ceases, the rectifier restarts.
Charger alarm levels	All of the set alarm levels have hysteresis of the system on the level of alarm stimulation.
Battery voltage thermal compensation	The battery's buffer voltage changes with the temperature fluctuations. In accordance with the recommendations of the battery manufacturers, the battery's charging voltage thermal compensation is applied. The rectifier may carry out a procedure of automatic temperature compensation to adapt the battery's voltage to the environmental conditions.
Limitation of the battery charging current	The rectifier limits the battery's charging current to the value set by the user and expressed by the time in which we want to charge the battery. During the supervised charging, the current is limited to the value set by the personnel when configuring the supervised charging parameters.
Battery earth fault isolation resistance	The rectifier is equipped with a microprocessor earth fault control system. The earth fault control system is intended for measuring the value of the insulation resistance in the direct current installation circuits (the battery's poles ground faults control). The device measures and signals a drop of the symmetrical and asymmetrical resistance. A drop of the value of resistance below the warning or alarm threshold is signalled in the status of the device and trips relevant alarm relays.
Auto-restart	The PBI rectifiers are equipped with an auto-restart function when the power supply voltage appears, if a power supply voltage break caused the rectifier to turn off.
Fans operation control	The fans installed in the modules are equipped with damage sensors. Stoppage of the fans is signalled by illumination of the "warning" diode on the rectifier's console. Information about the damage is stored in the event buffer. There is a possibility to signal such a state using relay outputs.
Controlled cabinet fans	The MS version PBI rectifier allows controlling the operation of the roof fans. The roof fans (which extract air from inside the cabinet) may work in two speeds. Application of alternating current power supply starts the fans on the 1st speed. When the temperature inside the cabinet exceeds the 2nd speed tripping threshold of the roof fans, their efficiency of extraction of hot air from inside the cabinet will increase.
Data archiving	The events buffer is an area in the permanent memory of the rectifier, in which all alarm events, including date and time, are saved. The archive buffer is an area of the permanent memory of the rectifier, in which measurement series are stored with an interval set by the user. USB 2.0 ports enable communication between the power supply and the computer system or transferring alarm logs to a FLASH portable memory (USB flash drive).
Communication with the user	Communication between the user and the device may take place both locally and remotely. Locally, using the console (keyboard, LCD, indicating diodes), located on the front side of the device. Electrical parameters are displayed constantly, regardless of the selected operation mode of the panel. Alarm states are indicated using glowing diodes and the display. Additionally, a sound signal is generated, which informs about an alarm state (the sound signaller is located behind the panel's board). Remotely, using the binary inputs and outputs, as well as communication ports. You may assign different functions to the binary inputs to change the operation of the rectifier. The functions are assigned in the rectifier's menu. The transmission communication ports (RS485, USB) allow connecting multiple transmitters and loads. The following transmission protocols are available at the rectifier's connections: Selected from the controller's menu: APS6000, Modbus RTU, IEC 60870-5-103. Available with the converter: IEC 61850, PROFIBUS DP, SNMP, Modbus TCP. They allow to read the full set of data from the rectifier.
Parallel operation of rectifiers	During operation on the common load bus, all PBI type rectifiers automatically and evenly distribute the load between each other by equalising the output currents.
Self-test	Thanks to the "self-test" function, the user obtains information about correctness of internal and intermediate parameters responsible for proper operation of the device.
Soft Start	Thanks to the "Soft Start" function, when the rectifier starts-up, there is no sudden load of the power supply lines. The soft start of the rectifier is carried out in two stages: in the first one, the condensers are loaded and the rectifier's controls are started-up, and then the rectifier gradually increases the voltage at the output until reaching the operating point. The soft start cycle lasts several to a dozen or so seconds depending on the load.

THERE ARE TWO VARIANTS OF THE PBI RECTIFIERS:

• RECTIFIERS WITH AN INTERNAL BATTERY CURRENT MEASUREMENT (WPP)

Rectifiers with an internal current measurement (WPP) are characterised by a separation of outputs of loads (X5) and the battery's output (X4) inside the rectifier. Current measurement takes place inside the rectifier without the necessity to use an external current measurement transducer. The battery output and the loads output are protected with fuses.

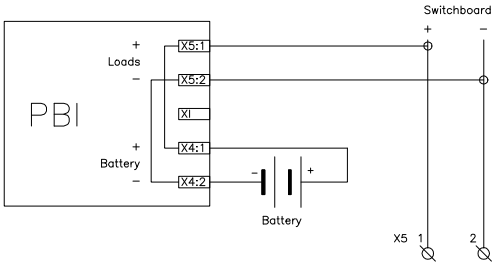


Fig. 3. A rectifier with an internal battery current measurement

• RECTIFIERS WITH AN EXTERNAL BATTERY CURRENT MEASUREMENT (ZPP)

The rectifiers with an external current measurement (ZPP) require connection of an external current measurement transducer to the XI connector of the rectifier. The rectifier has a single output (X5), common for the battery and the loads. The battery's circuits and the loads must be separated in an external distribution board.

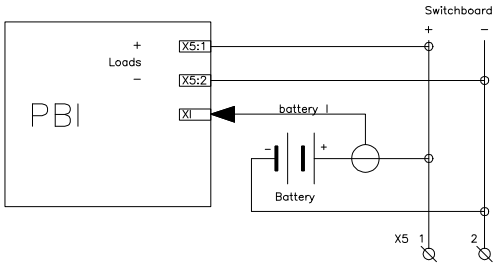


Fig. 4. A rectifier with an external battery current measurement

OPTIONAL ACCESSORIES FOR THE PBI TYPE RECTIFIERS

Optional	Equipment	Description
Special designs	Upon request, it is possible to adapt the devices to special requirements of a given project in relation to:	
	Module, cabinet, compact	• greater DC rated currents; • standard of voltages and frequencies of AC power supply: (110 / 190 V, 115 / 200 V, 120 / 208V, 127/220 V, 50 / 60 Hz); • level of the DC output voltages; • extension of the range of input voltages;
	Cabinet, compact	• environmental requirements related to ambient temperature (-20 °C to +55 °C), presence of aggressive factors, etc.;
	Cabinet	• enclosure design, including seismic resistant designs, IP degree of protection, design of the bus bars, access to the cables from the top, coating colour, etc.;
	Cabinet, compact	• measurements and communication: digital or analogue meters of appropriate class, indication of states, visualisation of operating modes, synoptic of connections, communication protocols, etc.
Automatic load disconnection	Module, cabinet, compact	The PBI rectifier may be equipped with a contactor that disconnects loads when the battery's voltage drops below the value set via the "load disconnection" parameter. The loads will remain disconnected until the rectifier's voltage reaches the level above the "connection of loads" parameter.
Measurement of the charge accumulated in the battery		The charge is calculated during charging and discharging of the battery considering the battery charging efficiency coefficient. The user may set the current parameters of the battery (e.g., after a controlled discharge); these parameters will be the starting point for calculation of the charge.
Counter cell system	Cabinet, compact	The counter cell consists of diodes connected in series and bypassed by the contactor's pin. This is a system that allows lowering of voltage in DC loads. Voltage on the load bus is reduced by activation of the serial diode stack at the output of the loads. When the battery's voltage drops (e.g., when the rectifier turns off), the contactor closes the diode stack circuit. The voltage of loads is equal to the voltage of the battery. The counter cell system may be controlled based on the power supply voltage break or drop of the battery's voltage.
Active input filter (sinusoidal input current from the mains)	Cabinet	To improve THDi of the current drawn from the mains, you may use another parallel active filter or a serial active power supply in the rectifier. By using this solution, you achieve sinusoidal characteristics of drawing of current from the mains by the rectifier.
ATSE system		The automatic transfer switching equipment (ATSE) decides about the selection of the source of power for a device. During presence of the voltage of the source no. 1, the rectifier is supplied by it. In the case of break (a complete or of one of the phases) of the source no. 1, the ATSE automatically switches supply of the rectifier to the source no. 2.
The system of connecting the booster battery		The PBI rectifiers may be equipped with a booster battery connecting system in a series with the main battery. Connection and disconnection take place without interruptions (from the point of view of loads). The booster battery is connected after the voltage of the main battery drops to the specified level, and is disconnected when the voltage of the main battery increases. Connection and disconnection take place automatically. The booster battery may be connected to the positive or negative pole of the main battery (depending on the design specification).
Cable entry from the top		It is possible to design the enclosure in a way to allow cables entering from the top.

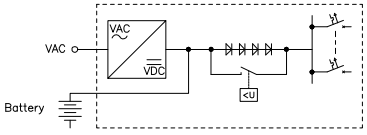


Fig. 5. A rectifier with an internal battery current measurement and the counter cell system

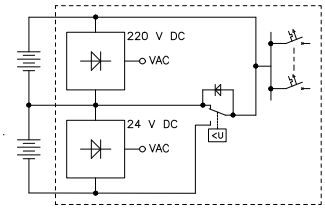


Fig. 6. A rectifier with an internal battery current measurement and the booster battery

MODULAR DESIGN RECTIFIERS

This chapter presents the PBI type rectifiers in a form of a 19" module. They are adapted for mounting in industrial cabinets. The main task of a rectifier is to continuously supply loads with a guaranteed DC voltage.

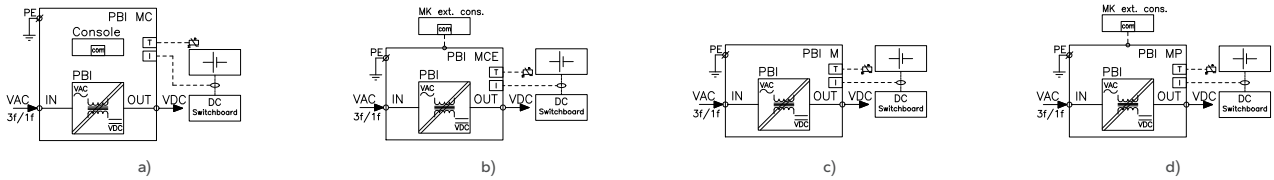


Fig. 7. Block diagram of the PBI type rectifier module for autonomous operation:
a) with a built-in console; b) with an external MK console; c) without a console; d) with natural cooling.

