SALTEK®

Overvoltage controlled. ANYWHERE.

Voltage limiting devices (VLDs)

PVL-1000-120-R01(-O) (class 4.1)
PVL-1000-060-R01(-O) (class 4.2)
PVL-1000-045-R01(-O) (class 4.2)

Installation and Usage Instructions

These Installation and Usage Instructions contain the information necessary for proper installation, commissioning, operation and maintenance of the product. If further detailed information regarding the usage and servicing of the product is required, contact the manufacturer or its representative.

C17013.02/20260127

Table of Contents

1 General provisions, definitions....4
1.1 Manufacturer´s declaration....4
1.2 Abbreviations, acronyms, terms and definitions....4
2 Safety....4
2.1 Use of the product, expertise of persons....4
2.2 Symbols nad important instructions....4
2.2.1 Symbols used in the text....4
2.2.2 Symbols used on the device....4
2.3 Safety precautions....5
3 Description of the product and its variants....5
3.1 General description of the product....5
3.2 Dimensions....5
3.3 Control elements, controls....6
3.4 Internal arrangement....6
3.5 Design options....7
4 Transport and storage....7
5 Mechanical assembly, electrical connection, installation check....8
5.1 Mechanical assembly....8
5.2 Electrical connection....8
5.2.1 Connecting the protected system....8
5.2.2 Connecting the power supply....9
5.2.3 Connecting the LAN communication cable....9
5.2.4 Interconnection between the EARTH and PE terminals (cabinet frame)....10
5.3 Installation check....10
6 Description and principles of the function (basic description of the algorithm, factory settings, user settings)....10
6.1 VLD block diagram and description of its functional parts....10
6.2 Description of the control algorithm.....12
6.3 Factory settings of the PVL product....13
6.3.1 Switching voltage....13
6.3.2 Reaction (response time) of the main contactor (changes possible by software settings)....13
6.3.3 Parameterization of the main contactor switching depending on the temperature of the BVL thyristor heatsinks....14
6.3.4 Indication of overcurrent and overvoltage....14
6.3.5 Cooling fan switching....14
6.3.6 User settings....14
7 Commissioning (putting into operation)....14
8 Manual control, remote control, automatic operation mode....14
8.1 Manual control....14
8.2 Remote control and monitoring of VLD....16
9 Events and their monitoring (logs, communication with SCADA system, default MODBUS settings, registered operational and fault events and variables)....16
10 Identification and troubleshooting of operational faults....17
11 Maintenance....18
12 Technical data....19

1 General provisions, definitions

1.1 Manufacturer´s declaration

The manufacturer declares that if the product is used in a manner other than that specified in this manual, the product may malfunction or be damaged or destroyed. When installing and using the product, the legal requirements or the provisions of the technical standards for wiring must be observed. The manufacturer accepts no liability for any direct or indirect damage caused by using the product in a manner other than that specified in these instructions, or by handling the product in violation of the technical standards specified. Any use or connection of the product other than the procedures and connections specified in this manual is considered incorrect and the manufacturer shall not be held liable for any consequences caused by such actions. Furthermore, the manufacturer shall not be liable for damage or destruction or loss of the product caused by improper placement, improper installation, improper operation, acts of God, or as a result of tampering with the product, which includes, for example, replacement of parts, rewiring of the circuit, or modification of the control algorithm. The manufacturer provides no warranty for loss or corruption of data. The manufacturer assumes no liability for damages caused by product failure.

The Declaration of Conformity / Product Safety Assurance can be downloaded from the manufacturer‘s website at www.saltek.eu.

1.2 Abbreviations, acronyms, terms and definitions

SALTEK PVL products have been developed, manufactured and tested in accordance with the requirements of European standards, in particular EN 50122-1, EN 50526-2 and EN 50526-3. Definitions, abbreviations and technical terms used in this manual are based on these standards.

2 Safety

2.1 Use of the product, expertise of persons

The PVL-1000-...-R01(-O) product is intended for limiting dangerous touch voltages especially in railway DC power supply systems with nominal voltage of up to 3 kV. Persons authorised to install, commission, operate and maintain it must have the necessary electrical qualifications, be familiar with the function of the product and its installation in the railway power supply and protection system. Unauthorised and improper handling of the product can cause serious damage to property, health and life of persons.

2.2 Symbols nad important instructions

2.2.1 Symbols used in the text

Pay close attention to information marked with the following pictograms:

Important information to ensure the correct functioning of the product and the safety of the product operator and persons who may come into contact with equipment protected by the product. If we want to avoid damage to property, railway infrastructure, health and life of persons, it is essential to follow all the instructions marked by this symbol.

Risk of electric shock. This symbol highlights important instructions that must be followed to prevent electric shock during product installation, operation and maintenance.

Reference to important information regarding the installation or operation of the product.

2.2.2 Symbols used on the device

The device is marked with the following safety and information pictograms:

Electrical device - hazardous voltage

The equipment may only be installed and operated by properly qualified and trained personnel.

Read the Installation and Usage Instructions before installing and handling the product.

The product must be disposed of in an environmentally friendly manner within the framework of electronic waste return collection.

The product complies with the relevant EU requirements.

The product complies with the relevant UK requirements.

2.3 Safety precautions

To ensure that the maximum level of protection is achieved, the following instructions must be followed:

- use the product only for the purpose for which it is intended
- use the product in accordance with the instructions given in the Installation and Usage Instructions, which must be made known to persons who operate, maintain and periodically check the function of the product
- prevent unauthorised persons from handling the product
- periodically check the correct functioning of the product
- in the event of damage to the product (e.g. excessive overloading, etc.), ensure that the damaged parts are replaced immediately by an expert or that the product is completely replaced by a faultless one
- observe the principles and standards of safe working on electrical equipment, in particular EN 50110 (or relevant national versions of the standard)
- before starting work on the product or the technology connected to it, the following must be performed:
  - disconnect the product from the power supply
  - ensure that the product cannot be inadvertently connected to the power supply during work
  - verify that no part of the product is live
  - ground the rail (short or cross-connect the leads leading to the RAIL and EARTH terminals)
  - secure parts that must remain energized so that live parts cannot be touched by working staff (or ensure that only a person having the authorization for working on energized equipment is involved in the performance of the works)
  - before starting the work, check that parts of the product are not hot due to its previous operation (i.e. risk of burns)
  - follow the rules for working on live equipment

3 Description of the product and its variants

3.1 General description of the product

The voltage limiting device (VLD) SALTEK of the PVL-1000-...-R01 (-O) series is a compact product supplied in a metal enclosure with IP 54 protection level, intended to be mounted on a wall or on a suitable frame or base. The enclosure is fitted with a lockable door for easy access to the individual parts of the product and for easy connection. A control display is located on the door for manual operation and display of VLD information. Connection terminals for the protected circuit, power supply and communication cables are accessible by opening the cabinet door. All cable connections are routed through bushings on the underside of the enclosure.

