PLUTON TURN ON THE FUTURE

THYRISTOR CONTROLLED RECTIFIERS (TCR)

CITY ELECTRIC TRANSPORT ■
RAILWAYS ■ METRO

THYRISTOR CONTROLLED RECTIFIERS (TCR)

Thyristor Controlled 12-pulse Rectifiers (TCR) manufactured by Pluton are a modern solution for metro, light rail, as well as urban electric transport and railways traction networks modernization.

Thyristor Controlled Rectifiers provide constant voltage on substation busbars over a wide range of traction loads, taking into account AC network fluctuations.

Effectiveness of Thyristor Rectifiers application for powering traction networks with regulated voltage makes it possible to develop new flexible solutions that can be adapted to the most diverse Customers' needs.

Application of TCR to power electric transport traction networks has a number of benefits over standard diode systems.

▲ Thyristor controlled rectifier manufactured by PLUTON at Arninge substation (Stockholm, Sweden)

BENEFITS

DC traction network voltage regulation, and thus energy savings (reduction of losses) in the traction network

Implementation of electronic current protection leads to reduction in surge currents at the rectifier output

Possibility of power and load control system implementation with online parameters setting in remote control system

Reduction of traction substations number when designing a new line, thus reducing construction costs

Possibility to increase the line capacity or to use more powerful trains, when modernizing existing substations with diode rectifiers

BENEFITS OF THYRISTOR RECTIFIERS

Customization

/ production in fixed and withdrawable versions;

/ manufacturing by 12-pulse and 6-pulse “bridge” rectification circuits;

/ power part of the rectifier is made based on “thyristor-fuse” circuit;

/ connection of AC power supply to the top or bottom of the rectifier;

/ application for all types of traction networks with the following standard output voltage: 600, 750, 825, 1500, 1650, 3000, 3300 V and rated power: 800 - 4000 kW.

Ease of maintenance

/ easy access to circuit components to facilitate maintenance;

/ maintenance-free contact connection technology is applied in the rectifiers power section;

/ controlled thyristors compression force due calibrated compression components of “thyristor-cooler” assembly application.

Reliability and safety

/ innovative circuit and technological solutions;

/ microprocessor-based control, protection and diagnostic system;

/ high reloading capacity;

/ efficient multi-level protection system against internal switching and external overvoltage;

/ rectifiers are manufactured for different failure modes of semiconductor devices (T, F, R modes) in accordance with EN 50328;

/ long life cycle and high level of technical and operational characteristics due to the use of modern high-quality, reliable and safe components;

/ safety guarantee due to electrical and mechanical interlocks.

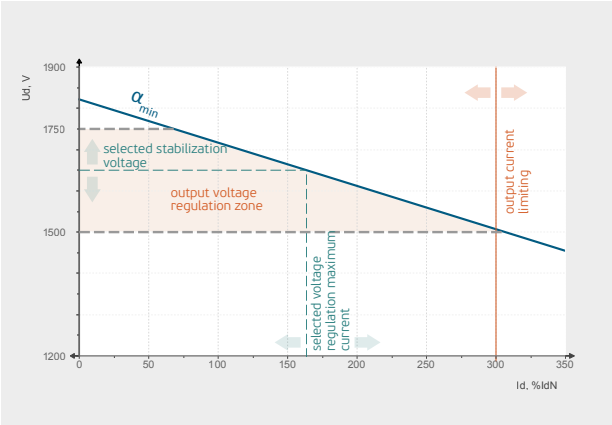
Compliance with international standards

The rectifiers meet requirements of IEC 60146-1-1:2009, EN 50328:2003 international standards.

Application

	600 V	750 V	825 V	1500 V	1650 V	3000 V	3300 V
Tram	■	■	■	■			
Trolleybus	■	■					
Light rail transport	■	■	■	■			
Metro		■	■	■			
Railways				■	■	■	■

BENEFITS OF THYRISTOR RECTIFIERS



▲ Example, external characteristic of a thyristor controlled rectifier with UdN = 1500 V DC