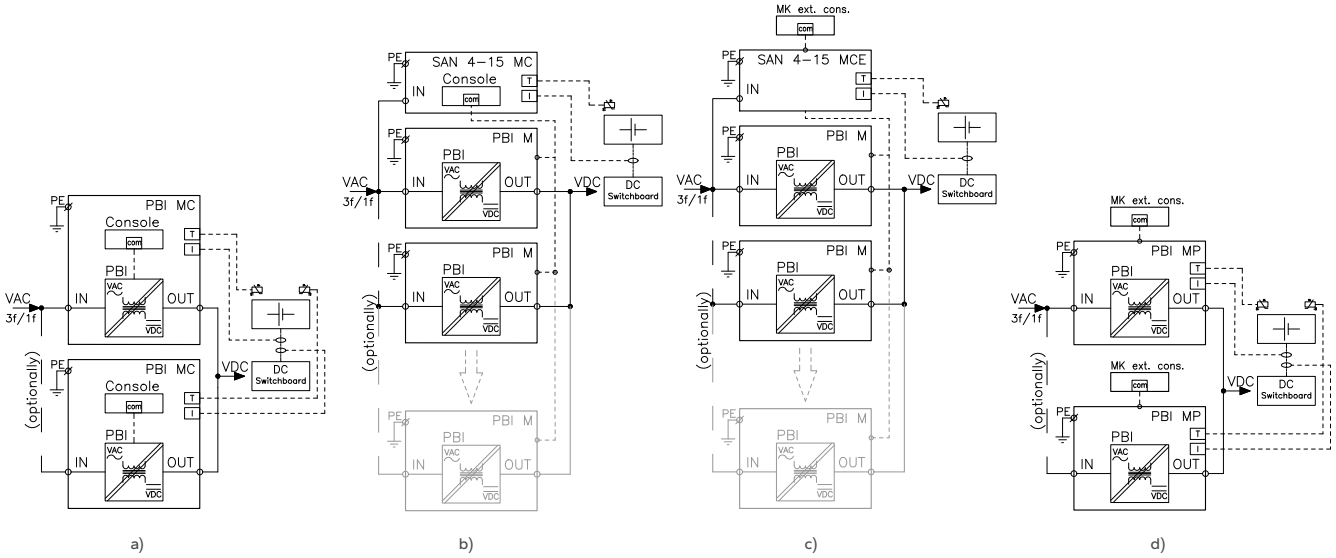


Fig. 8. Block diagram of the modules of the PBI type rectifier for parallel operation:
a) the PBI MC type modules system; b) the PBI M modules and the SAN 4-15 MC type controller system;
c) the PBI M type modules and the SAN 4-15 MCE type controller system including an external MK console; d) the PBI MP type modules system.

The PBI type rectifier module is supplied by a single-phase or three-phase AC mains. The modules with a built-in console belong to the MC modules family (Fig. 7a), the modules with an external MK console belong to the MCE modules family (Fig. 7b), and the modules without the console are a part of the M modules family (Fig. 7c).

The rectifier converts alternating current to direct current of a value according to the order. The galvanic isolation of the rectifier's output voltage from the AC supply voltage is ensured by the high-frequency isolating transformer located in the mains converter.

The devices may operate on their own (autonomously – Fig. 7) or in n×PBI configuration (in parallel – Fig. 8). The PBI MC, PBI MCE, and PBI MP modules for parallel operation do not require an external controller. The PBI M modules are adapted to parallel operation via use of an external controller in systems consisting of a larger number of modules (>4).

The SAN 4-15 external controller module is used to control, supervise, visualise operating and emergency states of the system. The SAN 4-15 modules in a version with a built-in console belong to the MC family (Fig. 8b), while the modules with an external console are a part of the MCE modules family (Fig. 8c) of overall dimensions of the M4 module shown on Figure 9a, c).

When the rectifier is only used to supply loads with output DC voltage, this device will be configured without functions related to the battery.

Each M or MC module is cooled using fans. RPM of fans is adjusted seamlessly in the external temperature function of the device, significantly increasing their lifetime. While the MP family modules (Fig. 7 d and Fig. 8 d) are cooled by the natural air circulation (passive cooling).

SERIES TYPE: RECTIFIER MODULE 10 ÷ 350 A FOR AUTONOMOUS AND PARALLEL OPERATION:

Rated output current, [A]	DC rated input voltage, [V]	AC rated input voltage, [V]	Example type	Enclosure dimensions**
25 / 30 / 50 / 75 / 100 / 150 / 200	24	3×400 or 230	PBI 24/25 MC*	M4
250 / 300 / 350		3×400	PBI 24/250 MC*	
60		3×400 or 230	PBI 24/60 MP	M3-MP
25 / 30 / 50 / 75 / 100	48		PBI 48/25 MC*	M4
150 / 200		3×400	PBI 48/150 MC*	
250 / 300 / 350			PBI 48/250 MC*	M3
30		3×400 or 230	PBI 48/30 MP	M3-MP
25 / 30 / 50 / 60	60		PBI 60 / 25 MC*	M4
75 / 100 / 150		3×400	PBI 60/75 MC*	
200 / 250 / 300			PBI 60 / 200 MC*	M3
10 / 20 / 25 / 30 / 50	110	3×400 or 230	PBI 110 / 10 MC*	M4
60 / 75 / 80 / 100		3×400	PBI 110 / 60 MC*	
150 / 200			PBI 110 / 150 MC*	M3
20			PBI 110 / 20 MP	M3-MP
10 / 20 / 25 / 30 / 40 / 50	125	3×400 or 230	PBI 125/10 MC*	M4
75		3×400	PBI 125/75 MC*	
100 / 150			PBI 125/100 MC*	M3
10 / 20 / 25	220	3×400 or 230	PBI 220 / 10 MC*	M4
30 / 50		3×400	PBI 220/30 MC*	
60 / 75 / 80 / 100			PBI 220 / 60 MC*	M3
10			PBI 220 / 10 MP	M3-MP
10 / 20	240	3×400 or 230	PBI 240 / 10 MC*	M4
25 / 30 / 40		3×400	PBI 240 / 25 MC*	
50 / 75 / 80			PBI 240/50 MC*	M3
10 / 20 / 25	400		PBI 400 / 10 MC*	M4
30 / 50 / 60			PBI 400/30 MC*	M3
25	700		PBI 700 / 25 MC*	

* – Possible options: M / MC / MCE;

** – M4 (4U): 482×142×496; M3 (6U): 482×267×496. (W×H×D).

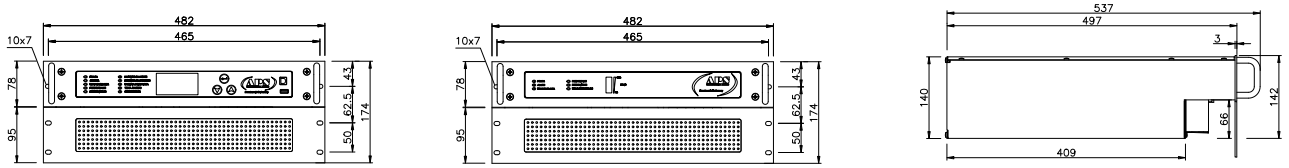


Fig. 9. Views with dimensions of the M/MC/MCE PBI rectifier module in the M4 enclosure:
a) front view – a module with a built-in console; b) front view – a module without a console; c) left-side view.

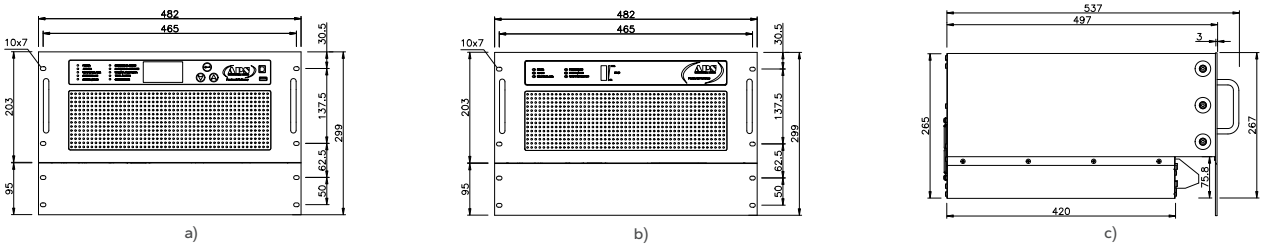


Fig. 10. Views with dimensions of the M/MC/MCE PBI rectifier module in the M3 enclosure:
a) front view – a module with a built-in console; b) front view – a module without a console; c) left-side view.

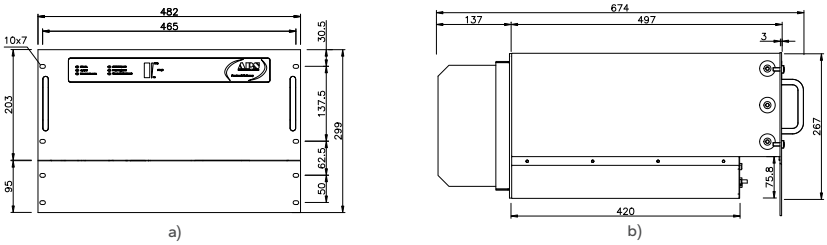


Fig. 11. Views with dimensions of the MP PBI type rectifier module in the M3-MP enclosure:
a) front view; b) left-side view.

RECTIFIERS BUILT IN A CABINET

This chapter presents the PBI type rectifiers in a form of a 19" industrial cabinet for installation on a substrate. The main task of a rectifier is to continuously supply loads with a guaranteed DC voltage.

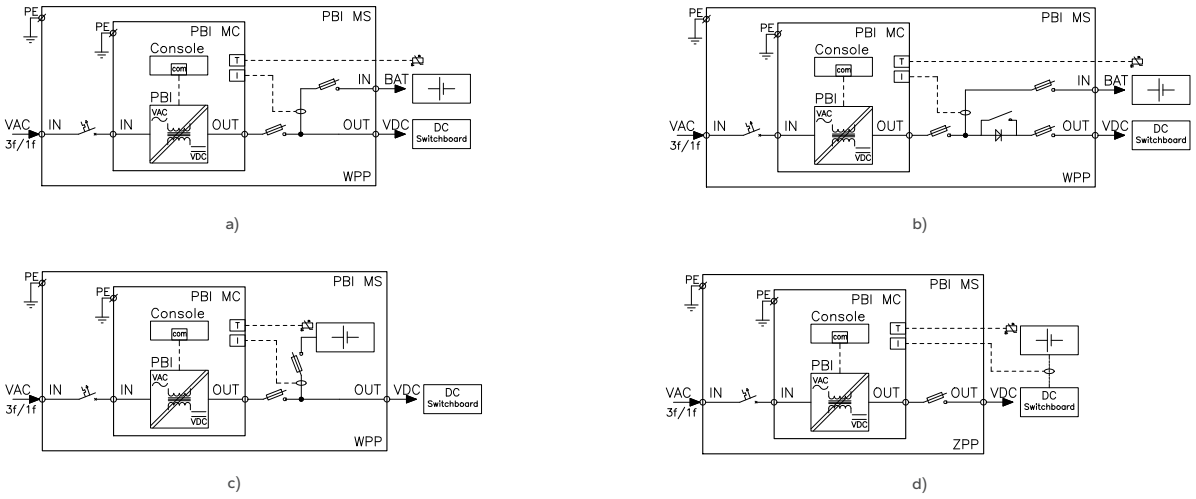


Fig. 12. Block diagram of the PBI type rectifier cabinet for autonomous operation:
a) a system with WPP; b) a system with WPP and a counter cell; c) a system with WPP and an external battery in the rectifier's cabinet; d) a system with ZPP.