3.2 Dimensions

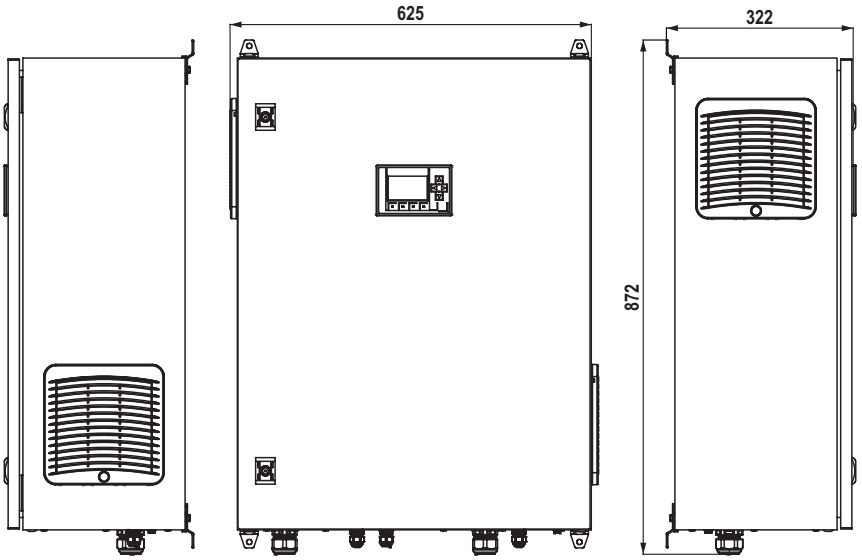

Fig. 1: Cabinet dimensions

3.3 Control elements, controls

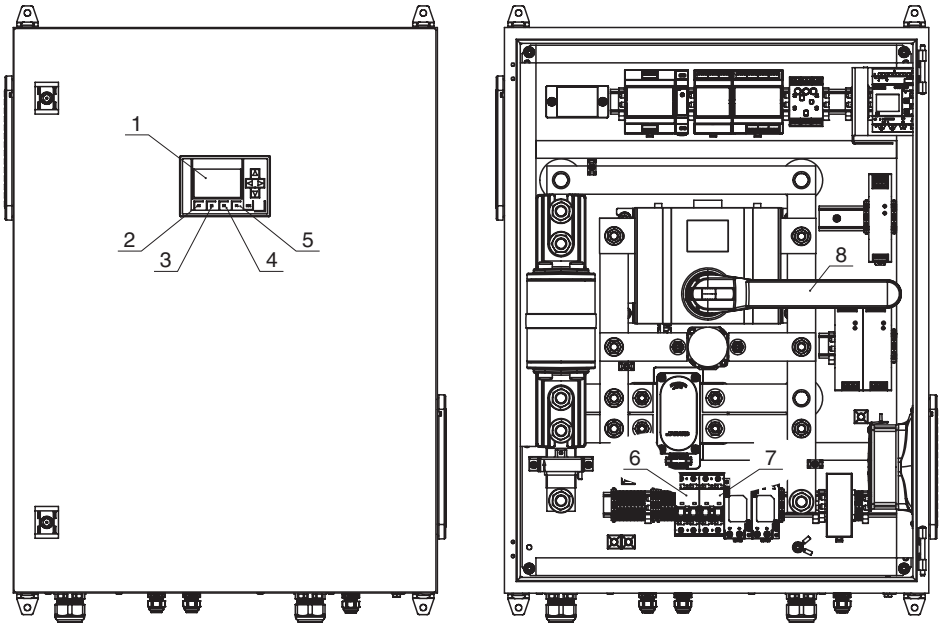

Fig. 2: Control elements

1	control display
2	RELAY ON/OFF (F1) button - switching on/off the main contractor
3	AUTOTEST (F2) button - start self-test
4	AUTO (F3) button - start automatic protection mode
5	BYPASS (F4) button - switch ON main contractor
6	B 10 A circuit breaker (FA1)
7	B 10 A circuit breaker (FA2)
8	manual short-circuiting device (only type PVL-1000-...-R01-O)

3.4 Internal arrangement

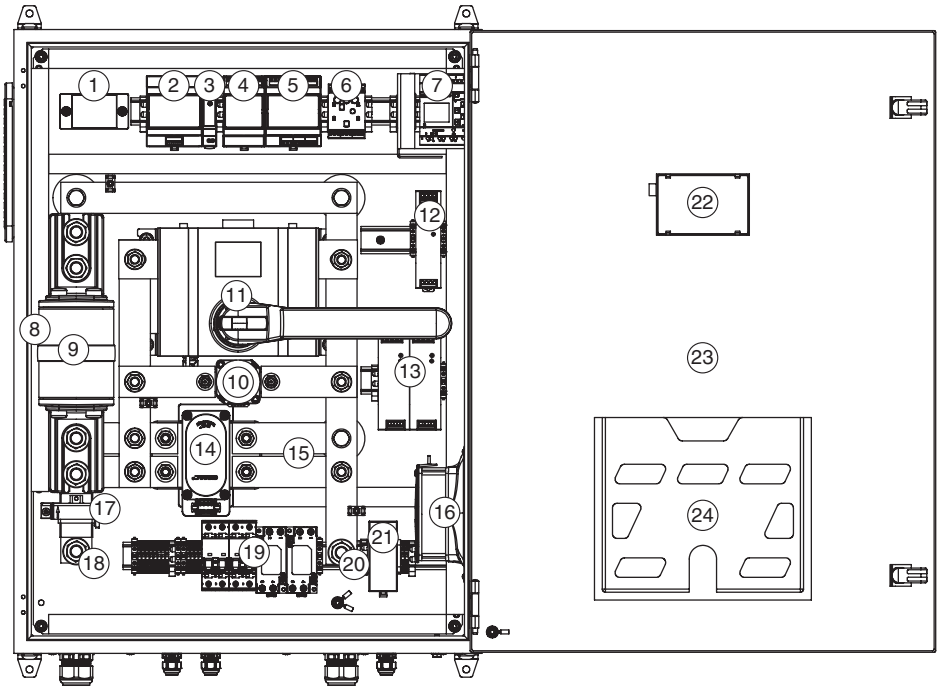

Fig. 3: Internal arrangement

1	PVL-ND voltage divider	13	90-264 V AC / 24 V DC power supply unit (2×)
2	PVL-U voltage separator	14	MAIN RELAY (main contactor)
3	DC/DC voltage converter	15	main power circuit
4	PVL-I current probe signal transducer	16	ventilator

5	PVL-T signal transducer of temperature sensors	17	current probe
6	24 V DC power supply terminal board	18	RAIL - main power circuit terminal (of the rail)
7	PLC controller	19	power supply inlet – terminal board, protection
8	temperature sensor with Pt100 (2×) sensing element	20	EARTH – main power circuit terminal (of the earthing)
9	integrated voltage limiter of 2.2 class (BVL-50-xxx)	21	Ethernet splitter with PVL-EO SPD
10	FAILSAFE RELAY (emergency relay)	22	control display
11	MANUAL BYPASS (manual short-circuiting device) – only type PVL-1000-...-R01-O	23	installation box with doors
12	power supply redundance module	24	document pocket

3.5 Design options

Type designation	Ordering number	Nominal triggering voltage U_{Tn}	VLD Class	Manual short-circuiting device
PVL-1000-045-R01-O	A07131	45 V	4.2	yes
PVL-1000-045-R01	A07134			no
PVL-1000-060-R01-O	A07132	60 V		yes
PVL-1000-060-R01	A07135			no
PVL-1000-120-R01-O	A07133	120 V	4.1	yes
PVL-1000-120-R01	A07136			no

4 Transport and storage

The product described is a sensitive electrical and electronic device. Do not expose it to shocks and do not exceed tne specified storage temperature and humidity ranges. The limit values for storage and transport of the product are:

Storage temperature range: –40 to +70 °C

Humidity range: 10 to 95 %, non-condensing

Protect the product from falling or tipping over! On receipt of the product from the carrier, check that the packaging is not damaged and shows no signs of dropping, bumping, etc. If you find any signs of damage, contact the carrier or distributor. In this case, only an employee authorized by the manufacturer or distributor can assess the possibility of installing and operating the product.

Any tipping or transport in a position other than that specified may cause damage to the product. The unpacked product can be stored only in a dry, ventilated and dust-free warehouse. When handling the product, take into account its weight and dimensions. Use appropriate handling equipment or arrange for more than one person to handle the product. After unpacking the product, allow for its temperature compensation for at least 2 hours at the place where it will be installed.

The manufacturer shall not be liable for any damage to the product caused during transportation, unless otherwise agreed in the delivery conditions.

After unpacking the product, check the completeness of the delivery. The basic delivery package includes:

- PVL-1000-xxx-R01(-O)
- Installation and Usage Instructions
- Installation material
- Connection material to be connected to the „RAIL“ and „EARTH“ terminals
- Quality check-out reportt

Do not install a product that has been subject to dropping or other visible damage, extreme temperatures or other influences that could result in damage to its electrical and electronic parts during transport! There is a risk of injury!