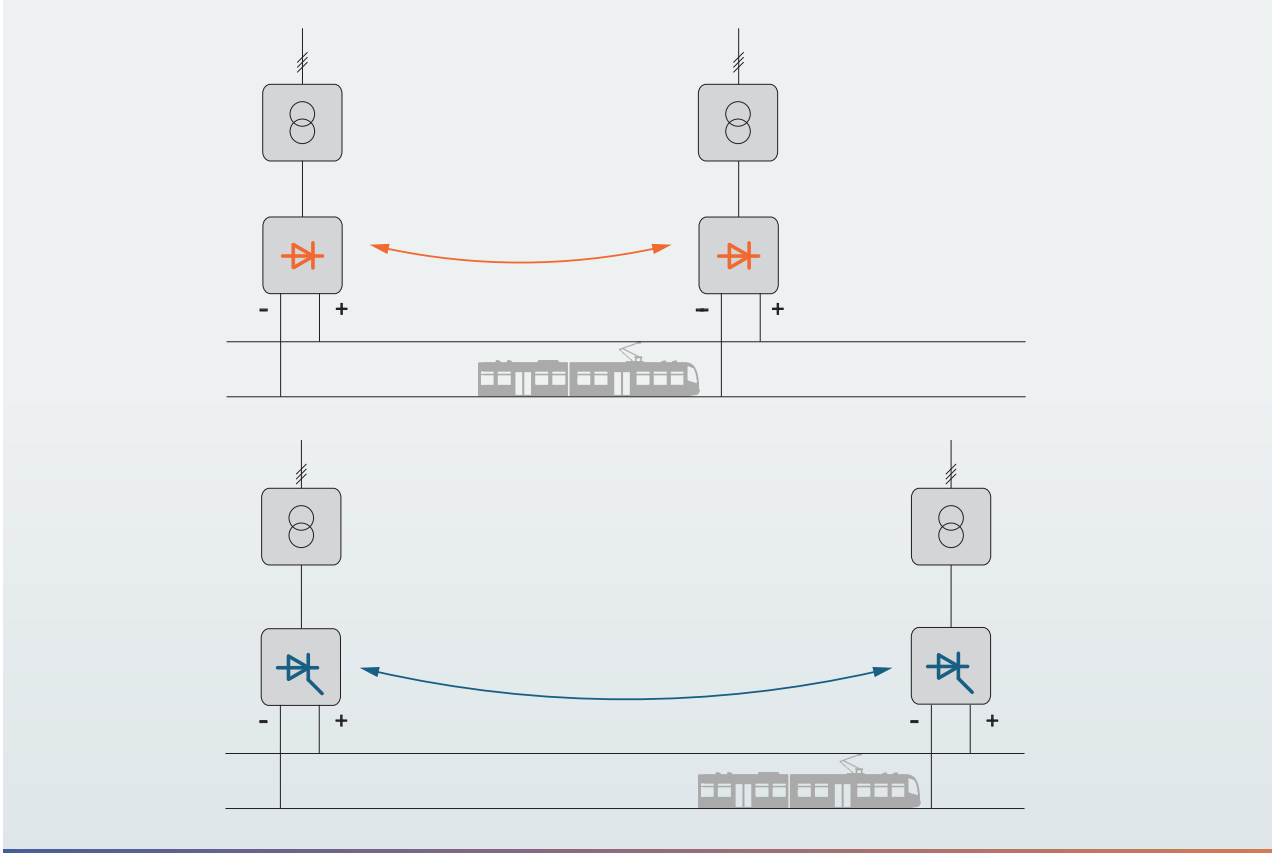
Output voltage regulation zone is defined by traction network permissible parameters and is limited by thyristor minimum opening angle α_{min}.

Current limiting mode (from 100% to 350% IdN) is provided to limit the rectifier output current at a specified level.

The following regulation function is basically implemented in a thyristor controlled rectifier: Ud = Uref + k · Id%

When k coefficient is set to more than 0, external characteristic becomes positively sloped, leading to compensation of a part of resistive voltage drop in catenary and running rails.

This voltage regulation reduces losses in DC traction network, making it possible to increase the distance between supply stations.



▲ Power supply systems based on TCRs allow to increase the distance between substations, leading to significant reduction in the number of substations on the line and considerable savings in construction costs

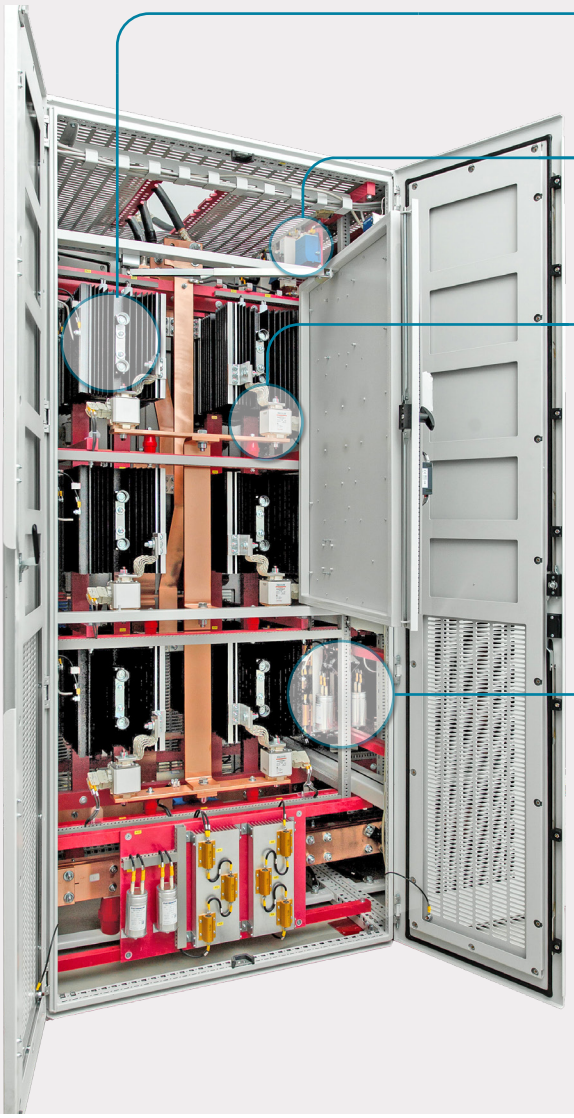
DESIGN
(fixed rectifiers)

Depending on power, a Thyristor controlled rectifier includes one or two cabinets with power thyristors, fuses, protection, control and monitoring components. It is supplied by a dry three-winding converter transformer.

Tablet power thyristors are used in the rectifier. High-speed power fuses are installed in series with each thyristor to provide protection against internal short circuits. Cooling is natural air.

The rectifier also provides protection of power semiconductor devices against internal and external switching overvoltages. Protection against internal switching overvoltages is provided by RC circuits, against external overvoltages - in combination: RC circuits and varistors.

MAIN COMPONENTS



PROTECTIONS

Protection against external overvoltage

Protection against internal short circuits

Protection against internal overvoltage

CONTROL SYSTEM

The rectifiers are equipped with microprocessor control and diagnostic system based on SOTA® controller, conforming to IEC 61131 series of PLC standards and supporting IEC 61850 protocol.

MC-POWER module is connected to SOTA® controller to control thyristor bridge.

Functions of MC-POWER module:

- generation of thyristor opening control pulses;
- implementation of regulation modes (output voltage stabilization, load current limitation, short circuit control at startup);
- transfer of control angle to inverter area and further release of thyristor opening pulses by external high-speed signal or internal overcurrent protection.