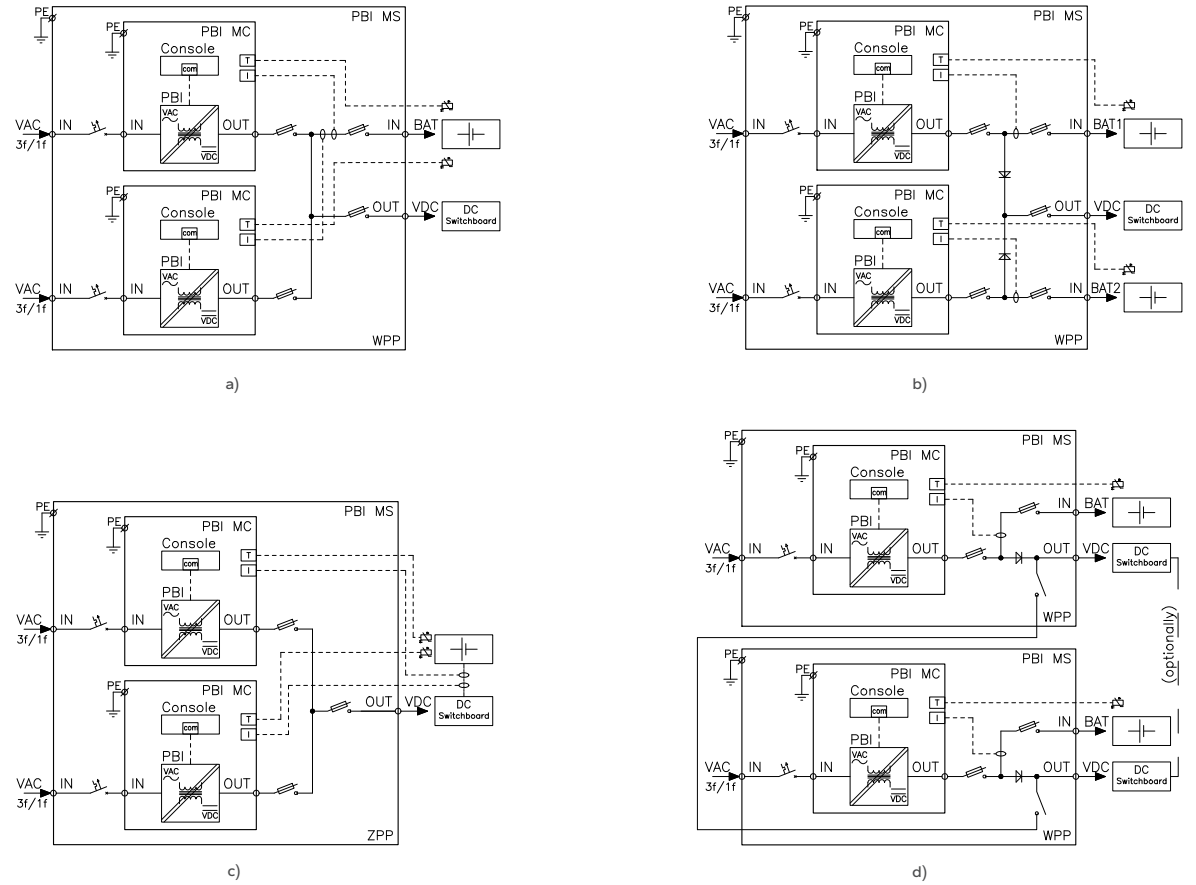


Fig. 13. Block diagram of the PBI type rectifier cabinet (on the basis of the PBI MC modules) for parallel operation:
a) the PBI MC system with WPP for operation with a single battery; b) the PBI MC system with WPP for operation with two batteries;
c) the PBI MC system with ZPP; d) the PBI MS system for operation with two batteries.

The PBI MS type rectifiers are multi-modular power supply systems intended for supplying loads in cooperation or without cooperation with the battery. The design of the rectifier is based on rectifier modules of PBI M or MC types. The description of the modules is provided in the chapter "MODULAR DESIGN RECTIFIERS". The modules feature a compact design, optimised for operating conditions of the modules. The functionality of the PBI MS systems allows designing rectifiers of significant output power, as well as more complex systems.

Fig. 12 – Fig. 14 present a standard solution for modular rectifiers built in an industrial cabinet. The devices may operate on their own (autonomously – Fig. 12) or in n×PBI configuration (in parallel – Fig. 13, Fig. 14).

Fig. 12 b) presents a cabinet with an additional option – a counter cell system (for details, see tab. "OPTIONAL ACCESSORIES FOR THE PBI TYPE RECTIFIERS").

The rectifier converts alternating current to direct current of a value according to the order. The galvanic isolation of the rectifier's output voltage from the AC supply voltage of the rectifier is ensured by the high-frequency isolating transformer located in the mains converter.

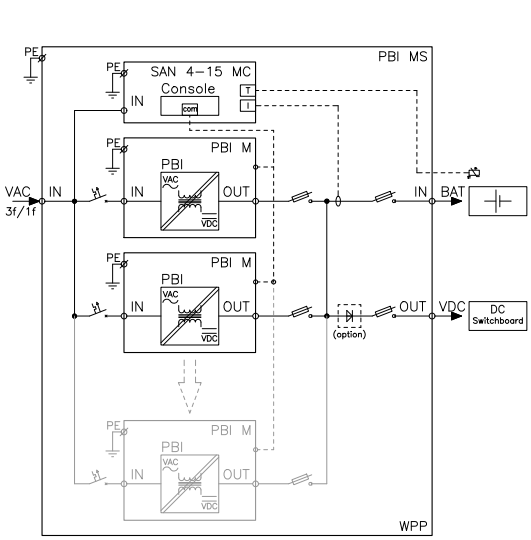
The system presented in Fig. 13 a) may have up to 4 PBI MC type rectifier modules.

The system presented in Fig. 14 may have up to 16 PBI M type rectifier modules.

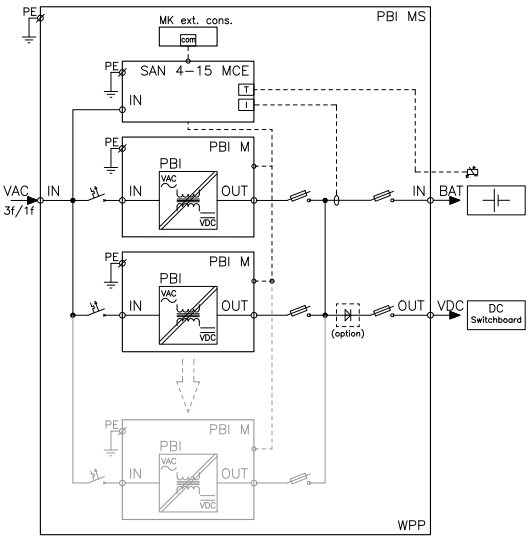
Use of the blocking diode presented in Fig. 13 b), d), and Fig, 14 a), b) allows connecting two systems for parallel operation with two batteries.

When the rectifier is only used to supply loads with an output DC voltage, this device will be configured without functions related to the battery.

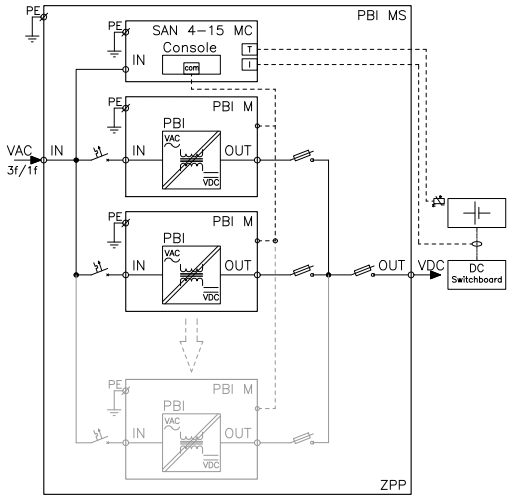
The industrial cabinet is cooled by a forced air circulation via redundant roof fans. Moreover, each module is cooled by fans. RPM of fans is adjusted seamlessly in the external temperature function of the device, significantly increasing their lifetime.



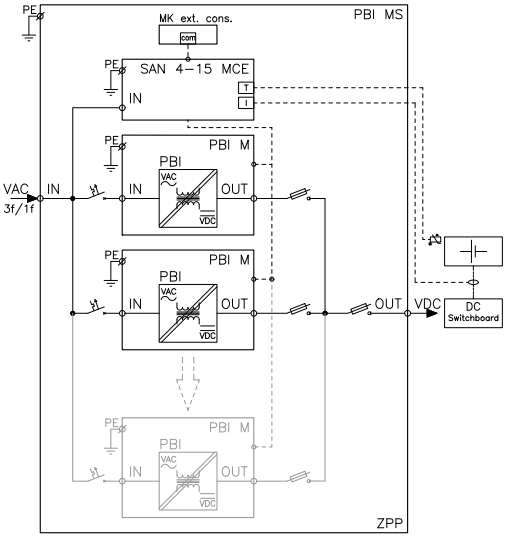
a)



b)



c)



d)

Fig. 14. Block diagram of the PBI type rectifier cabinet (on the basis of the PBI M modules) for parallel operation:
d) the PBI M type modules and the SAN 4-15 MC type controller system with WPP; b) the PBI M type modules and the SAN 4-15 MCE type controller system with WPP;
c) the PBI M type modules and the SAN 4-15 MC type controller system with ZPP; d) the PBI M type modules and the SAN 4-15 MCE type controller system with ZPP.

SERIES TYPE: RECTIFIER CABINETS 10 ÷ 1500 A FOR AUTONOMOUS AND PARALLEL OPERATION WITH WPP*

Rated output current, [A]	DC rated output voltage, [V]	AC rated input voltage, [V]	Example type	Modules configuration	Max. enclosure dimensions [W×D×H**], [mm]
25	24	3×400 or 230 (for modules with output current max. 200 A)	PBI 24/25 MS	1×25 A	600×800×2,000
30			PBI 24/30 MS	1×30 A	
50			PBI 24/50 MS	1×50 A	
				2×25 A	
75			PBI 24/75 MS	1×75 A	
100			PBI 24/100 MS	1×100 A	
				2×50 A	
200			PBI 24/200 MS	1×200 A	
				2×100 A	
250			PBI 24/250 MS	1×250 A	
300			PBI 24/300 MS	1×300 A	
				2×150 A	
400			PBI 24/400 MS	2×200 A	
				4×100 A	
500			PBI 24/500 MS	2×250 A	
				3×200 A	800×800×2,000
				5×100 A	1,200×800×2,000
600			PBI 24/600 MS	2×300 A	800×800×2,000
				3×200 A	
				6×100 A	1,200×800×2,000
700			PBI 24/700 MS	2×350 A	
				3×250 A	
				7×100 A	1,400×800×2,000
1,000			PBI 24/1000 MS	3×350 A	
				4×250 A	
1,200			PBI 24/1200 MS	4×300 A	1,800×800×2,000
1,500			PBI 24/1500 MS	5×300 A	2,400×800×2,000
				6×250 A	
25	48	3×400 or 230 (for modules with output current max. 100 A)	PBI 48/25 MS	1×25 A	600×800×2,000
30			PBI 48/30 MS	1×30 A	
50			PBI 48/50 MS	1×50 A	
				2×25 A	
75			PBI 48/75 MS	1×75 A	
100			PBI 48/100 MS	1×100 A	
				2×50 A	
150			PBI 48/150 MS	1×150 A	
				2×75 A	
200			PBI 48/200 MS	1×200 A	
				2×100 A	
300			PBI 48/300 MS	1×300 A	
				2×150 A	
400			PBI 48/400 MS	2×200 A	
				4×100 A	
500			PBI 48/500 MS	2×250 A	800×800×2,000
				5×100 A	1,200×800×2,000
600			PBI 48/600 MS	2×300 A	800×800×2,000
				6×100 A	1,200×800×2,000
700			PBI 48/700 MS	2×350 A	
				7×100 A	1,400×800×2,000
1,000			PBI 48/1000 MS	3×350 A	
				5×200 A	
1,200			PBI 48/1200 MS	4×350 A	1,800×800×2,000
				6×200 A	
1,500			PBI 48/1500 MS	5×300 A	2,400×800×2,000