5 Mechanical assembly, electrical connection, installation check

5.1 Mechanical assembly

The product is mounted onto the wall (or on a suitable frame or base) using hanging brackets and the supplied installation material. The spacing of the mounting holes is shown in Fig. 1

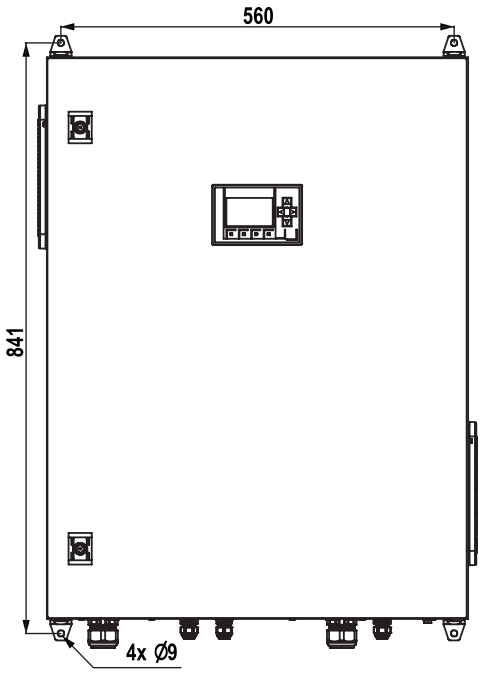

Fig. 4: Mounting holes

5.2 Electrical connection

ATTENTION! The product is connected to operating systems where dangerous voltages may occur on the parts to be connected! There is a risk of electric shock.

The electrical connection of the product and its incorporation into the system may only be carried out by a person with the necessary electrical qualifications and authorization for carrying out the specified works.

Before connecting the product to the protected system the following must be observed:

- disconnect the system to be connected from the power supply
- ensure that no one can arbitrarily connect the system to the power supply without the consent of persons performing the connection works
- verify that no electrical charge remains in the system (e.g. with a discharge rod)

Before connecting the product to the power supply, in particular the following activities must be carried out:

- verify that the power supply features the necessary parameters (voltage, protection level, etc.)
- disconnect the connection point from the mains before connecting the product
- verify that the connection point is de-energised
- verify/ensure that no back-up power supply (diesel generator, batteries, etc.) can react by restoring voltage to the connection point

5.2.1 Connecting the protected system

The protected system is connected to the VLD by means of two connection wires terminated with cable lugs (being not part of the delivery) according to Fig. 5. The DC traction return circuit (the track) is connected to the screw terminal marked with „RAIL“; the screw terminal marked „EARTH „ is connected either to the main equipotential busbar or to the ground point.

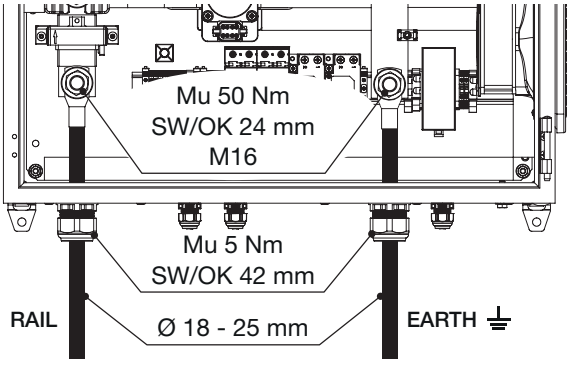

Fig. 5: Protected system connection (Mu – tightening torque, SW/OK – mounting wrench size)

The cross-section of the connecting cables is chosen depending on the expected mean and maximum current of the VLD, which can be determined from operational simulation using suitable software or operational tests. The ability to carry fault short-circuit currents shall also be taken into account when determining the appropriate cross-section of connecting cables. The recommended cross-sections of the connecting wires for standard operation are 95 mm^2 and the recommended tightening torque of the cable lugs to the terminals is 50 Nm.

The VLD is equipped with bushings for the connection of power cables of diameters ranging from 18 to 25 mm. The tightening torque of the bushing cap nuts is 5 Nm.

The installed connection cables must not put mechanical stress on the connection terminals of the VLD.

The bottom of the cabinet must be removed for proper assembly and tightening of the clamps. It is recommended to install the cable lugs after the wires have been pulled through the bushings. When handling the enclosure, it is recommended to disconnect the protective conductor connector and reconnect it after the installation.

It is recommended to regularly check the quality of the VLD connection to the cabling depending on its location and the frequency of switching. The recommended inspection interval is 12 to 24 months.

Prior finally connecting the protected railway track system to the VLD, perform an initial test of the VLD - see chapter 7.

5.2.2 Connecting the power supply

The VLD can be connected to up to two independent sources of AC (rated voltage 110 V / 115 V / 120 V / 127 V / 220 V ± 10 % / 230 V ± 10 % and rated frequency 50 Hz / 60 Hz) and/or DC (130 V / 220 V / 250 V) power supplies. For the power supply connection, a 3 × 1.5 - 2.5 mm2 cable (L/+, N/–, PE) is recommended. The cable is connected to the supply terminals marked „POWER SUPPLY 1 (2)“.

The product is fitted with bushings for power cable connections with a diameter ranging from 5 to 10 mm. The tightening torque of the bushing cap nuts is 2,5 Nm.

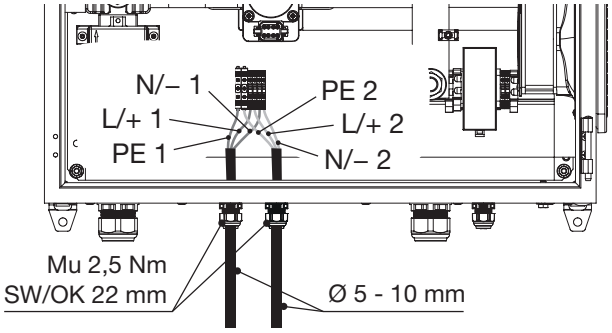

Fig. 6: Connecting the power supply (Mu – tightening torque, SW/OK – mounting wrench size)

In the case of power supply from only one source, it is necessary to connect the relevant terminals with a plug-in jumper (part of the package) according to Fig. 7 and fit the unused cable bushing with a blanking plug to maintain the IP protection level (part of the package).

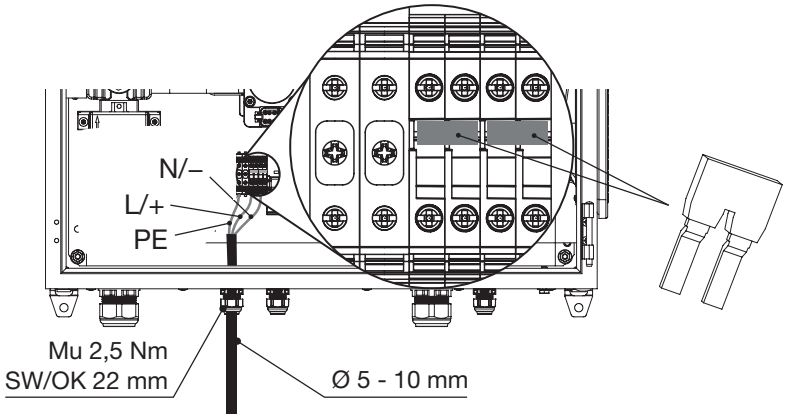

Fig. 7: Power supply from one source - connecting terminals

When supplying power from two sources, the plug-in jumper must not be connected!

5.2.3 Connecting the LAN communication cable

Connection of the VLD to the remote control system (SCADA, etc.) takes place via Ethernet cable with 100 Mbps throughput. It is

recommended to use an STP cable min. Cat 5e terminated with RJ45 connector. The cable is inserted into the connector marked „ETHERNET“.