SOTA® with MC-POWER module allows to implement all the requirements to control, regulation and protection of rectifiers, as well as the requirements of technological algorithms for ensuring the traction network power supply.

The rectifier communicates with protection devices of medium-voltage switchgear and upper-level SCADA system.

HMI is provided by an operator panel in the form of 7-inch TFT touchscreen display, allowing the user to exchange data with the control system.

The rectifier and its elements status information can be viewed on visualization panel, mobile devices (smartphone, tablet) or on a computer monitor via Web interface or a specialized program.

System functions (for fixed rectifiers):

Control:
temperature, 2 levels
transformer heating in 2 stages (maximum heating and overheating)
fuses tripping: - on input protection panels - on power thyristors - on output protection panels
temperature inside the cabinet (optional)
condition of the cabinet doors
Visualization:
rectifier status (on/off)
rectifier single-line circuit
status of high-voltage and high-speed circuit breakers
values of rectified current and voltage
Control:
setting, changing, and saving settings parameters
selecting the rectifier control mode
Additional functions:
warning and alarm messages displaying
events log keeping
testing of the rectifier separate components
communication with the upper level (SCADA system)
support of IEC 61131, IEC 61850 protocols

TECHNICAL CHARACTERISTICS
(fixed rectifiers)

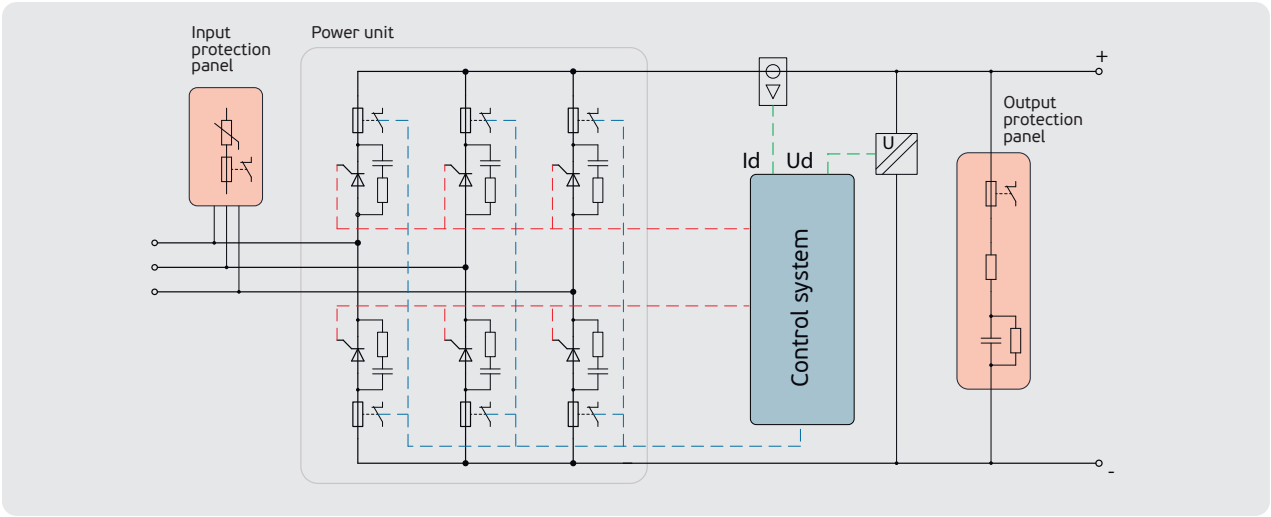
Parameter name	Unit	Value		
Rated voltage	V	600, 750, 825	1500, 1650	3000, 3300
Rated current	A	1330...2670*	1250...2500*	
Auxiliary power network voltage	V	=110/220*; ~230		
Rectification circuit	-	bridge (6-pulse, 12-pulse)		
Connection diagram number (according to EN 50328)	-	8, 9 (Fig. 1-2 page 9)		12 (Fig. 3 page 10)
Rectifier type of cooling (according to EN 50328)	-	natural, air (AN)*		
Duty class (according to EN 50328)	-	VI*		
Overload	-	1.0 — continuous 1.5 — 7200 s 3.0 — 60 s		
Semiconductor devices failure mode (according to EN 50328)		T, F, R modes		
Maximum ambient temperature	°C	40*		
Height above sea level, max, without rated power reduction	m	1000		
IP class (according to IEC 60529)	-	IP20, IP21*		

* other values - optional

POWER SECTION CIRCUITS
(fixed rectifiers)