SERIES TYPE: RECTIFIER CABINETS 10 ÷ 1500 A FOR AUTONOMOUS AND PARALLEL OPERATION WITH WPP* – CONTINUED

Rated output current, [A]	DC rated output voltage, [V]	AC rated input voltage, [V]	Example type	Modules configuration	Max. enclosure dimensions [W×D×H**], [mm]
25	60	3×400 or 230 (for modules with output current max. 60 A)	PBI 60 / 25 MS	1×25 A	600×800×2,000
30			PBI 60/30 MS	1×30 A	
50			PBI 60/50 MS	1×50 A	
60			PBI 60 / 60 MS	1×60 A	
				2×30 A	
75			PBI 60/75 MS	1×75 A	
100			PBI 60 / 100 MS	1×100 A	
				2×50 A	
150			PBI 60 / 150 MS	1×150 A	
				2×75 A	
200			PBI 60 / 200 MS	1×200 A	
				2×100 A	
250			PBI 60 / 250 MS	1×250 A	
300			PBI 60/300 MS	1×300 A	
				2×150 A	
				3×100 A	
400			PBI 60 / 400 MS	2×200 A	
				4×100 A	
500			PBI 60/500 MS	2×250 A	800×800×2,000
				5×100 A	1,200×800×2,000
600			PBI 60 / 600 MS	2×300 A	800×800×2,000
				6×100 A	1,200×800×2,000
700			PBI 60/700 MS	4×200 A	
				7×100 A	1,400×800×2,000
1,000			PBI 60 / 1000 MS	4×250 A	
1,200			PBI 60 / 1200 MS	6×200 A	2,000×800×2,000
1,500			PBI 60 / 1500 MS	5×300 A	2,400×800×2,000
10	110	3×400 or 230 (for modules with output current max. 50 A)	PBI 110 / 10 MS	1×10 A	600×800×2,000
20			PBI 110 / 20 MS	1×20 A	
25			PBI 110 / 25 MS	1×25 A	
30			PBI 110/30 MS	1×30 A	
50			PBI 110/50 MS	1×50 A	
				2×25 A	
75			PBI 110/75 MS	1×75 A	
100			PBI 110 / 100 MS	1×100 A	
				2×50 A	
150			PBI 110 / 150 MS	1×150 A	
				2×75 A	
200			PBI 110 / 200 MS	1×200 A	
				2×100 A	
300			PBI 110/300 MS	2×150 A	
				3×100 A	
400			PBI 110 / 400 MS	2×200 A	
				4×100 A	
500			PBI 110/500 MS	5×100 A	1,200×800×2,000
600			PBI 110 / 600 MS	3×200 A	800×800×2,000
				6×100 A	1,200×800×2,000
700			PBI 110/700 MS	7×100 A	
800			PBI 110/800 MS	4×200 A	
				8×100 A	
900			PBI 110/900 MS	9×100 A	1,800×800×2,000
1,000			PBI 110 / 1000 MS	5×200 A	1,400×800×2,000
				10×100 A	1,800×800×2,000
1,100			PBI 110 / 1100 MS	11×100 A	2,400×800×2,000
1,200			PBI 110 / 1200 MS	6×200 A	1,800×800×2,000
1,400			PBI 110 / 1400 MS	7×200 A	
1,500			PBI 110 / 1500 MS	8×200 A	2,000×800×2,000

SERIES TYPE: RECTIFIER CABINETS 10 ÷ 1500 A FOR AUTONOMOUS AND PARALLEL OPERATION WITH WPP* – CONTINUED

Rated output current, [A]	DC rated output voltage, [V]	AC rated input voltage, [V]	Example type	Modules configuration	Max. enclosure dimensions [W×D×H**], [mm]
10	125	3×400 or 230 (for modules with output current max. 40 A)	PBI 125/10 MS	1×10 A	600×800×2,000
20			PBI 125 / 20 MS	1×20 A	
25			PBI 125 / 25 MS	1×25 A	
30			PBI 125/30 MS	1×30 A	
40			PBI 125/40 MS	1×40 A	
				2×20 A	
50			PBI 125/50 MS	1×50 A	
				2×25 A	
60			PBI 125/60 MS	1×60 A	
				2×30 A	
80			PBI 125/80 MS	2×40 A	
120			PBI 125/120 MS	2×60 A	
				3×40 A	
150			PBI 125/150 MS	1×150 A	
				2×75 A	
200			PBI 125 / 200 MS	2×100 A	
				3×75 A	
300			PBI 125/300 MS	2×150 A	
				3×100 A	1,200×800×2,000
400			PBI 125/400 MS	3×150 A	
				6×75 A	
600			PBI 125/600 MS	4×150 A	
				6×100 A	1,800×800×2,000
700			PBI 125/700 MS	5×150 A	
900			PBI 125/900 MS	6×150 A	
1,000			PBI 125/1000 MS	7×150 A	2,000×800×2,000
1,200			PBI 125/1200 MS	8×150 A	2800×800×2,000
1,500			PBI 125/1500 MS	10×150 A	3400×800×2,000
10	220	3×400 or 230 (for modules with output current max. 25 A)	PBI 220 / 10 MS	1×10 A	600×800×2,000
20			PBI 220 / 20 MS	1×20 A	
25			PBI 220 / 25 MS	1×25 A	
30			PBI 220/30 MS	1×30 A	
50			PBI 220/50 MS	1×50 A	
				2×25 A	
60			PBI 220 / 60 MS	1×60 A	
				2×30 A	
75			PBI 220/75 MS	1×75 A	
80			PBI 220/80 MS	1×80 A	
100			PBI 220 / 100 MS	1×100 A	
				2×50 A	
150			PBI 220 / 150 MS	2×75 A	800×800×2,000
200			PBI 220 / 200 MS	2×100 A	
300			PBI 220/300 MS	3×100 A	
400			PBI 220 / 400 MS	4×100 A	1,800×800×2,000
500			PBI 220/500 MS	5×100 A	
600			PBI 220 / 600 MS	6×100 A	
700			PBI 220/700 MS	7×100 A	2,600×800×2,000
800			PBI 220/800 MS	8×100 A	
900			PBI 220/900 MS	9×100 A	
1,000			PBI 220 / 1000 MS	10×100 A	4,600×800×2,000
1,100			PBI 220 / 1100 MS	11×100 A	
1,200			PBI 220 / 1200 MS	12×100 A	
1,300			PBI 220 / 1300 MS	13×100 A	5,200×800×2,000
1,400			PBI 220 / 1400 MS	14×100 A	
1,500			PBI 220 / 1500 MS	15×100 A	

* – for rectifier cabinets with ZPP, the overall dimensions may be lesser than the ones provided in the table;

** – add the height of the pedestal to the height of the device: by standard, 100 mm.

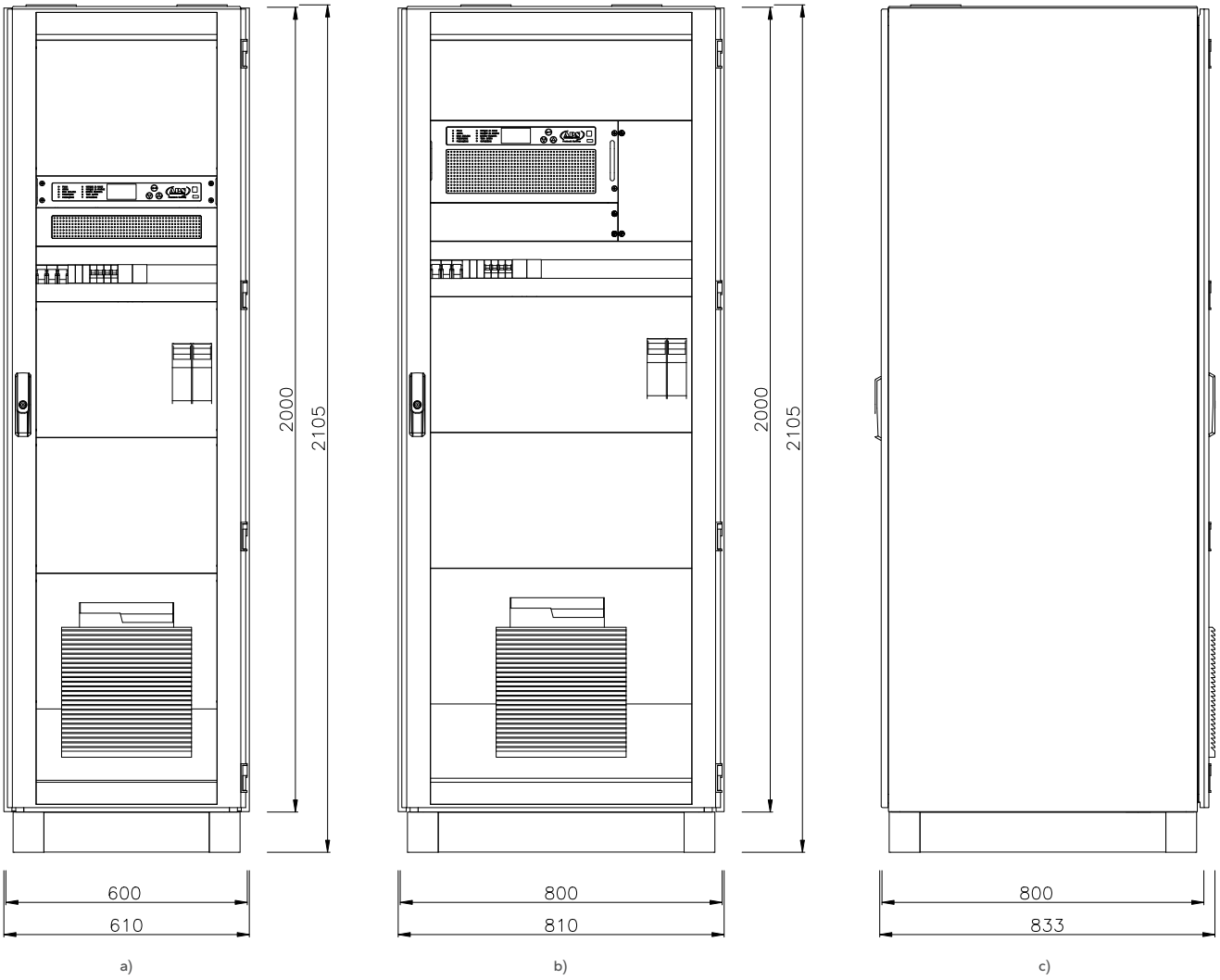


Fig. 15. Views with dimensions of the PBI type rectifier cabinet:
a) 600×800×2,000 cabinet – front view; b) 800×800×2,000 cabinet – front view; c) cabinet of depth of 800 mm – left-side view.

COMPACT DESIGN RECTIFIERS

This chapter presents the PBI type rectifiers in a compact form. They are intended for installation on a substrate (CS standing compact) or on a wall (CW wall-mounted compact). The main task of a rectifier is to continuously supply loads with a guaranteed DC voltage.