As for the data cable, there is a separate cable bushing at the bottom of the enclosure that can accommodate a cable with a diameter of 5 to 10 mm. The bushing cap nut is tightened to a torque of 2,5 Nm

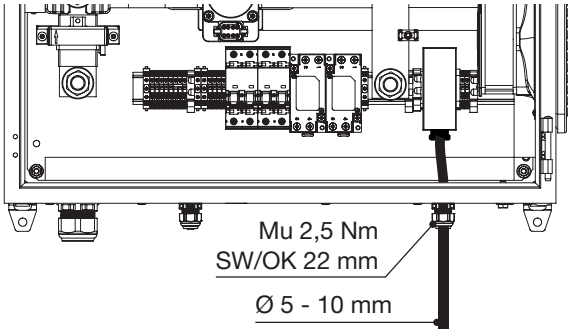

Fig. 8: Connection of Ethernet cable (Mu – tightening torque, SW/OK – mounting wrench size)

The RJ45 connector shall be crimped onto the cable after it has been pulled through the bushing.

5.2.4 Interconnection between the EARTH and PE terminals (cabinet frame)

From the factory, the VLD is wired so that the „EARTH“ power circuit terminal is conductively connected to the power supply PE terminal and both of them to the metal structure of the enclosure. This factory wiring is used if a same earth terminal is used for both the temporary track earthing and for the power supply PE protective earth. In case the grounding point of the rail is separated from the power supply PE protective earth, the above mentioned connection must be removed or broken - see Fig. 9.

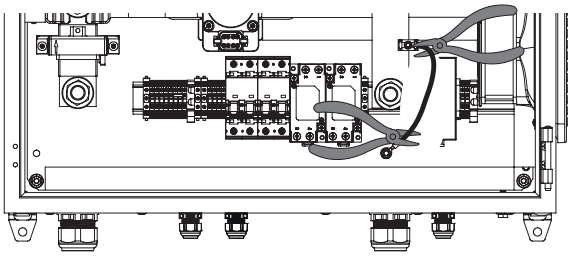

Fig. 9: Removal of the interconnecting link

5.3 Installation check

After completing the installation work, make sure that:

- the VLD cabinet is firmly mounted to the wall, frame or base so that it does not come loose and fall
- the cabinet doors can be opened or closed properly and freely
- all electrical wiring connections are properly connected, tightened and do not put mechanical stress on the VLD cabinet or its components
- the steel body of the cabinet is connected to the protective earth (PE)

6 Description and principles of the function (basic description of the algorithm, factory settings, user settings)

6.1 VLD block diagram and description of its functional parts

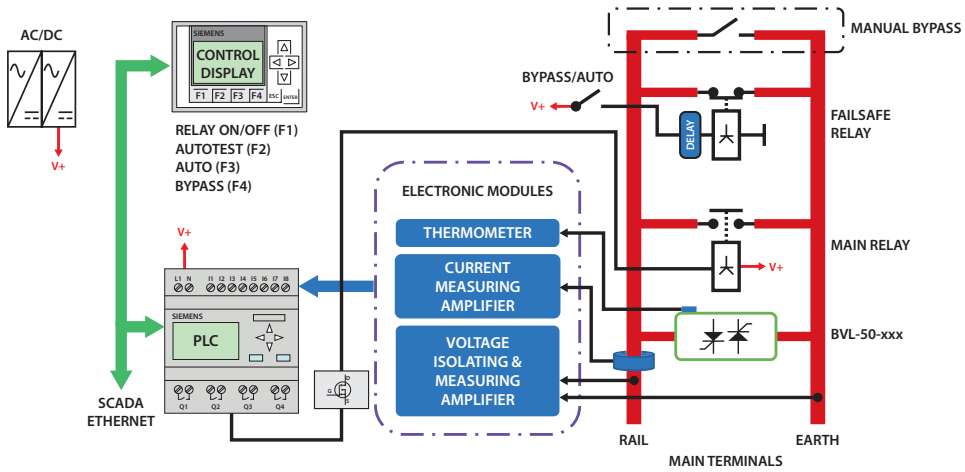

Fig. 10: Block diagram of PVL-1000-...-R01(-O)

The individual blocks have the following function:

1. BVL-50-xxx - a fast switching element that autonomously evaluates voltages between the RAIL and EARTH terminals. In case the voltage level is exceeded (xxx is the nominal triggering voltage of the BVL - 45 V / 60 V / 120 V), it short-circuits both terminals and limits the voltage to a permissible value. This is essentially a Class 2.2 VLD equipped with anti-parallel thyristors and a Type A2 surge arrestor (to provide lightning protection). The advantage of this concept is that the PVL is able to react to line voltage overruns in the event of a fault or lightning strike. This concept also ensures maximum speed of response of the PVL and maximum availability of protection for persons who may come into contact with the protected system. The BVL-50-xxx operates as a stand-alone VLD-O+F. When loaded according to the characteristics in Fig. 11, it behaves as a renewable VLD-O+F and when the load is exceeded, it transitions to a permanently conductive state as a VLD-F. If it is overloaded, it can be replaced without the need to integrate a new BVL into the system (i.e., without the need of adjusting and checking the other parts of the PVL).

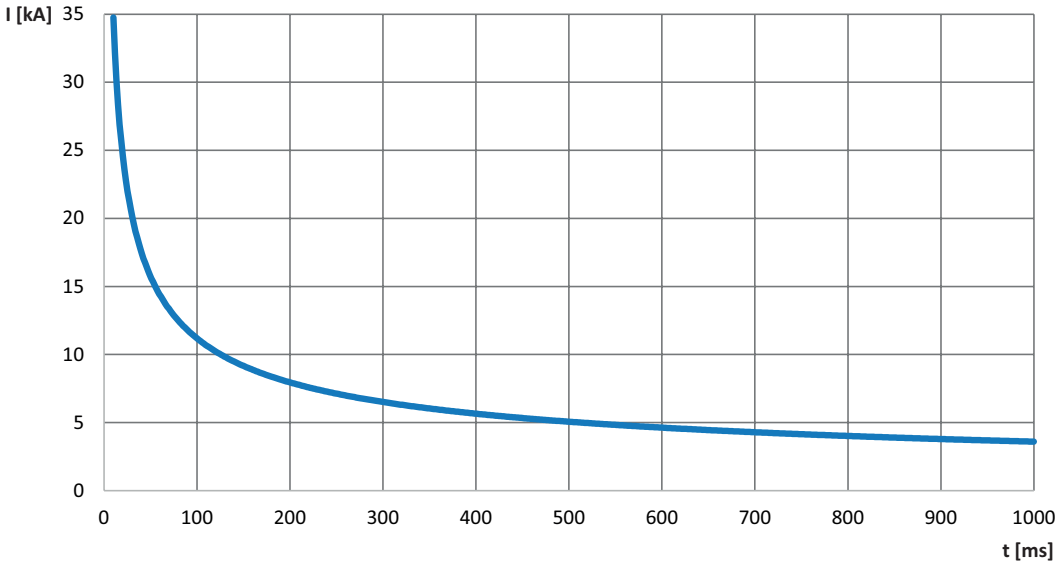

Fig. 11: Load characteristic for BVL function recoverability

2. MAIN RELAY – a special contactor capable of withstanding high loads, which becomes connected with a certain delay to the BVL, i.e. between the RAIL and EARTH main terminals. The connection and disconnection algorithm of this contactor is electronically controlled by sensing the current and voltage waveform at the RAIL terminal. The contactor is able to continuously transmit rated current of 1 kA, and significantly higher short-circuit currents during shorter periods. If we consider that typical VLD activity times move in the interval 0 to 30 seconds, the PVL is capable of operating with currents up to 3 kA. The combined load characteristic of the entire PVL is shown in Fig. 12.

