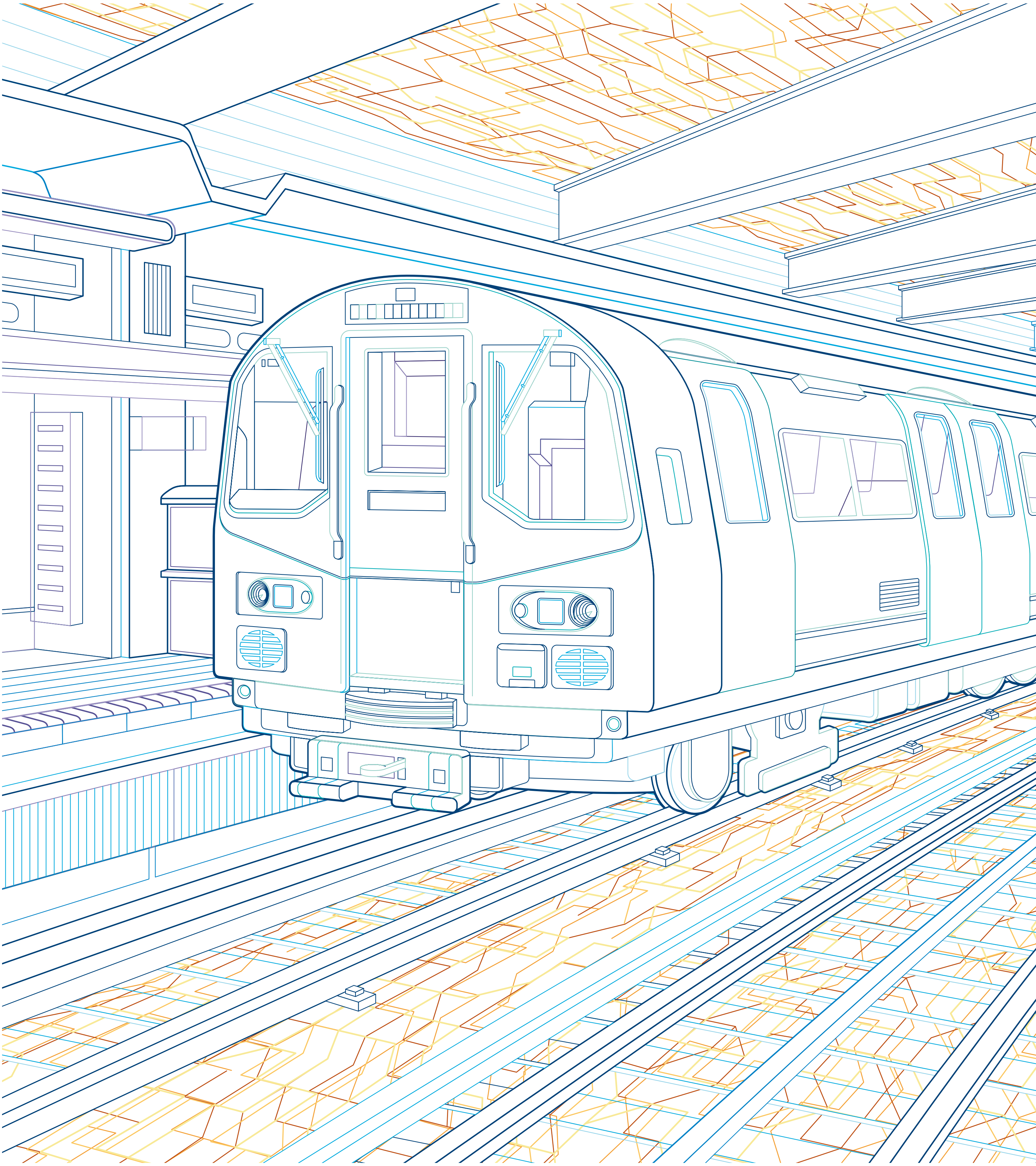