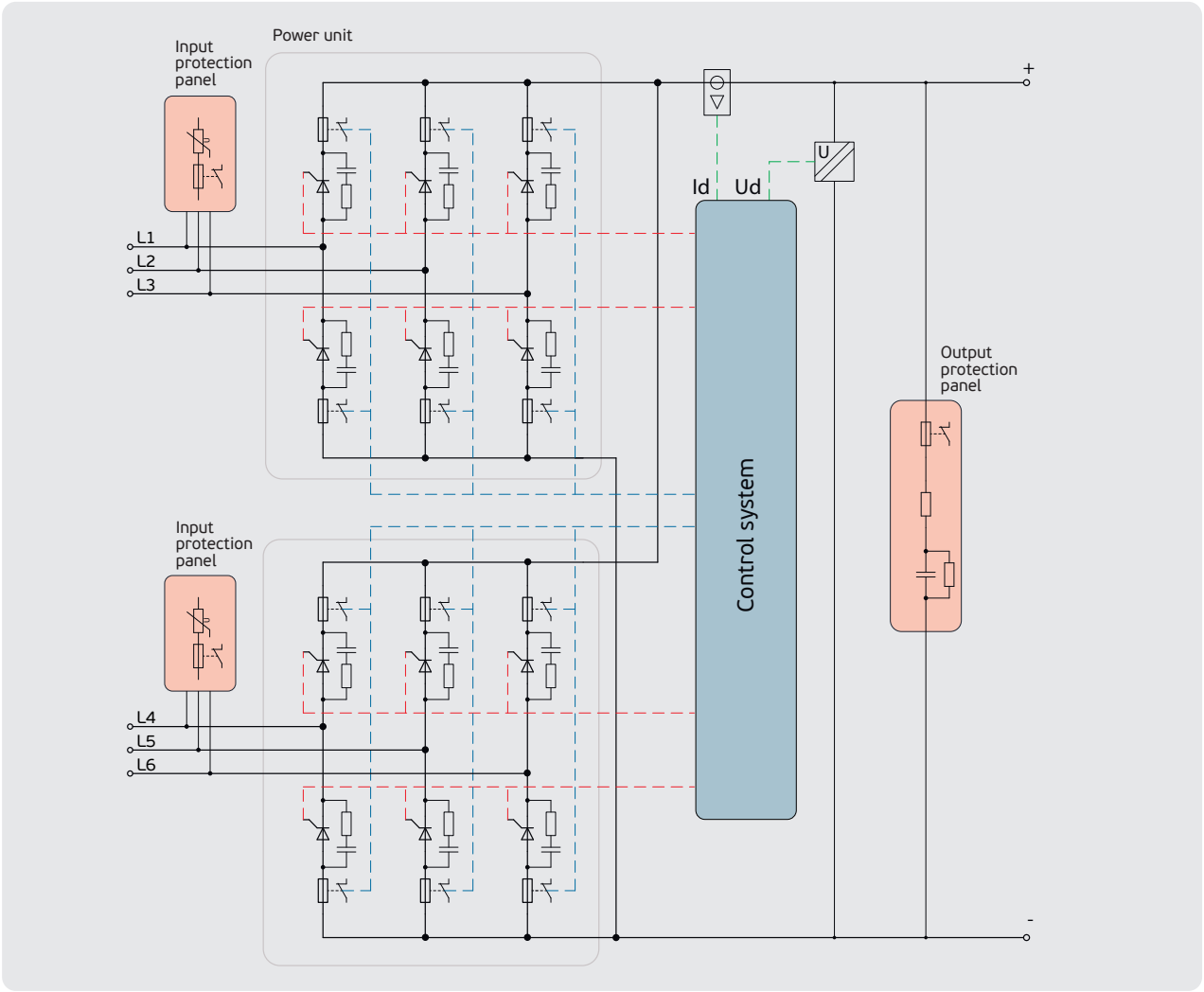
1

600 V, 750 V, 825 V, 1500 V, 1650 V 6-pulse rectification circuit



2

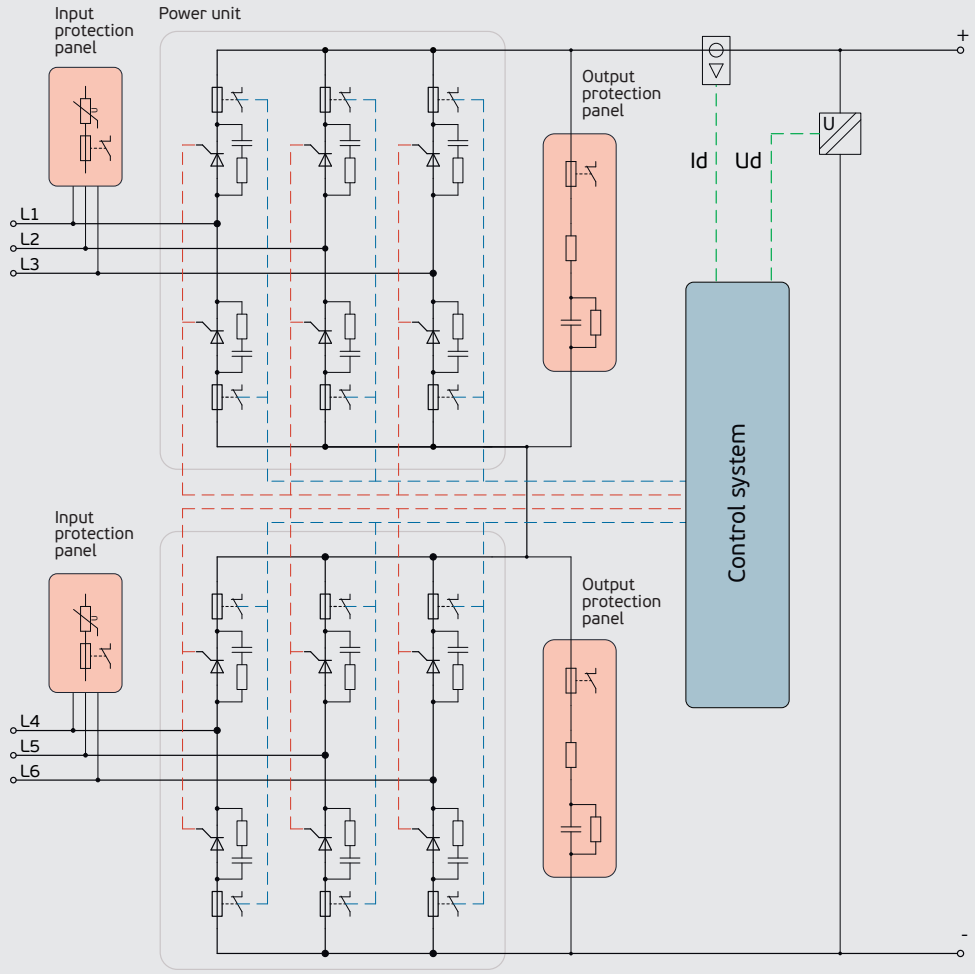
600 V, 750 V, 825 V, 1500 V, 1650 V 12-pulse rectification circuit



POWER SECTION CIRCUITS
(fixed rectifiers)