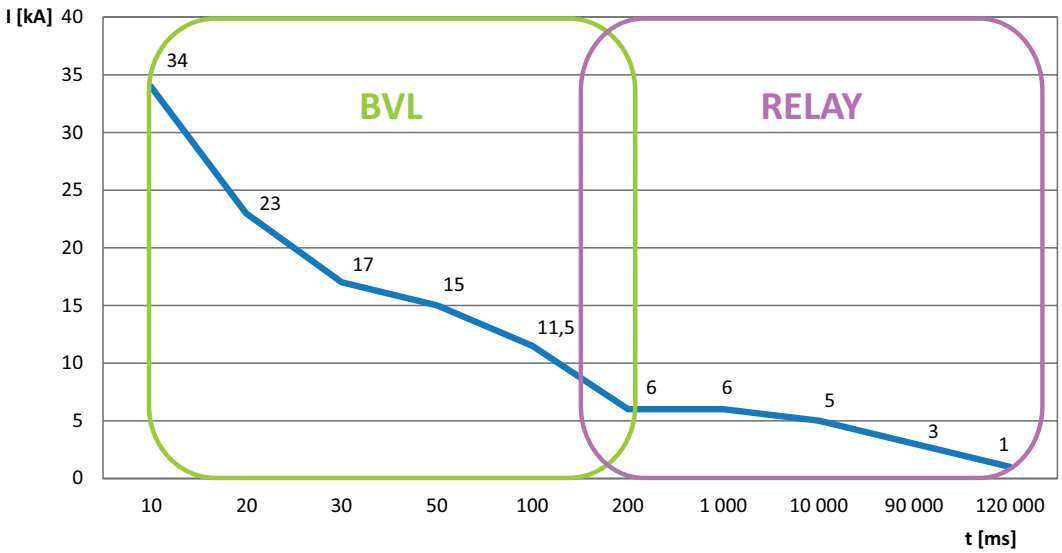

Fig. 12: Overall load characteristic of PVL-1000

3. FAILSAFE RELAY – emergency relay, which provides failsafe function as per the requirement of Article 5.4.3 of EN 50526-2, i.e. it short-circuits the RAIL and EARTH terminals in case of PVL power failure. The load characteristic of the relay can be seen in Fig. 13.

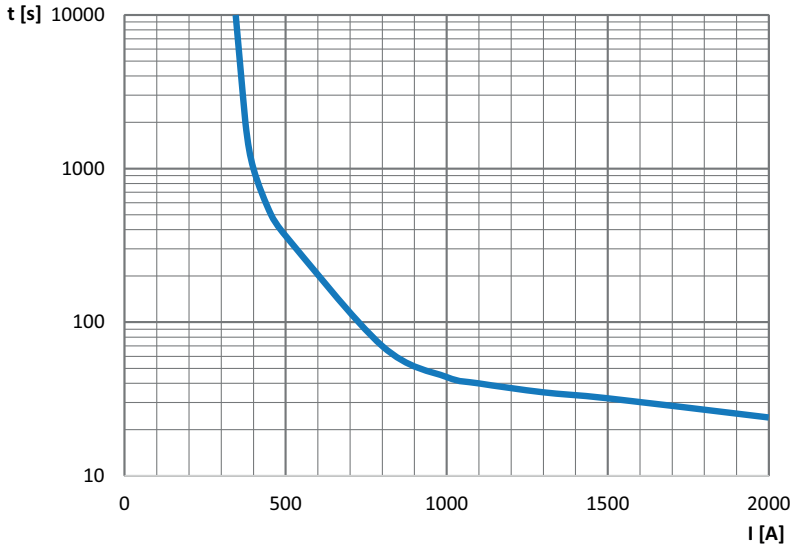

Fig. 13: Load characteristic of the FAILSAFE RELAY

Since at the time of short-circuiting of the terminals by the switching contacts of this relay (power failure, bypass activated - see block number 5 bellow) the path for stray currents is open for a long time, it is necessary to restore the normal state of the PVL in the shortest possible time to prevent damage to the conductive metallic structures along the line.

4. MANUAL BYPASS (only the PVL-1000-...-R01-O type) – manual short-circuiting device for the RAIL and EARTH terminals. It serves as additional protection for track personnel during installation and maintenance works on the section of track protected by the PVL. The shorting device keeps the circuit in a shorted state so that service personnel can be sure that no dangerous voltage can occur on the section. Information about the status of the shorting device is sent to the control electronics (and remotely to the SCADA system). The shorting device is recommended for use where there are increased safety requirements for personnel servicing the line, or where prolonged loads on the shorting device in excess of the FAILSAFE RELAY load curve can be expected.
5. CONTROL DISPLAY is used to indicate the VLD status and control the basic VLD functions:
   a. The RELAY ON/OFF button (F1) is used to force the main contactor ON, regardless of the instantaneous conditions at the connection terminals. In this way, the RAIL and EARTH terminals can be temporarily shorted for short-term service work, etc. (contactor tripping is indicated on the control panel). Caution! In the event of even a short-term power interruption, the command to switch on the main contactor is reset. To ensure a voltage-free state for service work, it is preferable to use a BYPASS button or a mechanical short-circuit switch MANUAL BYPASS (only type PVL-1000-...-R01-O).
   b. The AUTOTEST button (F2) is used by the operator to initiate a self-test of the main contactor function. Pressing it manually activates the triggering electronic circuits and the main contactor must trip (contactor tripping is indicated on the control panel).
   c. The AUTO button (F3) is used to set the VLD to the automatic protection mode.
   d. The BYPASS button (F4) is used to manually activate the bypass using the contacts of the main contactor or emergency relay even in normal operating condition. This can achieve permanent short-circuiting of the main terminals for service work etc. This condition is signalled to the control electronics (and remotely to the SCADA system) and switching of the main contactor is thus blocked.
6. The ELECTRONIC MODULES consist of a set of isolating and measuring amplifiers the purpose of which is to ensure that:
   a. the main protected circuit be isolated from the command and control circuitry (SELV circuits),
   b. instantaneous values of voltage be determined at the main terminals, as well as current passing through the main current circuit between the RAIL and EARTH terminals, and temperatures of the BVL heatsinks be identified in cooperation with current, voltage and thermal sensors,
   c. the identified quantities be converted linearly to values required by the PLC.
7. PLC – microprocessor, which on the basis of data obtained from voltage, current and temperature sensors and status inputs from the main elements controls the switching of the main contactor to the BVL in line with a specified algorithm, ensures safe operation of the VLD, communicates with the remote SCADA system using Ethernet interface, communicates with the operator and stores status variables in internal or external memory, evaluates fault and operating conditions and indicates them to the operator.
8. AC/DC is a set of power supply units of the PVL. An automatic transfer switch (redundancy module) indicates possible source failures to the PLC and remotely to the SCADA system for timely replacement of the power supply units without interrupting the VLD operation.

6.2 Description of the control algorithm.

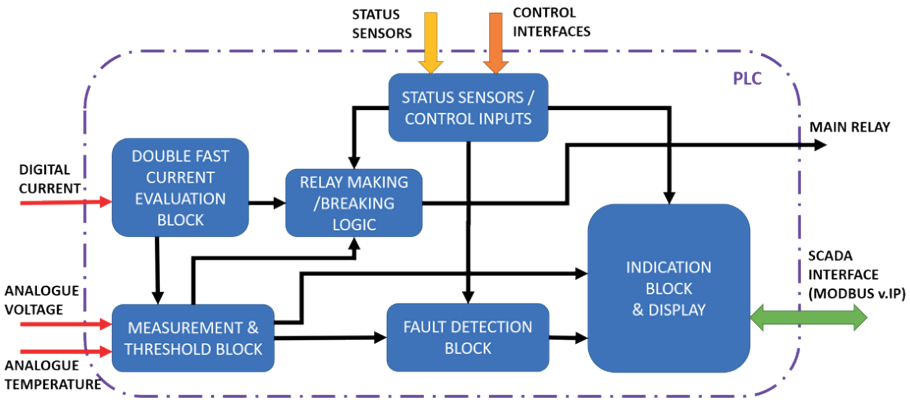

Fig. 14: Blocks of the control program

Information about the instantaneous values of current in the main circuit is fed from the measuring transducer to the fast digital input. Here, the current state is evaluated by two parameterized integrators and the instantaneous magnitude and mean current values are determined. From these, the switching delay of the main contactor is then determined. The evaluation also takes place in a third fixed integrator whose output controls the disconnection of the main contactor. Subsequent switching and tripping logic controls the switching of the main contactor depending on the state of the sensors.