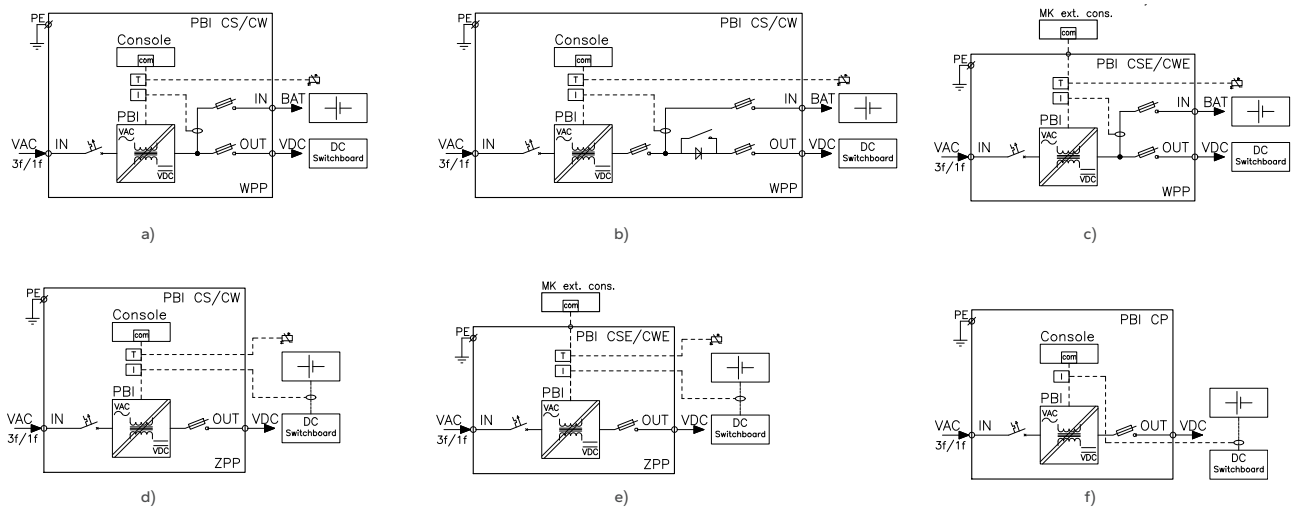


Fig. 16. Block diagram of the PBI type rectifier compact for autonomous operation:
a) a system with WPP; b) a system with WPP and a counter cell; c) a system with WPP and an external MK console;
d) a system with ZPP; e) a system with ZPP and an eternal MK console; f) a portable compact system.

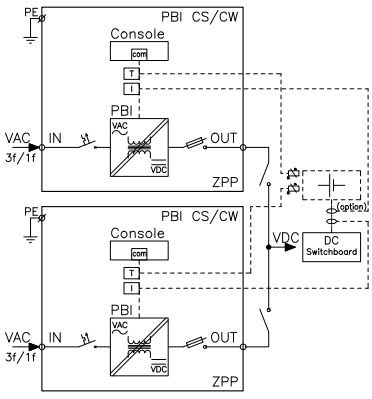


Fig. 17. Block diagram of the PBI type rectifier compact for parallel operation – a system with ZPP.

The PBI rectifier compact is intended for supplying loads in cooperation or without cooperation with the battery.

Compacts with a built-in console are presented in Fig. 16 a), b), d), f), while compacts with an external MK console are presented in Fig. 16 c), e).

The rectifier converts alternating current to direct current of a value according to the order. The galvanic isolation of the rectifier's output voltage from the AC supply voltage of the rectifier is ensured by the high-frequency isolating transformer located in the mains converter.

The devices may operate autonomously (Fig. 16) or in parallel (Fig. 17).

When the rectifier is only used to supply loads with an output DC voltage, this device will be configured without functions related to the battery.

The compact is cooled by a forced air circulation via fans. RPM of fans is adjusted seamlessly in the external temperature function of the device, significantly increasing their lifetime.

The PBI CP type rectifier compact is a special case – Fig. 16 f). This is a rectifier usually used for service purposes. By design, it is a portable version of the compact enclosure, having an ejected handles and wheels that ensure comfortable transport. You may set any output voltage in the range from 0 V to the rated value of the power supply. Similarly to the standard battery rectifiers, it features a battery charging thermal compensation and other functions present in the standard version.

SERIES TYPE: RECTIFIER COMPACTS 10 ÷ 350 A FOR AUTONOMOUS AND PARALLEL OPERATION

Rated output current, [A]	DC rated output voltage, [V]	AC rated input voltage, [V]	Example type	Enclosure dimensions**
25 / 30 / 50	24	3×400 or 230	PBI 24/25 CS*	CS4 / CW4 / CS7 / CW7
75 / 100			PBI 24/75 CS*	CS4 / CW4 / CS8 / CW8
150		3×400	PBI 24/150 CS*	CS4 / CW4 / CS8
200 / 250 / 300 / 350			PBI 24/200 CS*	CS6 / CW6
25 / 30 / 50	48	3×400 or 230	PBI 48/25 CS*	CS4 / CW4 / CS7 / CW7
75 / 100		3×400	PBI 48/75 CS*	CS4 / CW4 / CS8 / CW8
150			PBI 48/150 CS*	CS6 / CW6 / CS8
25 / 30 / 50	60	3×400 or 230	PBI 60/25 CS*	CS4 / CW4 / CS7 / CW7
75 / 100		3×400	PBI 60/75 CS*	CS4 / CW4 / CS8 / CW8

SERIES TYPE: RECTIFIER COMPACTS 10 ÷ 350 A FOR AUTONOMOUS AND PARALLEL OPERATION – CONTINUED

Rated output current, [A]	DC rated output voltage, [V]	AC rated input voltage, [V]	Example type	Enclosure dimensions**
10 / 20 / 25 / 30 / 50	110	3×400	PBI 110/10 CS*	CS4 / CW4 / CS7 / CW7
10 / 20 / 25 / 30 / 50		230	PBI 110/10 CS*	CS4 / CW4 / CS8 / CW8
60 / 75 / 80 / 100		3×400	PBI 110/60 CS*	
10 / 20 / 25 / 30	125	3×400 or 230	PBI 125/10 CS*	CS4 / CW4 / CS7 / CW7
50		3×400	PBI 125/50 CS*	
50		230	PBI 125/50 CS*	CS4 / CW4 / CS8 / CW8
60 / 75 / 80		3×400	PBI 125/60 CS*	
10 / 20	220	3×400 or 230	PBI 220/10 CS*	CS4 / CW4 / CS7 / CW7
25			PBI 220/25 CS*	CS4 / CW4 / CS8 / CW8
30 / 50		3×400	PBI 220/30 CS*	CS4 / CW4 / CS8 / CW8
60 / 75 / 80 / 100			PBI 220/60 CS*	CS6 / CW6
25	400		PBI 400/25 CS*	CS4 / CW4 / CS8 / CW8
50 / 60			PBI 400/50 CS*	CS6 / CW6

* – possible options: CS / CSE / CW / CWE;

** – CS4: 400×(2×600)×250; CS6: 500×(2×700)×250; CS7: 600×(2×600)×300; CS8:600×(2×800)×300; CW4: 400×600×250; CW6: 500×700×250; CW7: 600×600×300; CW8:600×800×300. (W×H×D)

SERIES TYPE: RECTIFIER COMPACTS 10 ÷ 50 A FOR SERVICE OPERATION

Rated current, [A]	DC rated output voltage, [V]	Example type	Enclosure dimensions*
50	from 24 to 220	PBI 24-220/50 CP	CP

* – CP: 400×600×250. (W×H×D).

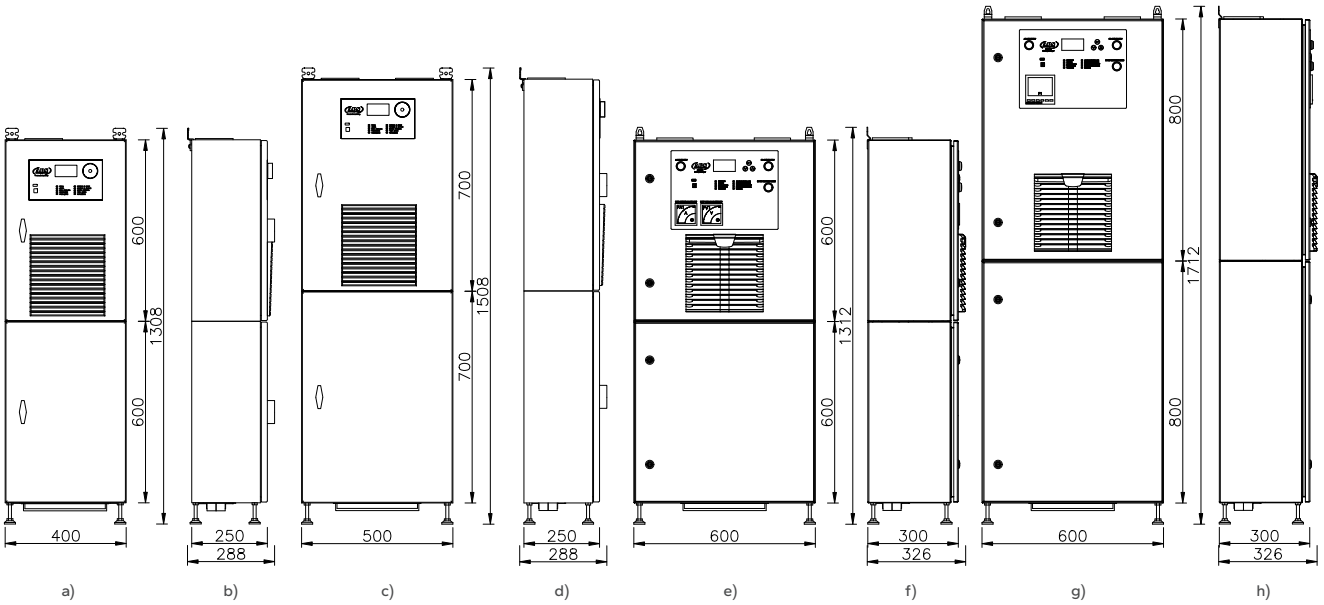


Fig. 18. Views with the dimensions of the PBI type rectifier compact (standing enclosure):
a) CS4 compact – front view; b) CS4 compact – left-side view; c) CS6 compact – front view; d) CS6 compact – front view;
e) CS7 compact – front view; f) CS7 compact – left-side view; g) CS8 compact – front view; h) CS8 compact – left-side view.