3

3000 V, 3300 V 12-pulse rectification circuit

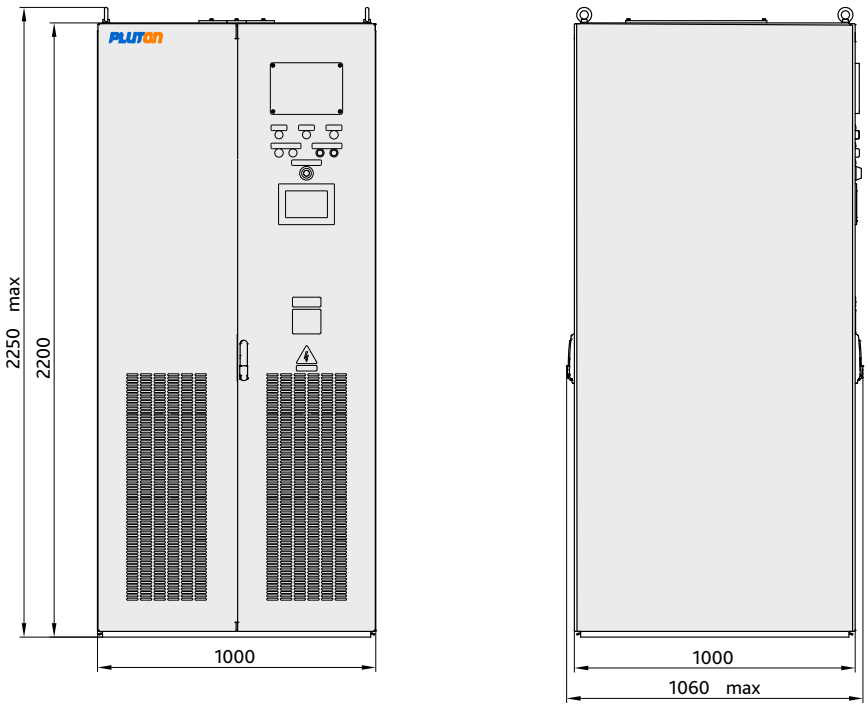


OVERALL DIMENSIONS
(fixed rectifiers)

Rated output voltage, V	Rated current, A	Rectification circuit according to EN 50328	W (Width), mm	H (Height), mm	D (Depth), mm	Dimensional drawing
600, 750, 825	1330	8, 9	1000	2200	1000	(Fig. 4 page 11)
1500, 1650	1250					
600, 750, 825	2670	8, 9	2000	2200	1000	(Fig. 5 page 12)
1500, 1650	2500					
3000, 3300	1250	12	2000	2200	1000	(Fig. 5 page 12)
	2500		4000	2200	1000	(Fig. 6 page 12)

4

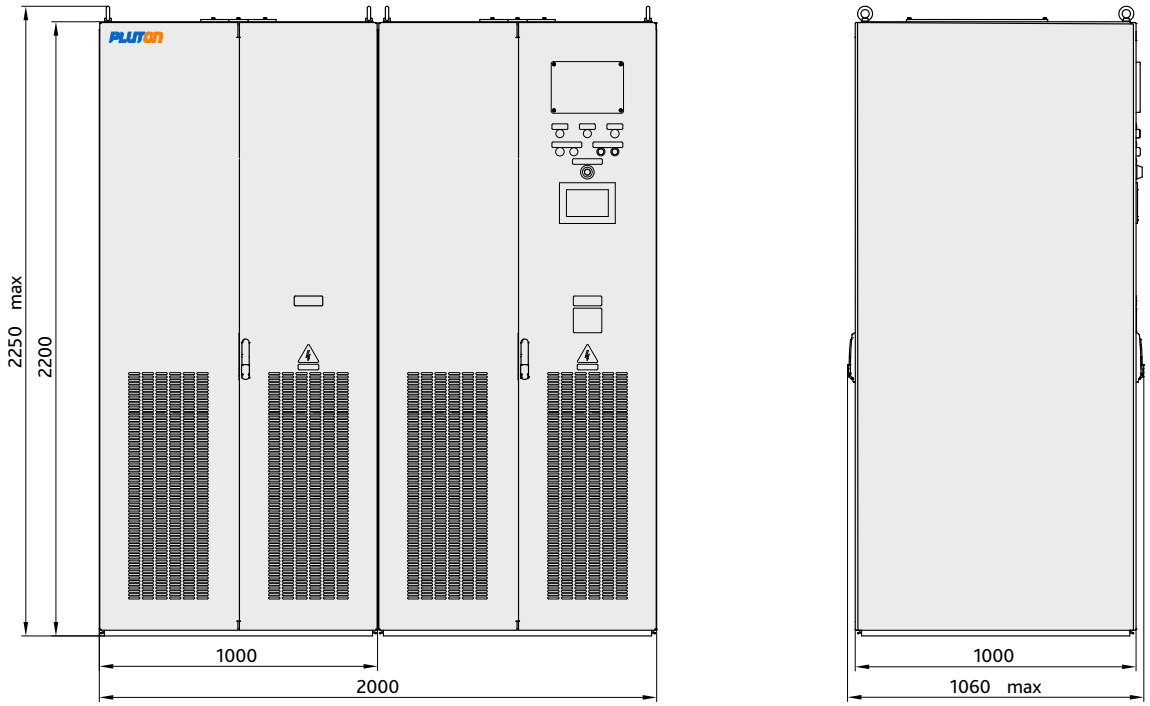
6-, 12-pulse rectification circuit



OVERALL DIMENSIONS
(fixed rectifiers)