Analog values of voltage at the RAIL terminal and temperature of BVL thyristor heatsinks are used for parameterization of the integrators and displaying of voltage and temperature on the display. Overshoot of voltage limit values is followed by voltage limiter malfunction as a consequence of BVL overload or a malfunctioning of the main contactor.

The fault detection block receives data about the status of the main contactor, manual short-circuiter, power supplies, etc. and compares them with that issued by the electronics commands. If this block detects a discrepancy between the commands and the status of the individual blocks or a non-standard condition, it will sound an alarm. The system reports the following types of faults/states:

- failure of the main contactor or its control
- failure of the power supply
- BVL thyristor heatsink temperature limit exceeded
- exceeding the permissible voltage at the RAIL terminal (faulty VLD function)
- exceeding the number of cycles of the main contactor
- VLD rated current exceeded (more than 1 kA)

The display block provides information to the user about the condition of the product and the circuit connected to the same by:

1. permanently measured voltage and current values (RAIL terminal)
2. information texts (in case of multiple messages, the priority is given to displaying messages with the highest importance)
3. changing the colour of the display backlight
   a. red backlight indicates a malfunction or undesired condition
   b. orange backlight indicates the activation of VLD (temporary terminal shorting) and current flowing
   c. white (or no) backlight indicates normal VLD condition

The PLC controller can communicate with the remote monitoring system (SCADA) via MODBUS protocol (via TCP/IP), i.e. either directly connected via Ethernet cable to the Local SCADA unit, or connected via Ethernet cable to the local SCADA gateway. The Ethernet interface is equipped with an isolation module for galvanic isolation of the external LAN from the product´s SELV circuits.

6.3 Factory settings of the PVL product

6.3.1 Switching voltage

The switching voltage of PVL-1000-xxx-R01(-O) is fixed and is determined by the choice of the specific type of the built-in BVL:

- PVL-1000-120-R01(-O): UTn = 120 V DC
- PVL-1000-060-R01(-O): UTn = 60 V DC
- PVL-1000-045-R01(-O): UTn = 45 V DC
- Any other switching voltages must be agreed individually with the manufacturer.

Switching response times of the BVL:

- Response time of the A2 SPD: T_R = 25 ns
- Reaction (response time) of thyristors: T_R = 1,5 ms (the T_R value may be changed only during the manufacturing proces)

6.3.2 Reaction (response time) of the main contactor (changes possible by software settings)

- main contactor switching delay: T_R = min. 200 ms

The delay is controlled electronically depending on the current flowing through the RAIL terminal. If the load capacity of the BVL thyristors is not exceeded, there is no activation of the main contactor.

- opening moment of the main contactor:
  – the following conditions are met at the same time (factory settings):
    » instantaneous current flowing through the RAIL terminal is smaller than 10 A
    » the integral of the current through the RAIL terminal for 2 s is less than 40 As

- protective interval between disconnection and reconnection of the main contactor: 0,5 s

6.3.3 Parameterization of the main contactor switching depending on the temperature of the BVL thyristor heatsinks

- three stages (factory setting):
  - 1st stage: less than 60 °C
  - 2nd stage: 60 °C to 80 °C
  - 3rd stage: more than 80 °C

6.3.4 Indication of overcurrent and overvoltage

- overcurrent indication I > 1000 A
- overvoltage indication U > 120 V (or 60 V; or 45 V – depending on PVL type)

6.3.5 Cooling fan switching

The fan switching is controlled electronically depending on the BVL temperature and the current flowing through the RAIL terminal.

- The fan is started if at least one of the following conditions is met:
  - the BVL-50-xxx temperature is higher than 60 °C
  - the current passing through the RAIL terminal is higher than 750 A

6.3.6 User settings

The basic version of the control software has the parameters of the working algorithm set from the factory and these parameters cannot be changed manually by the user. Specific settings can be made by changing the parameterization of the algorithm during the production process or even after product installation based on an agreement between the user and the manufacturer. This (software) change can only be made by authorized personnel of the manufacturer.

7 Commissioning (putting into operation)

Follow the steps below when commissioning the product:

1. Install the product in accordance with Chapter 5 of this manual; do not connect (or disconnect) the RAIL terminal to the protected track system for the time being.
2. Check the status of the emergency relay before connecting to the power supply, i.e. that the RAIL and EARTH terminals are shorted in the de-energized state of the product.
3. Connect the supply voltage by switching ON both circuit breakers B 10 A (circuit breaker FA1 is used for POWER SUPPLY 1 and circuit breaker FA2 for POWER SUPPLY 2, see chapter 3.3 and chapter 5.2.2)
4. After software initialization (within 15 seconds), verify that the emergency relay has de-energized the shorted terminals with its opening contacts, i.e. high impedance only can be measured between the terminals. When the RAIL terminal is disconnected and the VLD is switched on (after software initialization), an impedance value of more than 200 kΩ must be measured between the RAIL and EARTH terminals (! The test voltage of the ohmmeter must not exceed the trigger voltage of the VLD !).
5. Test the operation of the VLD thyristors (optional test)
   a. Apply test voltage higher than the VLD triggering voltage to the terminals, using suitable power source with a current limiter (preferably using the SALTEK VLD tester).
   b. Depending on the polarity of the voltage, one of the thyristors must trip and cause electrical short-circuit between the terminals. This is verified either by the built-in ammeter on the VLD display (the throughflow current must be greater than 5 A), or by an ammeter connected in series with the RAIL terminal.
   c. After disconnecting the trigger voltage source the VLD must automatically restore the isolation condition between the RAIL and EARTH terminals.
6. Test the operation of the main contactor of the VLD
   a. Press the RELAY ON/OFF (F1) button. This must cause the main contactor to trip even without the trigger voltage applied.
   b. Using an ohmmeter verify the state between the RAIL and EARTH terminals.
   c. Press the RELAY ON/OFF (F1) button again to return the main contactor back to the automatic functioning, i.e. establishing high impedance between the RAIL and EARTH terminals.

   Note: The function can also be verified by the AUTOTEST (F2) button, when the main contactor is switched on for 3 seconds and disconnected again.
7. If the previous tests have a positive result, connect the RAIL terminal to the protected track circuit.
8. Ensure the VLD is in the normal automatic operating state, i.e. the bypass controls activated by the control elements (i.e. the RELAY ON/OFF (F1) button or the BYPASS (F3) button) are deactivated and the device is in the automatic operating mode (display without orange lit backlight).
9. Set the IP address of the monitoring system device on the control panel - after pressing the down arrow and ESC select the menu „LOGO! Settings“ and the main MENU will appear. Before changing the IP address, you must stop the program with STOP and confirm. Change of IP address can be found in Network/IP Address.
10. Verify that the product is communicating with the connected systems via the LAN cable.

8 Manual control, remote control, automatic operation mode

8.1 Manual control

The VLD is controlled by the control display on the front panel of VLD and the manual short-circuiting device (only type PVL-1000-...-R01-O).

1. Control elements (arrows, esc, enter) on the control display are used to navigate in the PLC internal menu, especially to display permanently measured values of voltage and current, to display multilevel indication and fault messages, to read

logs from the PLC memory, etc.

2. Control elements on the control display (F1-F4)
   a. Controls description – see chapter 3.3.
   b. Using the above controls the following functions can be run:
      A) RELAY ON/OFF (F1) - software bypass

      Pressing this button activates the main contactor triggering circuit of the VLD and thus gives the command to permanently switch it ON. Deactivation of this state, i.e. opening of the contacts of the main contactor, is achieved by pressing this button again. If this function is triggered in a situation where there is some voltage present between the VLD terminals (even below the VLD trigger voltage), the contacts of the main contactor will be closed on and, as a result, the RAIL and EARTH terminals will become connected. In this case, the message „VLD ACTIVE“ will appear on the PLC display and the current passing through the VLD can be measured. The bypass activation status is indicated by a flashing red backlight on the VLD display.

Use this function only for short-term activations of the VLD current path in case of quick operational or service interventions. For maintenance, use the AUTO (F3) and BYPASS (F4) buttons or manual shorting switch (PVL-1000-...-R01-O type only).