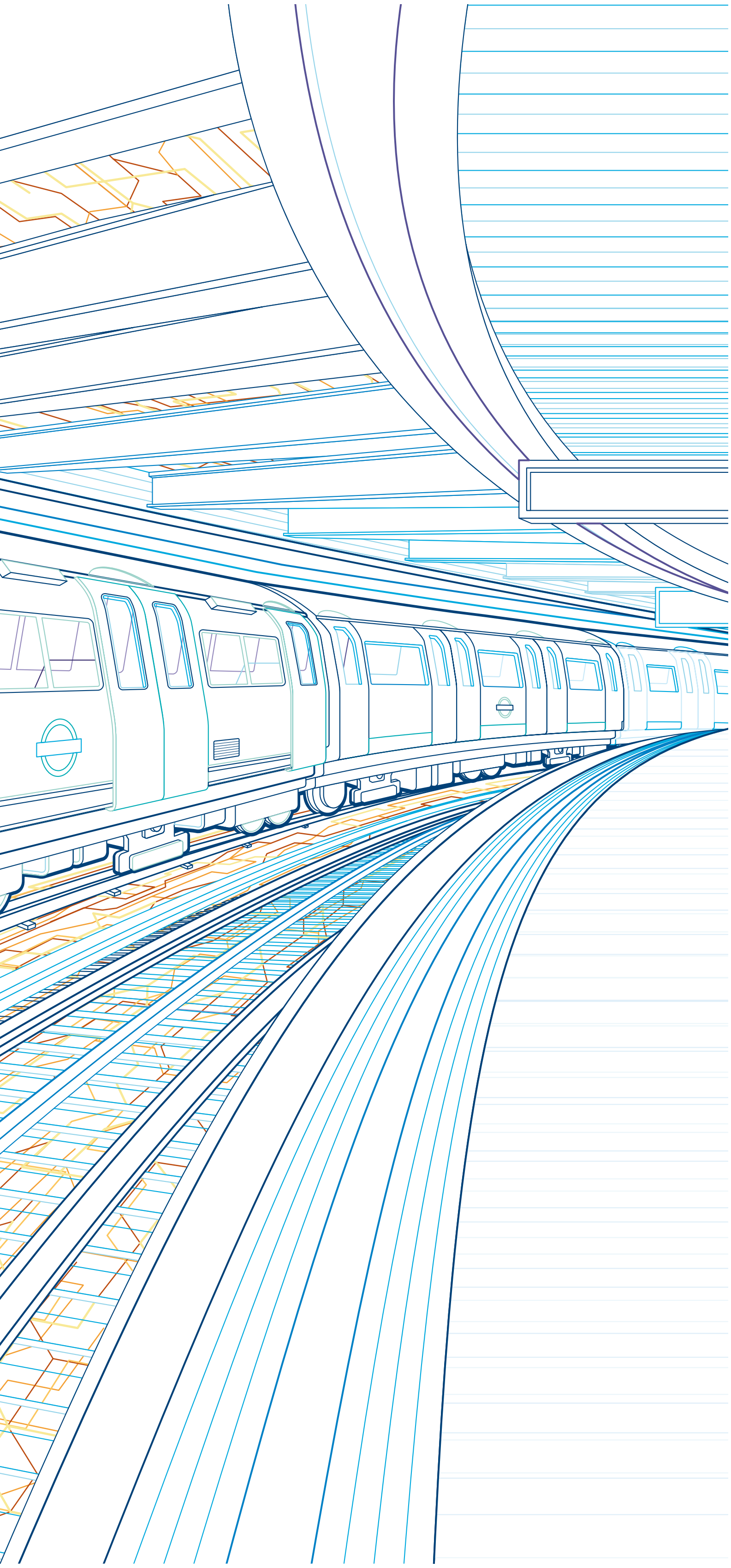
Traction Power Supply