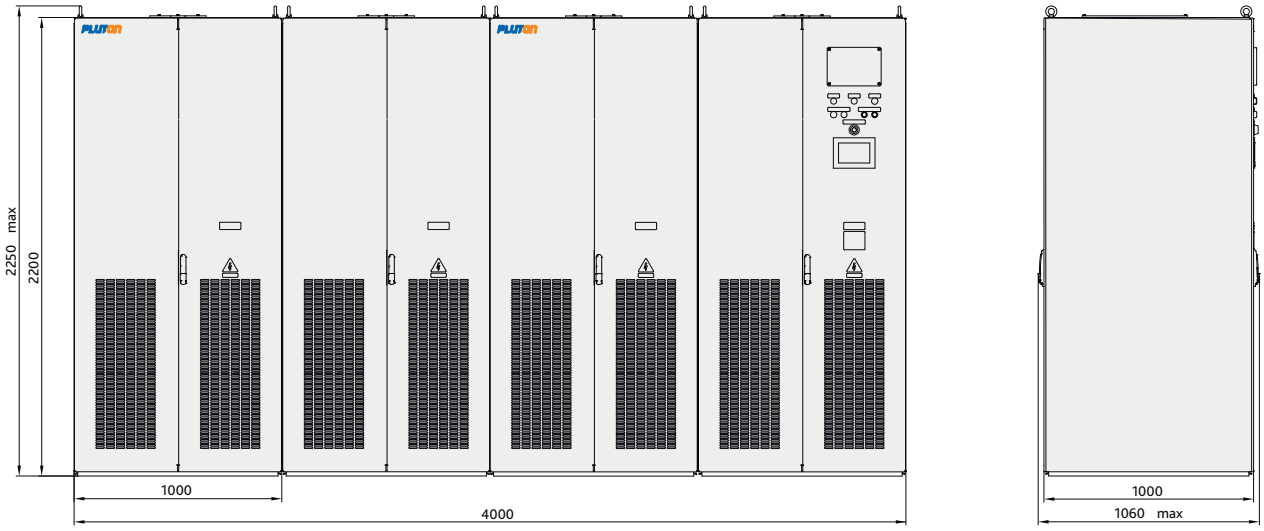
5

6-, 12-pulse rectification circuit



6

12-pulse rectification circuit



WITHDRAWABLE THYRISTOR RECTIFIERS

Withdrawable thyristor rectifiers are designed for construction of urban electric transport traction substations with load current electronic switching. These devices include **rectifier and switchgear functions**.

Thyristor rectifiers provide switching of a wide range of load currents without electromechanical system and without an arc, i.e. electronic switching is achieved by thyristors opening pulses removing.

BENEFITS

Power supply from the rectifier to the load is fully controlled in all operating modes

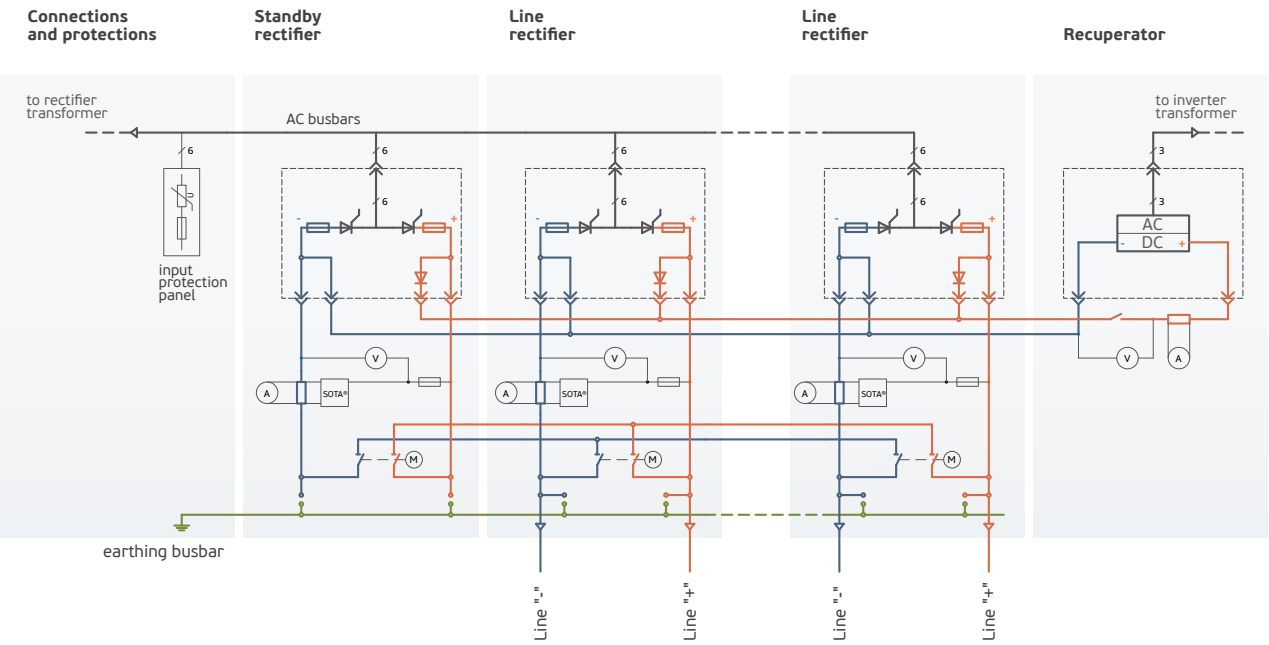
Implementation of “line test” function in traction network without additional equipment

No plasma emission at short-circuit currents interruption, since the switching is done with thyristors, as a result - no combustion products and their deposits

Easy inspection and maintenance due to application of withdrawable component

Reduction of fire hazard due to absence of plasma generation open sources

CONCEPT OF TRACTION SUBSTATION CONSTRUCTION WITH WITHDRAWABLE RECTIFIERS



The substation power equipment includes:

- Converter transformer for rectifiers (if necessary to connect more than one transformer, it is possible to sectionalize AC busbar);
- Line rectifiers - the main devices providing power and protection for a traction network section;
- Standby rectifier - provides reliable load power supply via a system of disconnectors in case of one of the line rectifiers failure or can be connected in parallel to the most loaded rectifier (optional);
- Recuperator - designed to transfer rolling stock braking energy to AC network and consists of inverter with switching device and matching converter transformer.