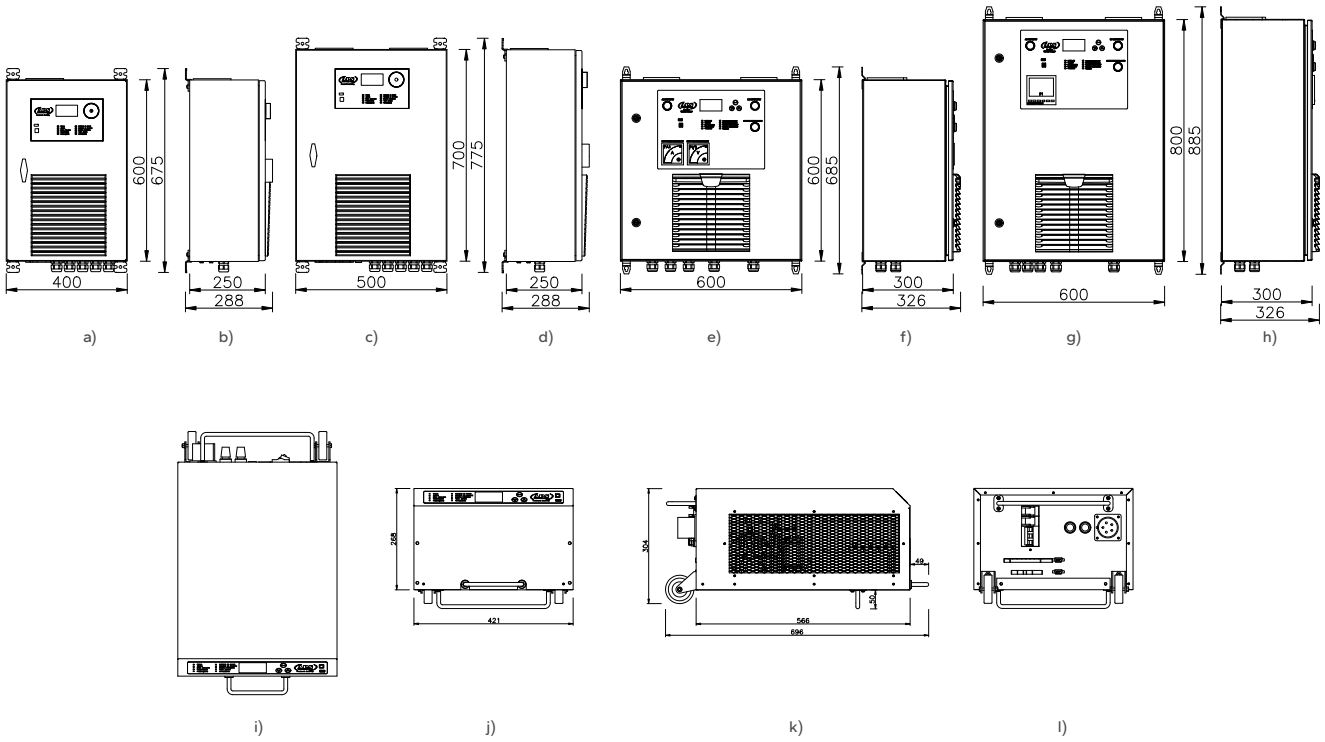


Fig. 19. Views with the dimensions of the PBI type rectifier compact (wall-mounted and portable enclosure):
a) CW4 compact – front view; b) CW4 compact – left-side view; c) CW6 compact – front view; d) CW6 compact – left-side view; e) CW7 compact – front view; f) CW7 compact – left-side view; g) CW8 compact – front view; h) CW8 compact – left-side view; i) CP compact – top view; j) CP compact – front view; k) CP compact – left-side view; l) CP compact – back view.

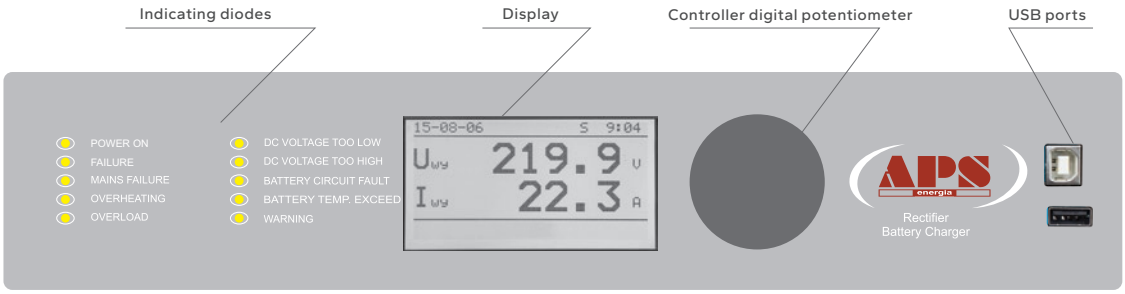
EXTERNAL COMMUNICATION – DIRECT CURRENT SYSTEMS

The rectifiers and DC converters are equipped with an extensive communication system with the user and master systems – HMI (Human Machine Interface).

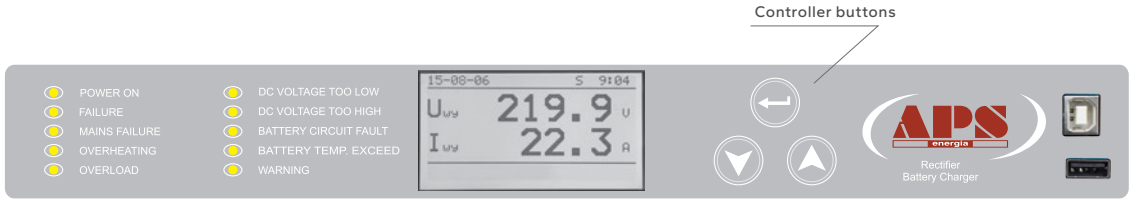
The communication system consists of:

1. A local user panel with an indicator diode system, an LCD screen for displaying messages and reading parameters, and a digital potentiometer or cursors for navigating the console menu.
2. A set of potential-free relay contacts for binary signals.
3. External communication links. Data transmission via RS485, Ethernet and USB ports (reading the archive buffer) is possible.

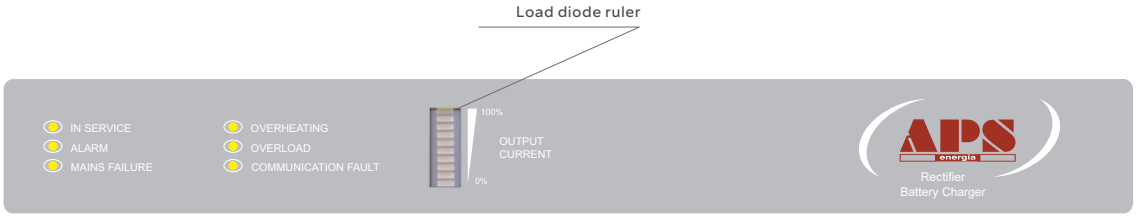
LOCAL USER PANEL



View of the console with a digital potentiometer



View of a console with navigation cursors



View of the console without a display, for modules in multi-module systems and with a separate controller.

SIGNALLED ALARMS ON THE LCD OF THE PBI RECTIFIER

output voltage is too low;	earth fault + warning;
output voltage is too high;	earth fault – warning;
voltage of loads is too low;	earth fault meter error;
voltage of loads is too high;	battery temperature is too high;
deep discharge of the main battery;	battery temperature is too low;
deep discharge of the booster battery;	rectifier temperature is too high;
deep battery discharge;	module failure;
module power supply failure;	failure;
power supply failure;	module overheating;
no power supply to the module;	overheat;
no power supply;	overload;
battery circuit discontinuity;	no communication;
damage of the battery temperature sensor;	fan fault;
earth fault + alarm;	no parallel communication;
earth fault – alarm;	XIN fuse tripping.

THE PBI RECTIFIER'S MEASURED PARAMETERS

output voltage;
battery current;
rectifier current;
battery temperature.

PARAMETERS MEASURED FOR THE "SELF-TEST" FUNCTION OF THE PBI RECTIFIER

by carrying out the self-test, the user obtains information about the internal and intermediate parameters responsible for proper operation of the device, such as:
current measurement transducers internal supply voltage;
processors supply voltages;
compliance of the measurements with the measurement range.

INTEGRATED RS485, USB, ETHERNET COMMUNICATION INTERFACES

RS485 LINK

RS485 is wired interface used in industrial networks. The basic advantage of data transmission via the RS485 bus bar is resistance to external distortions (e.g., of induction equipment, such as motors). The RS485 standard allows to connect many transmitters and loads (up to 32). The range of this standard is approx. 1,200 m.

The RS485 link of the rectifier features APS6000, Modbus RTU, IEC 60870-5-103 transmission protocols. They allow reading a complete set of data from the device.

By use of an external converter, it is possible to transmit data in the Profibus DP protocol and other protocols.

USB LINK

In the APS devices, the USB link is used to copy archive buffers saved during operation.

The USB port (A) is used to connect mass memory (USB flash drive).

The USB port (B) operating in the mass memory mode (mass storage device); after connecting it to a PC, it is shown as an additional drive.

ETHERNET LINK

Ethernet (IEEE 802.3) is the most commonly used technology in local networks (LAN). This interface allows connecting the device to a local computer network in the facility, and thus easily reading data even from several stations at the same time.

The Ethernet interface may be implemented by application of an additional converter, ensuring transmission using one of the following protocols:

- IEC 61850 (APS SAN KP1 converter)
- SNMP (AGENT- APS2)
- Modbus TCP.

Storage of events and states of the operation of the device on an SD card

A 2GB internal memory card stores data stored in the events buffer and the archive buffer. Lack of a card makes saving logs impossible and is indicated on the display by "SD" symbol.

Copying data to a FLASH memory stick:

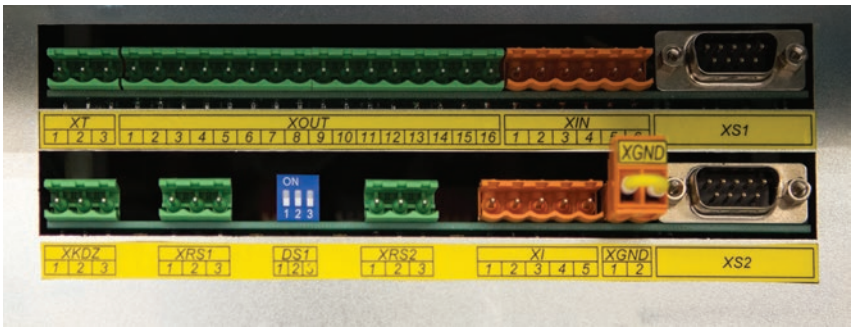
USB 2.0 ports enable communication between the power supply and the computer system or transferring alarm logs to a FLASH portable memory (USB flash drive).

The USB type port (B) sends archive data directly to a PC

The USB type port (A)

THE PBI RECTIFIER BINARY SIGNALS

INPUT BINARY SIGNALS:	OUTPUT BINARY SIGNALS:
charging interlock	general alarm 1
rectifier operation interlock	general alarm 2 (configurable)
fuse tripping	no power supply
DC +24 V auxiliary supply	output voltage is too high
	output voltage is too low
	battery circuit discontinuity
	correct operation
	alarm 8 (configurable)
	earth fault (option)



Connection panel of the PBI MC type rectifier

THYRISTOR RECTIFIERS

The PBI T systems are designed in a way to meet strict quality standards and reliability criteria for operation in difficult operating conditions, including the requirements related to operation of devices in nuclear plants. The topology of the PBI T rectifier allows designing rectifiers of high output power. The power supply is equipped with 12-pulse or 6-pulse thyristor rectifier with a transformer. The rectifier draws current of characteristics similar to a sinusoid from the mains (in 12-pulse version – lob content of THDi disruptions).

THE PBI T TYPE THYRISTOR RECTIFIER CHARACTERISTICS:

- IGBT technology with a DSP microprocessor controller;
- three operation modes (buffer, automatic, manual);
- high stability of voltages and output currents;
- charging algorithm (as per DIN 41773), for various types of batteries;
- low level of current ripple and voltage on the output;
- battery current control;
- battery temperature control;
- integrated communication RS485, USB interfaces;
- wide selection of external communication protocols: Modbus RTU, IEC 60870-5-103. Type of the protocol selected in the control menu panel;
- electromagnetic compatibility (EMI filters);
- option of parallel operation of the rectifiers;
- galvanic isolation from the mains;
- archiving of events and operating states (SD card);
- anti-seismic design;
- natural (convection) or forced (fans) cooling.