ABB traction rectifiers
Diode rectifiers for DC traction substations

Power and productivity
for a better world™





Traction power supply is one of the most important parts of the transport infrastructure. It links the general AC medium voltage supply system and the DC supply line (catenary or third rail) of the traction vehicles. For applications in DC electric traction the naturally cooled silicon diode rectifiers are the most suitable because they combine simply design, low maintenance, high overload capacity and a long lifetime.

This short form technical catalogue describes the main electrical, mechanical and environmental features of the PD family diode traction rectifiers.

Introduction

In practice, a three-phase power supply is the most often used electricity source. Therefore, to be able to power trains using direct current, it is necessary to use an electronic power converter (rectifier). A traction rectifier is the essence of two components of the modern technology: electronics and industrial power engineering. Thanks to this element, railway and municipal tractions are able to convert alternate current into direct current with power ensuring that hundred-tonne trains reach high speeds. ABB has a large experience in designing, construction and start-up of traction rectifiers, supported with many prestigious references. It is, among others, thanks to our solutions that the longest and most used London Underground line – Victoria – is able to transport more than 200 million passengers a year. Also, municipal transport systems in Belarus and Algeria could develop and significantly increase capacities thanks to our engineers. We cannot forget about ABB's contribution in modernization of railway infrastructure and municipal transport in Poland where the number of installed rectifiers reaches one thousand. However, the most unique technological achievement so far has been a design prepared for the underground transit system in Brazilian São Paolo. The power system for the underground was designed in a manner enabling maximum use of electricity surplus, returning it back to the municipal supply system after conversion into alternate current. Such installations require application of the most advanced technologies, and so far only several similar solutions have been used in public transport systems worldwide.

Designers, engineers, as well as assemblers of ABB traction rectifiers are world-class specialists. Of course, their competence is best proven by successfully completed contracts. Their actions are also ranked very high in ABB Group, which is proven by the fact that in 2010 a new factory will be open in Poland, which will start a new chapter in ABB traction rectifier history.

Example of short fully enclosed bus-bars duct between transformer and rectifier

General description and design

The PD rectifiers' family is designed for the supply of DC traction loads like urban transport systems or main-line railways in ranges of following standard output voltages:

– up to 825 V DC
– 1500-1650 V DC
– 3000-3300 V DC

PD rectifiers offer optimized for natural cooling power density (small footprint) and maintenance friendly mechanical design. All types are type tested according to EN50328/IEC60146 and offers overload classes according to these standards.

To minimize the harmonic distortion the PD rectifier consists of two diode bridges connected in series or in parallel. Both bridges are prepared to be supplied from the two secondary windings of the transformer, this solution provides 30º phase shift and 12-pulse influence on supply network. Two 12-pulse rectifiers supplied by two three windings transformers with +/-7.5º phase shift of primary windings create 24-pulse rectifiers configuration. Single bridge 6-pulse rectifiers are available on request only.

The equipment should be installed indoors, otherwise it should be requested and agreed during ordering (e.g.: the rectifier can be fitted with internal heater, higher IP class and other facilities).

The diode rectifiers are encased in steel sheet cubicles with welded or bolted internal frame. This internal structure frame joining method depends on weight and environment conditions (e.g. earthquake immunity). In case of bolting PD rectifiers are always equipped with welded bottom frame.

PD rectifiers provide many variants of AC and DC connections. Standard design offers cable connection through the bottom or/and through the top.
The bus-bars duct connection between transformer and rectifier is recommended for higher currents. ABB offers such enclosed bus-bars duct as an option even the transformer is ordered separately (in this case customer has to provide all requested mechanical data of transformer).