Remember that even a short interruption of the VLD power supply will deactivate this function and restore the VLD‘s automatic operation mode!

Do not activate the VLD current path unnecessarily as it increases the frequency of occurrence of stray currents and thus the risk of damage to conductive structures along the railway track. Remember to deactivate this function immediately after completing the works and before leaving the site.

      B) AUTOTEST (F2)

      Pressing this button once during normal operation of the VLD forces the main contactor to close followed with temporarily short-circuiting the VLD terminals for 3 seconds. This transient condition is indicated by orange background on the control display and the „MAIN RELAY ON“ indication message. If this test is run in a situation where some voltage is present between the VLD terminals (even below the VLD trigger voltage), the current path between the terminals will be activated. In this case, the message „VLD ACTIVE“ will also appear on the control display and the current through the VLD can be measured. After a period of 3 seconds, the VLD will automatically go into the normal standby mode.

Do not perform this test unnecessarily often as it increases the frequency of opening the channel for stray currents.

      C) AUTO (F3)

      Pressing the AUTO button sets the VLD protection mode to fully automatic.

      D) BYPASS (F4)

      By pressing the BYPASS button, the VLD terminals are in stable short-circuit state, necessary in case of performing service works on the connected protected rail system. In this position, the main contactor of the VLD becomes switched on, regardless of whether current is flowing through the VLD terminals or not.

The status of the forced BYPASS mode is indicated by a red backlight on the control display.

A permanent terminal short-circuit condition can also be achieved by simply disconnecting the VLD from the power supply. Resulting from the operational principle of the emergency relay, this will short-circuit the terminals by the relay´s opening contacts. In this case, however, the passing current and its duration must not go beyond the emergency relay load curve.

      E) MANUAL BYPASS (refers to the PVL-1000-...-R01-O type, only)

      The OT1000 manual shorting switch is installed inside the VLD cabinet and is accessible by opening the VLD door. The use of PVL-1000-...- R01-O VLD is recommended wherever the following is required:

      - possibility of mechanical interlocking of the shorting device when working on dangerous sections of the track
      - increased resistance to long-term short-circuit currents (in excess of the load curve of the emergency relay - see Fig. 13)

Attention! Risk of electric shock by touching dangerous live parts when the cabinet door is open.

      Recommended procedure for the activation of the OT1000 manual shorting switch:

      1. Check on the display that the VLD finds itself in disabled state, i.e. no current is flowing through it, no voltage greater than 28 V DC is present at the terminals (recommended condition - not necessary for bypass activation).
      2. Press the BYPASS button (F4) to activate VLD bypass mode..
      3. Open the VLD cabinet door and switch the OT1000 manual shorting switch to the SHORT-CIRCUITED position.
      4. Check that the voltage at the RAIL terminal is less than 1 V.
      5. Turn off power to the VLD (not necessary).
      6. If you want to maintain short-circuit on the track circuit during the works, place mechanical lock on the OT1000 manual shorting switch and keep the key well preserved. Use safety signs (e.g. „shorted, no tampering“)

where local regulations exist.
7. Close the VLD cabinet door.

Recommended procedure for the deactivation of the OT1000 manual shorting switch:

1. Ensure that all work on the protected section of track has been finished and that no person is in the vicinity.
2. Open the VLD cabinet door.
3. Unlock the mechanical lock from the OT1000 opening (trip) handle (if such is used).
4. Turn on power to the VLD and wait for the software to activate.
5. Verify that no more than 100 A of current is passing through the VLD, or verify the reason for the current passing or wait for the current to decrease (recommended - not necessary).
6. Switch the OT1000 manual shorting switch to the OPEN position and close the VLD enclosure door.
7. Press the AUTO button to activate the automatic VLD mode. Depending on the current voltage and current status, the automatic re-connection of the main contactor (higher current flowing through) will occur and the emergency relay contacts will open with a small delay.
8. Verify on the VLD display the magnitude of the voltage and current at the VLD terminals and check the corresponding VLD status (the VLD display is not allowed to be backlighted or flashing in red).

8.2 Remote control and monitoring of VLD

Online communication and information transfer from/to the SCADA system (or other monitoring system) is carried out via communication interface connected to the VLD control processor (PLC) using an isolation module. The communication takes place on the physical Ethernet 100BASE-T layer using the MODBUS communication protocol (via TCP/IP). The remote communication system enables continuous collection of information about the VLD status and its measured variables (instantaneous voltage and current passing through the RAIL terminal, VLD activity and status, VLD fault conditions, etc.).

9 Events and their monitoring (logs, communication with SCADA system, default MODBUS settings, registered operational and fault events and variables)

The PVL VLD enables the recording and archiving of selected operating states and variables. The default setting makes it possible to store the data on the SD memory card, which is a part of the product delivery. The card is inserted into the PLC slot.

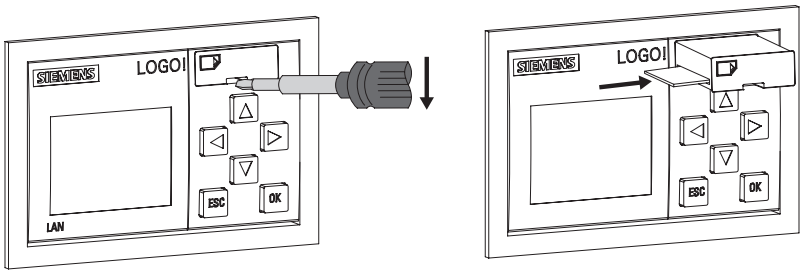

Fig. 15: Memory card location

From the factory, the data logging is set so that the VLD status is always written at the moment of occurrence of the following events:

1. on activation of the VLD
2. on deactivation of the VLD
3. on activation of any fault
4. on deactivation of a fault state (i.e. the transition to a fault-free state)
5. on activation of MAIN RELAY

Default setting of the logs is shown in the following table:

Event	MODBUS id
Active main contactor	Coil 8193
Fault, error	Coil 8194
BYPASS active	Coil 8195
Switching on the fan	Coil 8196
VLD active	Coil 8197
Defect of the main contactor or its control	Coil 8265
Power supply malfunction	Coil 8266
Temperature overshoot	Coil 8267
Not allowed voltage level	Coil 8268
Main contactor cycling	Coil 8269
Overcurrent	Coil 8270
Manual BYPASS	Coil 8271
AUTOTEST	Coil 8272

Event	MODBUS id
RAIL – EARTH voltage	Holding register 513
Current passing through the RAIL terminal	Holding register 514
Temperature	Holding register 515

Each PVL device undergoes a thorough output check in the laboratory - the number of contactor activations and other data from this check remain stored in the PVL memory.

The monitored data is stored according to the date and time set in the PLC. If necessary, this date can be set in the main MENU of the PLC (down arrow, ESC and selection LOGO! Settings) in the SETUP submenu.

10 Identification and troubleshooting of operational faults

The main operational faults are detected by the VLD software and the detection system of operational status of VLD main components. In addition to checking internal software sequences, it is also monitored:

- the status of power supplies
- the condition of the main contactor
- the status of the OT1000 manual shorting switch (only type PVL-1000-...-R01-O)
- the temperature of BVL thyristor heat sinks

Based on this, the VLD system can indicate faults via the control display (text info or display backlighted in red). The red backlit display appears in the following cases:

- any defect/error (see Table 1) evaluated by the PLC
- bypass implemented electronically (using the RELAY ON/OFF (F1), AUTO (F3) or the BYPASS (F4) button), or mechanically (OT1000 – applies to the PVL-1000-...-R01-O, type, only) – flashing
- OVERCURRENT (currents exceeding the rated value of Ir > 1 kA)
- OVERVOLTAGE (voltages on the RAIL terminal exceeding the VLD triggering level)

The following operations may only be carried out by an authorised and trained person!

The following operations are carried out in an open VLD cabinet where live parts of LV circuits are exposed! Risk of electric shock!