Thus, a new approach in organizing the equipment during construction or global reconstruction of traction substations is proposed.

OPERATING MODES

Two modes of the rectifier operation are provided:

- output voltage stabilization mode is the best solution for new traction substations;
- operation mode similar to diode rectifier (operation with minimum thyristor opening angle) - solution for modernized traction substations without replacing converter transformer.

DESIGN
(withdrawable rectifiers)

Withdrawable thyristor rectifier is based on standard arrangement of separate compartments common for many switchgear units:

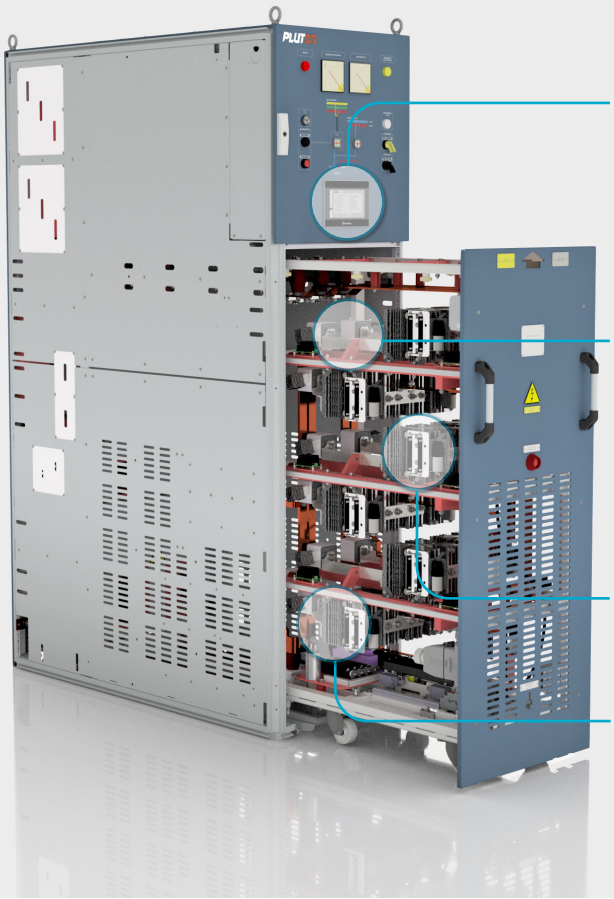
- automation and control compartment - low-voltage compartment with control and diagnostic system components;
- withdrawable unit compartment - power part of thyristor rectifier;
- busbar compartment - includes AC and DC busbars. The compartment is divided into several isolated compartments, allowing safe access for power cables maintenance even under voltage on power busbars.

Division into compartments also allows safe maintenance of high-voltage measuring circuits and standby disconnector, located in busbar compartment.

Withdrawable unit has three positions:
- operating;
- control;
- maintenance.

Withdrawable unit moves automatically from operating to control position with the help of low-power electric drive, without any effort from the operating personnel. At the same time, operational safety is guaranteed by electromechanical interlocks system and organizational measures.

MAIN COMPONENTS



Control system	**Traction network protection**
Power high-speed fuses	**Protection against internal short circuits**
Individualized RC circuits	**Protection against internal overvoltage**
Tablet power thyristors	

CONTROL SYSTEM
(withdrawable rectifiers)

Withdrawable rectifiers are equipped with microprocessor control and diagnostic system based on SOTA® controller and MC-POWER module.

System functions

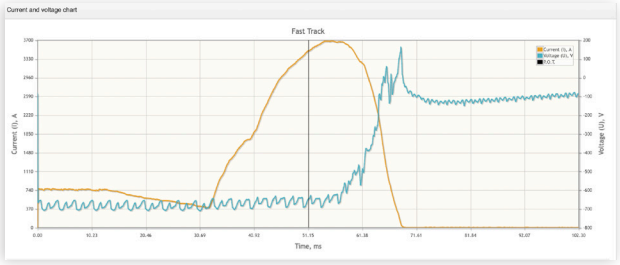
Control:
temperature, 2 levels
fuses tripping: - on power thyristors - on output protection panels
power unit position
Visualization:
rectifier status (on/off)
rectifier single-line circuit
values of rectified current and voltage
Control:
power unit rolling in/out
setting, changing, and saving settings parameters
selecting the rectifier control mode
Additional functions:
warning and alarm messages displaying
events log keeping
testing of the rectifier separate components
communication with the upper level (SCADA system)
support of IEC 61131, IEC 61850 protocols
Traction network protection:

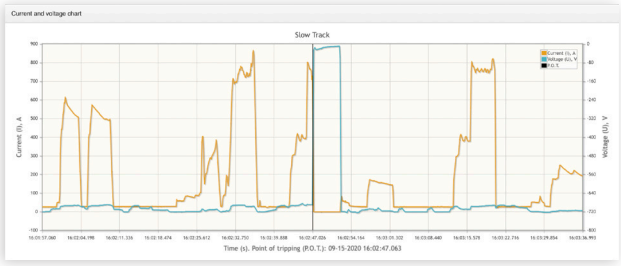
Types of electronic protection (ANSI code):
- instantaneous overcurrent (50);
- time overcurrent protection (76);
- current rate of rise protection;
- current increment directional protection;
- overvoltage protection (59);
- undervoltage protection (27);
- time/current protection (49);
- rectifier failure;
- DDL protection;
- impedance protection.