Individual silicon diodes are mounted on an air-cooled heat-sink having adequate heat dissipation properties. Such diode with double-side heat-sink creates a diode module. Each diode module is protected with RC circuit.
All internal main circuit connections are made of copper busbars. The busbars cross section is adequate to the rectifier rating and natural cooling. Wherever it is necessary, flexible junction are used (e.g. bus-bar duct between transformer and rectifier).
Auxiliary devices are separated from main circuit and located in separate compartment inside main cubicle or in separate box located on the side wall of rectifier's cubicle.
All components are easily accessible from the front of rectifier's cubicle. In case of low current rectifiers where AC and DC connections are made by cables, ABB offers front and rear access cubicles also for easier maintenance.
As an option our cubicles could be equipped with interior lamps and large windows in front doors to let customer's staff examine rectifier's interior without deenergizing. Another very useful option from maintenance point of view is white colour painting of rectifier's interior.

1. Diode bridge | 2. Terminal box of auxiliary connections | 3. Complete diode module (diode, heatsink and RC circuit)
4. Control box of the rectifier

Low power
3kV rectifier

Input transformer requirements

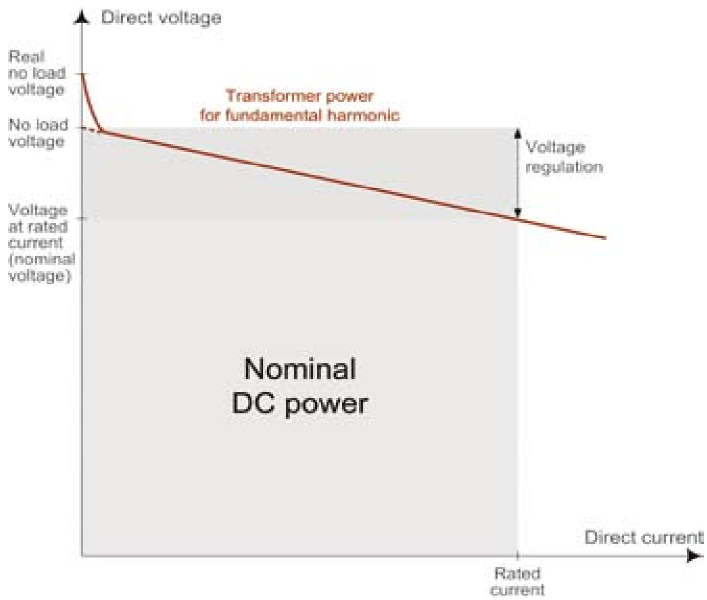
Each rectifier always cooperates with its supply transformer. This transformer provides adjustment the Medium Voltage (MV) to the level required by the rectifier and its load.

The next very important function of the input transformer is the output voltage regulation and short circuit current limitation. Both of these things depend on impedance voltage of the transformer and also on coupling factor of secondary windings (in three winding transformer). Higher impedance voltage causes higher voltage regulation and simultaneously lower short circuit current. The correct output voltage characteristic inclination provides appropriate load sharing between rectifiers supplying the same load. The limitation of short circuit current value is demanded by: supply network, DC switchgears or by rolling stock.

The input transformer has to provide also appropriate overload ability, which corresponds to the overload class of the rectifier.

ABB offers input transformer parameters calculation and other assistance even if transformer is ordered separately.