Displayed failure	Failure description	Recommended remedial action
PS FAULT	One of the power supplies is not supplying the correct voltage.	Check that the output voltage of the power supply(s) is within 24 V DC ± 10%. If not, disconnect the DC side power supply from the other circuits and measure again. If the voltage is still out of tolerance, replace the power supply with a new one. If the power supply is OK, there is probably a fault in the downstream circuits and in such a case the manufacturer or authorized service should be contacted.
RE CTRL FAULT	Inconsistency between the control signals of the main contactor and its operating status.	Disconnect the product from both the power supply and the protected circuit. Disconnect the main contactor control coil from the control circuitry. Measure both the operating and auxiliary contacts in the coil´s de-energized state and then repeat the contact measurements when the coil is connected to a 24 VDC source. Evaluate the correct operation of the main contactor and auxiliary contacts. Replace the main contactor with a new one if it is not working properly. If the contactor is functioning properly, contact the manufacturer or authorized service.
CYCLING	The software repeatedly triggers the main contactor in short time cycles (more than 5 times in 1 minute).	Verify that there really are repeated short pulses present in the protected circuit of the rails that can cause a rapid cycling of VLD activation and deactivation. If the result is negative, disconnect the VLD from the power supply and reconnect it after about 1 minute. Check if the phenomenon is repeated. If it does, it probably is caused by a malfunction of the VLD control system. In this case contact the manufacturer or an authorised service centre.
OVERCURRENT	Current flowing through the VLD is in excess of 1 kA.	The current measurement cycle is 1 s. An overcurrent indication in a single cycle indicates a high-energy pulse (e.g., a short circuit). Overcurrent for a longer period of time (more than 1 s) indicates high energy level of stray currents and a high risk of damage to metallic structures along the track. Prolonged occurrence of currents above 1 kA indicates a technological problem on the protected section of the track - initiate an investigation to detect and eliminate the causes of high currents flowing across the VLD.

Displayed failure	Failure description	Recommended remedial action
OVERVOLTAGE	A voltage higher than the permissible protection level has appeared at the VLD terminals.	The VLD is not responding properly and is not fulfilling its protective function. Check the correct function of the VLD: disconnect the protected track system from the VLD terminals. Connect a power supply to the RAIL and EARTH terminals (with current limiter) whose set voltage is higher than the nominal voltage of the VLD. The VLD must activate and create a short circuit between the terminals (residual voltage a the terminals in the active state of the VLD must be less than 5 V). If the test result is unsatisfactory, contact the manufacturer or authorized service.
HI TEMPERATURE	BVL thyristor heat sink temperature is higher than 60 °C	Check that the air circulation openings in the VLD cabinet are not covered or dirty. Clear them, if necessary. If the system still reports frequent temperature overshoot, this may be due to the VLD reacting very frequently with higher flow passages, or to the relatively high temperature of the VLD. In this case, check the function of the fan or replace it with a new one.

Table 1: List of faults and their troubleshooting

11 Maintenance

The product is designed to be maintenance-free. Nevertheless, it is recommended to inspect the equipment and check it regularly (see Table 2).

Interval (whichever comes first)	Recommended service action
12 months	Checking the cooling cabinet vents, cleaning dust filters, checking the fan.
60 months	Replacement of the cooling fan
2000 switching operations or 24 months	Checking the function of the main contactor, cleaning the cabinet of dust and dirt
300 000 switching operations	Checking the main contactor or replacing it

Table 2: Recommended periodic actions

Maintenance operations may only be carried out by an authorised and trained person!

Maintenance operations are carried out in the open VLD cabinet, where there are uncovered live parts of LV circuits! Danger of electric shock!

12 Technical data

Parameter name / Product type		PVL-1000-120-R01(-O)		PVL-1000-060-R01(-O)		PVL-1000-045-R01(-O)	
operational	Operation mode	VLD-O+F					
	Highest voltage of railway traction U_n	3 000 V DC					
	Overvoltage detection	both polarities DC					
	Main contactor rated current I_r	1 000 A @ 60 min					
	Rated current of manual shorting switch I_r	1 000 A @ 60 min					
	Rated current I_r when power is off	350 A @ 60 min					
	Nominal triggering voltage U_{Tn}	120 V		60 V		45 V	
	Withstand voltage U_w	100 V		48 V		36 V	
	Short-time withstand DC current @ 30 ms (repeatable) I_w	16 kA					
	Long-time withstand DC current @ 30 s (repeatable) I_w	3 kA					
	Short-time withstand DC current @ 1 s (repeatable) of the manual short-circuiting device I_w	50 kA					
	Maximal residual voltage U_{RES} at I_r = 1000 A	< 150 mV					
	Maximal residual voltage U_{RES} at I_w = 16 kA	< 10 V					
	Highest short-term pulse load (VLD-F)	120 MA^2s					
	Leakage current I_L at U_w	< 250 µA		< 120 µA		< 100 µA	
	Response time of A2 SPDs T_R	25 ns					
	Response time of thyristors T_R	< 1,5 ms					
	Response time of the contactor T_R	≥ 200 ms (programmable)					
	Remote monitoring (SCADA)	MODBUS using TCP/IP					
impulse	High charge impulse (10/350) I_{imp-hc}	30 kA					
	Lightning current impulse (8/20) I_{imp-n}	30 kA					
	High current impulse (8/20) $I_{imp-high}$	50 kA					
general	Rated power supply voltage AC 50 Hz / 60 Hz U_{PSAC}	110 V	115 V	120 V	127 V	220 V ± 10 %	230 V ± 10 %
	Active power consumption in idle/switched on mode at U_{PSAC}	10 W / 24 W	10 W / 24 W	10 W / 24 W	10 W / 24 W	12 W / 28 W	12 W / 28 W
	Current consumption in idle/switched on mode at U_{PSAC}	0,2 A / 0,45 A	0,2 A / 0,45 A	0,2 A / 0,45 A	0,2 A / 0,45 A	0,25 A / 0,35 A	0,25 A / 0,35 A
	Rated power supply voltage AC 50 Hz / 60 Hz U_{PSDC}	130 V		220 V		250 V	
	Active power consumption in idle/switched on mode at U_{PSDC}	10 W / 24 W		12 W / 28 W		12 W / 28 W	
	Current consumption in idle/switched on mode at U_{PSDC}	0,2 A / 0,45 A		0,25 A / 0,35 A		0,25 A / 0,35 A	
	Voltage measurement tolerance	±5 V; suppressed zero in the 0 to 5 V range					
	Current measurement tolerance	+5 A/–10 A up to 50 A; ±10 % from 50 A to 1000 A; +10/–0 % from 1000 A to 2500 A; suppressed zero in the 0 to 5 A range					
	Temperature measurement tolerance	±5 °C					
	Installation	indoor					
	Altitude	up to 2000 m above sea level					
	Relative humidity	20 % - 95 %					
	Pollution degree	1 - 2 (EN IEC 60664-1), PD1 - PD3 (EN 50124-1)					
	Protection degree	IP 54					
	Operating temperature range (min/max)	–20 °C / 55 °C					
	Rated insulation voltage Main power circuit – control circuit	3,0 kV AC / 4,2 kV DC					
	Required insulation of external circuits Main power circuit	CAT III (OV3) up to U_{Nm} 150 V – 1,4 kV AC / 2,0 kV DC					
	Required insulation of external circuits Power supply circuit 100 - 230 V AC	CAT II (OV2) up to U_{Nm} 300 V – 1,5 kV AC / 2,1 kV DC					
	Required insulation of external circuits Data circuit (Ethernet)	CAT I (OV1) up to U_{Nm} 50 V – 1,0 kV AC / 1,4 kV DC					
	Cable entry	from the bottom					
	Weight	~ 50 kg					
	Meets the requirements of standards (as amended)	EN 61010-1, EN 50526-2, EN 50124-1, EN 50122-1, EN 50121-4					

Station log

Date / Time	Event	Report sent to

Station log

Date / Time	Event	Report sent to

Station log

Date / Time	Event	Report sent to

Station log

Date / Time	Event	Report sent to

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