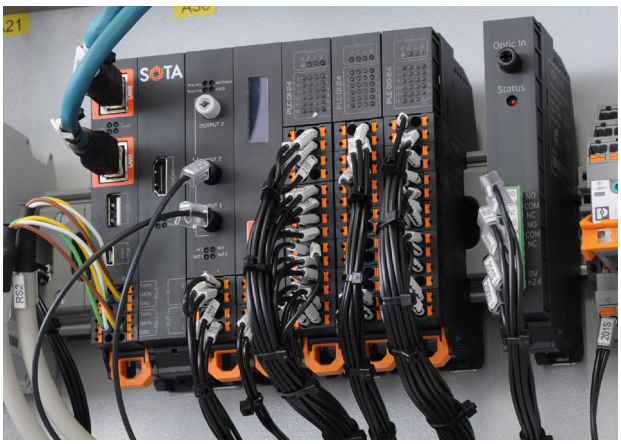
Similar to traditional switchgear, withdrawable thyristor rectifiers **protect traction network** by continuous monitoring and analysis of current and voltage variations dynamics in traction network and issuing rectifier tripping commands in case protective functions set parameters are exceeded.

SOTA® control system generates and saves two types of fault waveforms (current and voltage waveforms) each time one of protections trips:

- “Fast track” (time coverage depth is 100 ms);
- “Slow track” (time coverage depth is 100 s).







TECHNICAL CHARACTERISTICS
(withdrawable rectifiers)

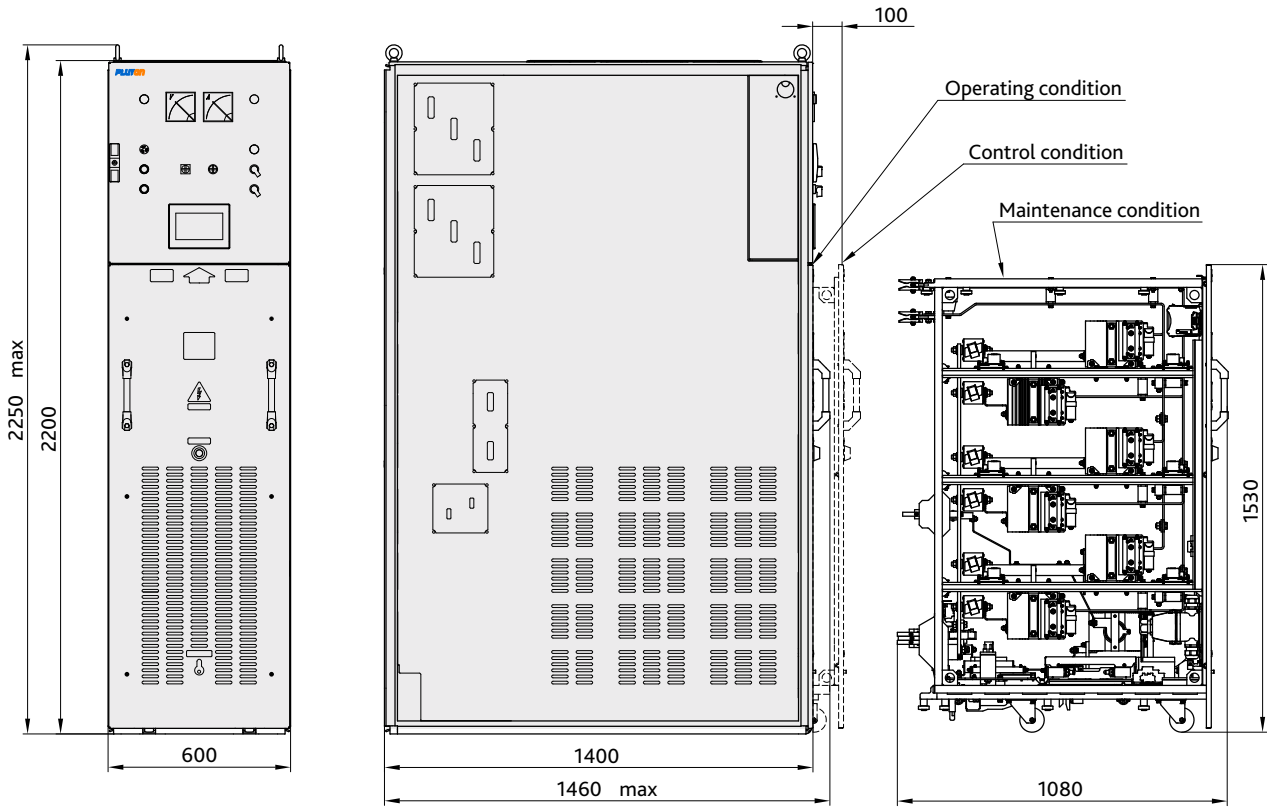
Parameter name	Unit	Value	
Rectifier power unit design circuit	-	thyristor-fuse	
Connection diagram number (according to EN 50328)	-	№ 9 (12-pulse, bridge)	
Rated voltage	V	600	750
Rated current	A	1000	
Auxiliary power network voltage	V	=110/220; ~230	
Rectifier type of cooling (according to EN 50328)	-	natural, air (AN) [1)]	
Duty class (according to EN 50328)	-	IV	
Output voltage adjustment range	V	500...700 [2)]	675...825 [2)]
Semiconductor devices failure mode (according to EN 50328)	-	T mode [3)]	
Efficiency factor (estimated), minimum	%	99	
Maximum ambient temperature	°C	40	
Height above sea level, max, without rated power reduction	m	1000	
Overall dimensions W x H x D	mm	600 x 2200 x 1400 (Fig. 7 page 18)	
IP class (according to IEC 60529)	-	IP2X	

1) ANAF combined cooling can be applied depending on current load requirements;
2) The parameter is specified by output voltage stabilization requirements;
3) Redundancy is provided by a standby rectifier.

OVERALL DIMENSIONS
(withdrawable rectifiers)

7

600, 750 V 12-pulse rectification circuit



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