Views of the PBI T type thyristor rectifier's cabinet

DESCRIPTION OF OPERATION OF THE PBI T RECTIFIER

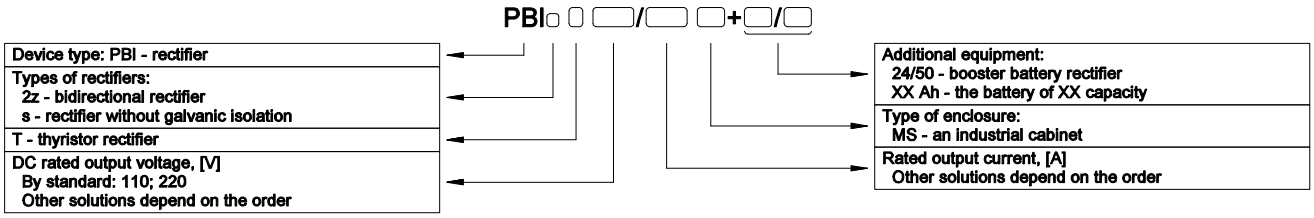
Buffer operation	The device supplies the battery and/or loads with voltage of high degree of stability and the required value (most often 2.23 V/cell). The buffering voltage is compensated thermally by a thermal probe (positioned in the vicinity of the supplied battery) present in the standard equipment. The output voltage of the power supply adapts itself to the needs of the battery, maintaining the fully charged state. During buffer operation, the continuity of the battery's circuit is cyclically checked.
Automatic charging (automatic mode)	This function is used in the case of partial or complete discharge of the battery (e.g., as a result of supply voltage break), when the battery must be quickly charged. The power supply will automatically charge the battery to 2.4 V/cell.
Supervised charging (manual mode)	This mode is used in the case of cooperation with open acid batteries, when there is a need to carry out an additional equalising charging to 2.7 V/cell. This charging process must be carried out strictly according to the guidelines of the manufacturer of the battery and always in the presence of the operating personnel.

OPERATION MODES PARAMETERS

Factory settings

Operation mode	Lead-acid batteries	Ni-Cd batteries	Adjustment range
Buffer mode (Float mode)	2.23 V/cell	1.41V/cell	0.8–2.4 V/cell
Automatic charging (Boost mode)	2.40 V/cell	1.50 V/cell	0.8–2.7 V/cell
Supervised charging (Equalising mode)	2.70 V/cell	1.80 V/cell	0.8–2.7 V/cell

METHOD OF DESIGNATION OF THE PBI T TYPE THYRISTOR RECTIFIERS



THE PBI T TYPE THYRISTOR RECTIFIERS – TECHNICAL CHARACTERISTICS – STANDARD PARAMETERS

PARAMETER	VALUE
AC INPUT*	
Three-phase input voltage	380 / 400 / 415 V
Input voltage tolerance	-15 % to +10 % (±15 % for 380 V)
Frequency of input voltage	50 / 60 Hz
Input voltage frequency tolerance	±8 %
DC OUTPUT	
Output voltage	110 / 220 V*
Output voltage stability**	±1 %
Output voltage ripple****	±2 %
Range of correction of the buffer charging voltage	between -10 and +50 °C
Temperature compensation of the buffer charging voltage**	0 to 10 mV/°C/cell
Rated output current	25 to 1,500 A
Overload capacity	1,2×In for 5 sec
Output current stability***	±1 %
Output current ripple***	±2 %
Battery charging characteristics	IU as per DIN 41773
Total efficiency	>91 % for 110 V; >93 % for 220 V
Available menu language versions	PL | EN | CZ | RU
OPERATING ENVIRONMENT	
Operating temperature (EN 50178 class 3k3)	+5 to +40 °C*
Storage temperature (EN 50178 class 1k4)	-25 to +55 °C*
Humidity (EN 50178 class 3k3)	5 to 85 % (non-condensing)*
Access to the device	operation and maintenance from the front*
Cable entry	from the bottom / from the top*****
Maximum height above the sea level without change of the rated parameters	1,000 m ASL

* – it is possible to design different parameters upon agreement with the manufacturer;
** – buffer operation, voltage regulator;
*** – battery charging, current regulator;
**** – at resistance load;
***** – only for installation in an industrial cabinet (MS enclosure type).

THREE-STAGE I_1 U_1 U_2 BATTERY CHARGING TECHNIQUE

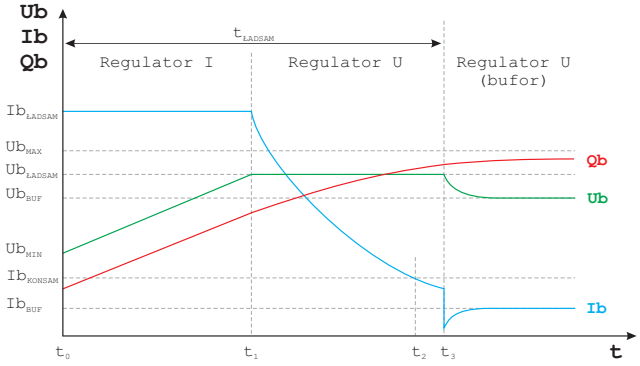
In the case of discharge of the battery, the PBI rectifier will automatically activate the quick charging mode. The charging parameters are configured in the memory of the rectifier in accordance with the requirements of the producer of the battery of a given type. The charging has three stages:

- 1st phase – direct current charging I_1 (the first limit parameter): This charging includes limitation of the battery charging current na; the rectifier gradually increases the battery voltage to not exceed the recommended charging current (most often, limitation at the level of current I_1 = 5 to 10-hour charging (I_{C10}));
- 2nd phase – direct current charging U_1 (the second limit parameter): The battery is partially charged after the first phase of charging, there is no risk that the increase of the charging voltage will exceed the set battery current I_1, the second limit parameter works, the allowed (maximum voltage at the DC bus due to loads or due to the battery) voltage U_1. Completion of the 2nd phase of charging depends on the adopted algorithm. APS Energia SA uses the DBC method.
- 3rd phase – direct current charging U_2; the system has completed quick charging, and the rectifier switches to voltage U_2 = Ubuf buffer voltage.

The DBC is a charging method developed by APS Energia SA based on the experienced in production of buffer rectifiers and in strict cooperation with the manufacturers and users of batteries. The Dynamic Battery Charging (DBC) is a method which controls all charging parameters, and thus ensures quick replenishment of the battery's electric charge according to all recommendations of the producer of a given type of cell. The method consists of charging of the battery with voltage U1 in the second phase until the two following criteria are met at the same time:

- Criterion no. 1 – achievement of the set value (e.g., $0.2 \times I_{C10}$) by the dropping charging current – a configurable parameter;
- Criterion no. 2 – charging of the battery after the criterion no. 1 has been met for 30 minutes – a configurable parameter.

CHARGING CHARACTERISTICS



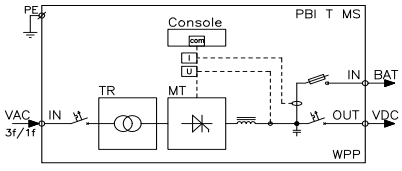
DBC model (*Dynamic Charge Characteristic*)

Configurable parameters:

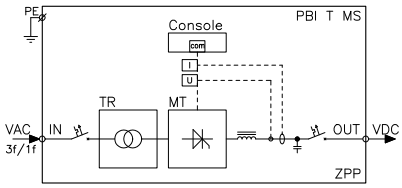
- charging current – Ib_{C10}
- maximum voltage – Ub_{MAX},
- recharge current – Ib_{DOL},
- automatic charging time – T_2.

KEY OF THE ABBREVIATIONS USED IN THE DIAGRAMS IN THE CHAPTER

BAT – battery	OUT – output
I – current measurement	TR – transformer
IN – power supply	VAC – alternating current (AC)
com – communication	VDC – direct current (DC)
MT – thyristor bridge	



a)



b)

Fig. 20. Block diagram of the PBI T type thyristor rectifier's cabinet:
a) a system with WPP; b) a system with ZPP

Fig. 20 presents a standard solution of the PBI T MS type thyristor rectifiers for free incorporation in the industrial cabinet. These systems are intended for supplying loads in cooperation or without cooperation with the battery. The functionality of the PBI T MS systems allows designing rectifiers of significant output power.
The thyristor rectifier converts alternating current to direct current of value according to the order. The galvanic isolation of the rectifier's output voltage from the AC supply voltage of the rectifier is ensured by the 50 Hz isolating transformer.

When the rectifier is only used to supply loads with an output DC voltage, this device will be configured without battery functions.
The industrial cabinet is cooled naturally or by a forced air circulation via fans. RPM of fans is adjusted seamlessly in the external temperature function of the device, which significantly increases their lifetime.

DESCRIPTION OF THE PBI T TYPE THYRISTOR RECTIFIER

Battery current measurement

The system measures the battery circuit current using a transducer. The transducer may be located inside the power supply (internal current measurement) or outside the power supply (external current measurement), e.g., in the user's distribution board or at the battery itself, on any pole.

Battery circuit continuity test

In the buffer operation state, the rectifier cyclically tests the continuity of the battery's circuit. The rectifier carries out the test by appropriately adjusting the voltage and measuring the current. After a positive test result, the rectifier's voltage goes back to the buffer voltage level. The test parameters are set in the rectifier's menu.

Charging interlock

Switching the rectifier into the "charging interlock" mode limits the current flowing to the battery at the 100-hour current level. This function is tripped by applying signal to the binary input. The charging interlock limits the current during the automatic charging and supervised charging.

Rectifier operation interlock

In this mode, the rectifier does not transfer energy from the mains to the loads and the battery, and only remains in the standby mode. The rectifier will start automatically after the "rectifier interlock" signal has been removed. This function is tripped by applying signal to the binary input.

Over-voltage protection of the load
When a voltage dangerous to loads is present for a time longer than 500 ms at the power supply's output, an over-current protection is activated to turn the rectifier off. This voltage is preset appropriately to the rated voltage of the power supply. After the excessively high voltage at the input ceases, the rectifier restarts.

Hysteresis of the power supply's alarm thresholds
All of the set alarm thresholds have a hysteresis that "deadens" the system at the limit of alarm tripping.

Battery voltage thermal compensation
The battery's buffer voltage changes with the temperature fluctuations. In accordance with the recommendations of the battery manufacturers, the battery's charging voltage thermal compensation is applied. The rectifier may carry out a procedure of automatic temperature compensation to adapt the battery's voltage to the environmental conditions.

Limitation of the battery charging current
The rectifier limits the battery's charging current to the value set by the user and expressed by the time in which we want to charge the battery. During the supervised charging, the current is limited to the value set by the personnel when configuring the supervised charging parameters.

Control of the resistance of the earth fault insulation of the SAN 2-0
The rectifier may be equipped with a microprocessor system that controls the SAN 2-0 earth fault. The earth fault control system is intended for measuring the value of the insulation resistance in the direct current installation circuits (the battery's poles ground faults control). The device measures and signals a drop of the symmetrical and asymmetrical resistance. A drop of the value of resistance below the warning or alarm threshold is signalled in the status of the device and trips relevant alarm relays.

Auto-restart
The PBI rectifiers are equipped with an auto-restart function when the power supply voltage appears, if a power supply voltage break caused the rectifier to turn off.

Data archiving
The events buffer is an area in the permanent memory of the rectifier, in which all alarm events, including date and time, are saved.

The archive buffer is an area of the permanent memory of the rectifier, in which measurement series are stored with an interval set by the user.

USB 2.0 ports enable communication between the power supply and the computer system or transferring alarm logs to a FLASH portable memory (USB flash drive).

Communication with the user
Communication between the user and the device (HMI, Human Machine Interface) may take place both locally and remotely.

Locally, using the console (keyboard, LCD, indicating diodes), located on the front side of the device. Electrical parameters are displayed constantly, regardless of the selected operation mode. Alarm states are indicated using diodes and the display. Additionally, a sound signal is generated, which informs about an emergency situation.

Remotely, using the binary inputs and outputs, as well as communication ports.

You may assign different functions to the binary inputs to change the operation of the rectifier (via the rectifier's menu).

RS485, USB, LAN transmission communication ports.

Available transmission protocols:

- selected from the controller's menu: APS6000, Modbus RTU, IEC 60870-5-103;
- available with the converter: IEC 61850, PROFIBUS DP, SNMP, Modbus TCP.

THE PBI T TYPE THYRISTOR RECTIFIER EQUIPMENT

POWER SUPPLY SYSTEM:

12-pulse transformer,

Two 6-pulse thyristor bridges,

DSP microprocessor controller (DC-DEV):

- Control of the pulse converter;
- Monitoring functions;
  - selection of the operating mode (automatic charging or buffer operation);
  - correction of the voltage value depending on the battery's temperature;
  - limitation of the battery's charging current to the set value;
  - generation of alarm signals;
- Local communication – issues and receives signals from the user's console;
- Communication with external monitoring systems via RS and Ethernet links.

Console (AR-CON)
It consists of an LCD, LED synoptic, and a three-button keyboard or a digital potentiometer. The console provides information about the state of the battery and operation of the rectifier, as well as allows making changes in the power supply settings.

Connection terminal
It consists of connections of power and output lines appropriate for the designed current and the projected wiring.

Protection fields
Includes over-current and over-voltage protections.

Analogue meters
Used to measure currents and output voltages in the first precision class.

Binary signals terminal
The PBI T rectifier is equipped with binary inputs and outputs, as well as auxiliary voltage sources to apply signals to those inputs. Potential-free contacts transfer binary information about the state of the device, operating conditions, and alarms. You may assign different functions to the binary inputs to change the operation of the inverter and the rectifier. The rectifier is equipped with two binary inputs.

Enclosure
The industrial cabinet of 600 mm or 800 mm width (or its multiple depending on the power). The structure of the cabinets is welded and protected against corrosion with metallic coatings and powder coating.

The battery current measurement system measures the battery's circuit current using the transducer on the pole of the battery's circuit.

INTERNAL PROTECTION AGAINST:

- increase of the voltage on the input;
- drop of the voltage on the input;
- supplying the rectifier with asymmetrical voltage;
- overheating of power systems (limitation of the output current without interrupting operation);
- increase of voltage on the thyristors;
- power surges caused by dynamic changes of the load;
- internal short-circuits;
- short-circuits at the loads;
- increase of the voltage on the output;
- excessive input ripple;

COOLING SYSTEM
Cooling air flows through the air intake in the lower part of the enclosure, and then via convection flows towards the upper part of the device, cooling the internal elements of the rectifier. Hot air flows out of the device through vents located at the top of the enclosure.

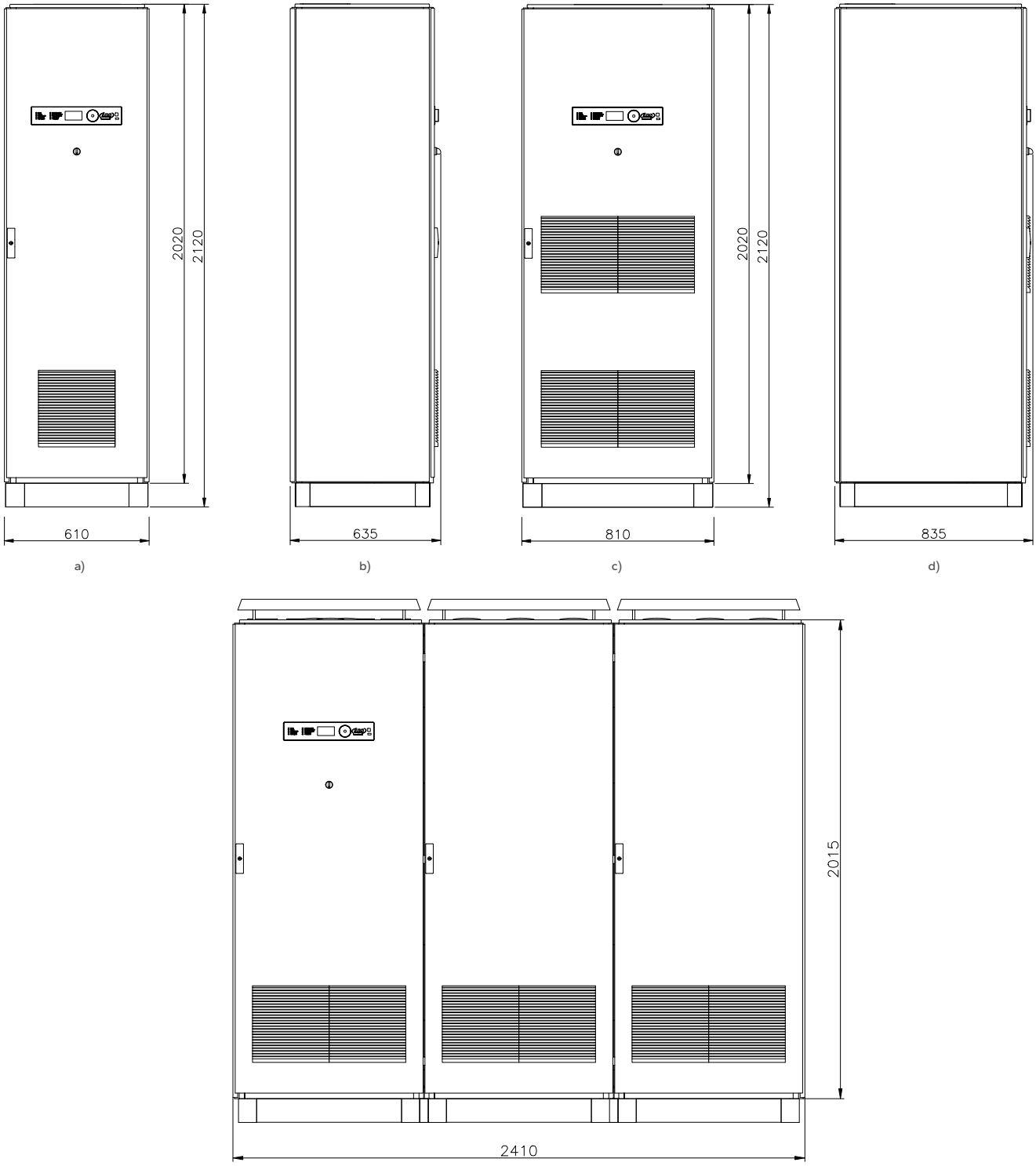
ADDITIONAL OPTIONAL EQUIPMENT FOR THE PBI T THYRISTOR RECTIFIERS

Special designs	Upon request, it is possible to adapt the devices to special requirements in relation to: • greater DC rated currents; • standard of voltages and frequencies of AC power supply: (110 / 190 V, 115 / 200 V, 120 / 208V, 127/220 V, 50 / 60 Hz); • level of the DC output voltages; • extension of the range of input voltages; • environmental requirements related to ambient temperature (-20 °C ÷ +55 °C), presence of aggressive factors, etc.; • enclosure design, including seismic resistant designs, IP degree of protection, design of the bus bars, access to the cables from the top, coating colour, etc.; • measurements and communication: digital or analogue meters of appropriate class, indication of states, visualisation of operating modes, synoptic of connections, communication protocols, etc.
ATSE system	The automatic transfer switching equipment (ATSE) decides about the selection of the source of power for a device. During presence of the voltage of the source no. 1, the rectifier is supplied by it. In the case of break (complete or one of the phases of the source no. 1), the ATSE automatically switches supply of the rectifier to the source no. 2.
Automatic load disconnection	The PBI T rectifier may be equipped with a contactor that disconnects loads when the battery's voltage drops below the value set by the "load disconnection" parameter. The loads will remain disconnected until the rectifier's voltage reaches the level above the "connection of loads" parameter.
Parallel operation of rectifiers	This option provides equal output currents of rectifiers that generate common load. It is possible for two PBI T type rectifiers to operate in parallel.
Booster battery connecting system	The PBI T rectifiers may be equipped with a booster battery connecting system in a series with the main battery. Connection takes place without interruptions (from the point of view of loads). The booster battery is connected after the voltage of the main battery drops to the specified level, and is disconnected when the voltage of the main battery increases. tripping and disconnection take place automatically. The booster battery may be connected to the positive or negative pole of the main battery (depending on the design).
Counter cell system	The counter cell consists of diodes connected in series and bypassed by the contactor's pin. This is a system that allows lowering of voltage in DC loads. Voltage on the load bus is reduced by activation of the serial diode stack at the output of the loads. When the battery's voltage drops (e.g., when the rectifier turns off), the contactor closes the shunt circuit, and the diode stack is bypassed. The voltage of loads is equal to the voltage of the battery. The counter cell system may be controlled based on the power supply voltage break or drop of the battery's voltage.
Cable entry from the top	It is possible to design the enclosure in a way to allow cables entering from the top.

SERIES TYPE: THYRISTOR RECTIFIER CABINETS 50 ÷ 1500 A FOR AUTONOMOUS AND PARALLEL OPERATION

Rated output current, [A]	DC rated output voltage, [V]	AC rated input voltage, [V]	Example type	Min. dimensions of the enclosure [W×D×H*], [mm]
100	110	3×400	PBI T 110 / 100 MS	600×600×2,000
200			PBI T 110 / 200 MS	
300			PBI T 110/300 MS	800×800×2,000
400			PBI T 110 / 400 MS	
500			PBI T 110/500 MS	
600			PBI T 110 / 600 MS	1,400×800×2,000
800			PBI T 110/800 MS	
1,000			PBI T 110 / 1000 MS	
1,200			PBI T 110 / 1200 MS	1,800×800×2,000
1,500			PBI T 110 / 1500 MS	
50	220		PBI T 220/50 MS	600×600×2,000
100			PBI T 220 / 100 MS	
200			PBI T 220 / 200 MS	800×800×2,000
300			PBI T 220/300 MS	
400			PBI T 220 / 400 MS	
500			PBI T 220/500 MS	1,600×800×2,000
600			PBI T 220 / 600 MS	
800			PBI T 220/800 MS	
1,000			PBI T 220 / 1000 MS	1,800×800×2,000
1,200			PBI T 220 / 1200 MS	
1,500			PBI T 220 / 1500 MS	2,400×800×2,000

* – add the height of the pedestal to the height of the device: by standard, 100 mm.



a) b) c) d)

e)

Fig. 21. Views with the dimensions of the PBI T type thyristor rectifier cabinet:
a) 600×800×2,000 cabinet – front view; b) cabinet of depth of 600 mm – left-side view;
c) 800×800×2,000 cabinet – front view; d) cabinet of depth of 800 mm – left-side view;
e) examples of a cabinet of width of 2,400 mm – front view.