DC voltage versus DC current characteristic



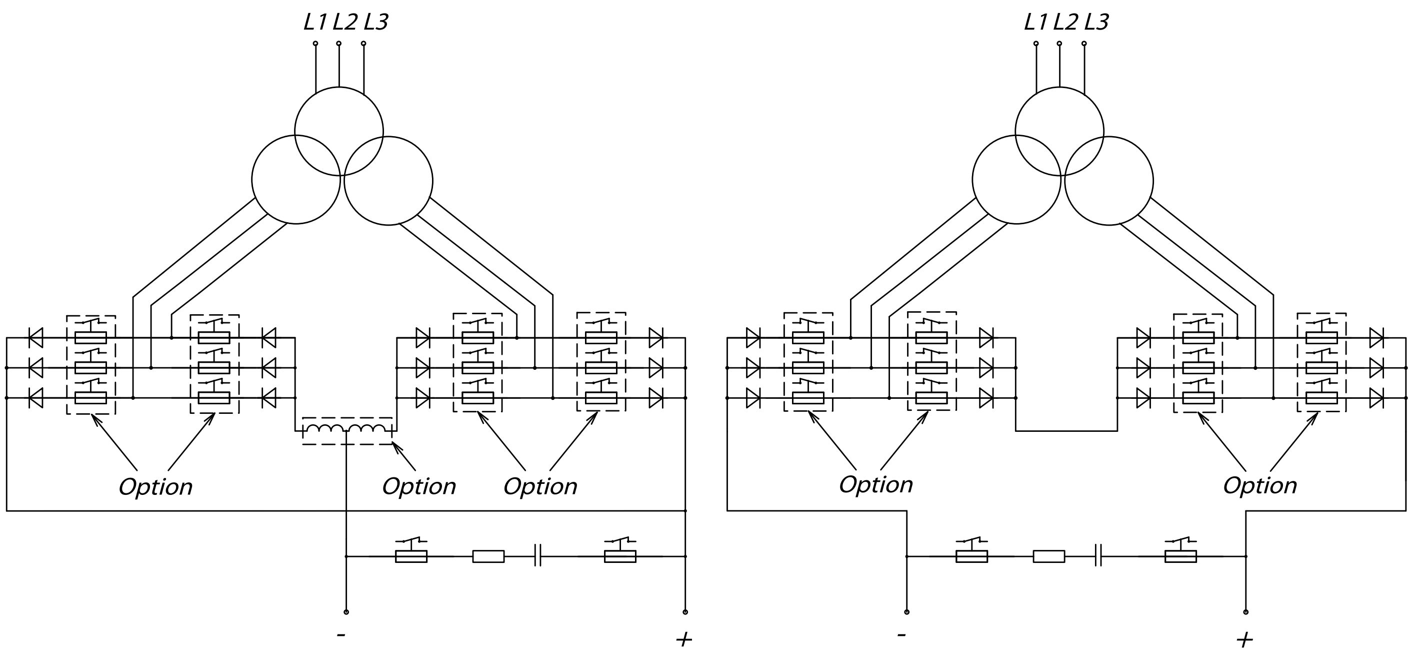
Advantages and disadvantages of serial and parallel topology

The most important advantage of parallel topology is decreasing of load losses (almost two times smaller than in serial configuration). It has an impact on the rectifier dimension, number of diodes and space required to dissipate heat produced by rectifier.

However the turn ratio unbalances between the Y- and D-windings of the converter transformer for 12-pulse converters (built up of two six-pulse bridges connected in parallel) causes discrepancies between theoretical and real harmonic level in supply network (especially for the 5-th, 7-th, 17-th and 19-th harmonics). To achieve the perfect balance the transformer windings connected to the rectifier bridges must generate exactly the same voltage. The number of turns should then be $\sqrt{3}$ times higher for the D-winding than for the Y-winding, but the number of turns must be an integer. Due to the low secondary voltage the number of turns must be comparatively few. Hence a turn ratio error is inevitable. The values of 5-th and 7-th harmonics are a few times higher in case of parallel than in serial topology however they do not exceed allowable level and this difference exists mainly at low load.

The conclusion is that a 12-pulse converter built up of two parallel-connected six-pulse bridges is very sensitive to turn ratio unbalances between the Y- and D-windings of the converter transformer. A 12-pulse converter built up of two series connected six-pulse bridges is much less sensitive to this type of unbalance. The secondary windings of the transformer should be made as decoupled to decrease this effect significantly (coupling factor < 0.2) or the output transition coil, which connects outputs of the parallel bridges, should be applied.

Parallel and serial configuration of rectifier's bridges.



3.3kV, 1700A rectifier with redundancy option

Protection

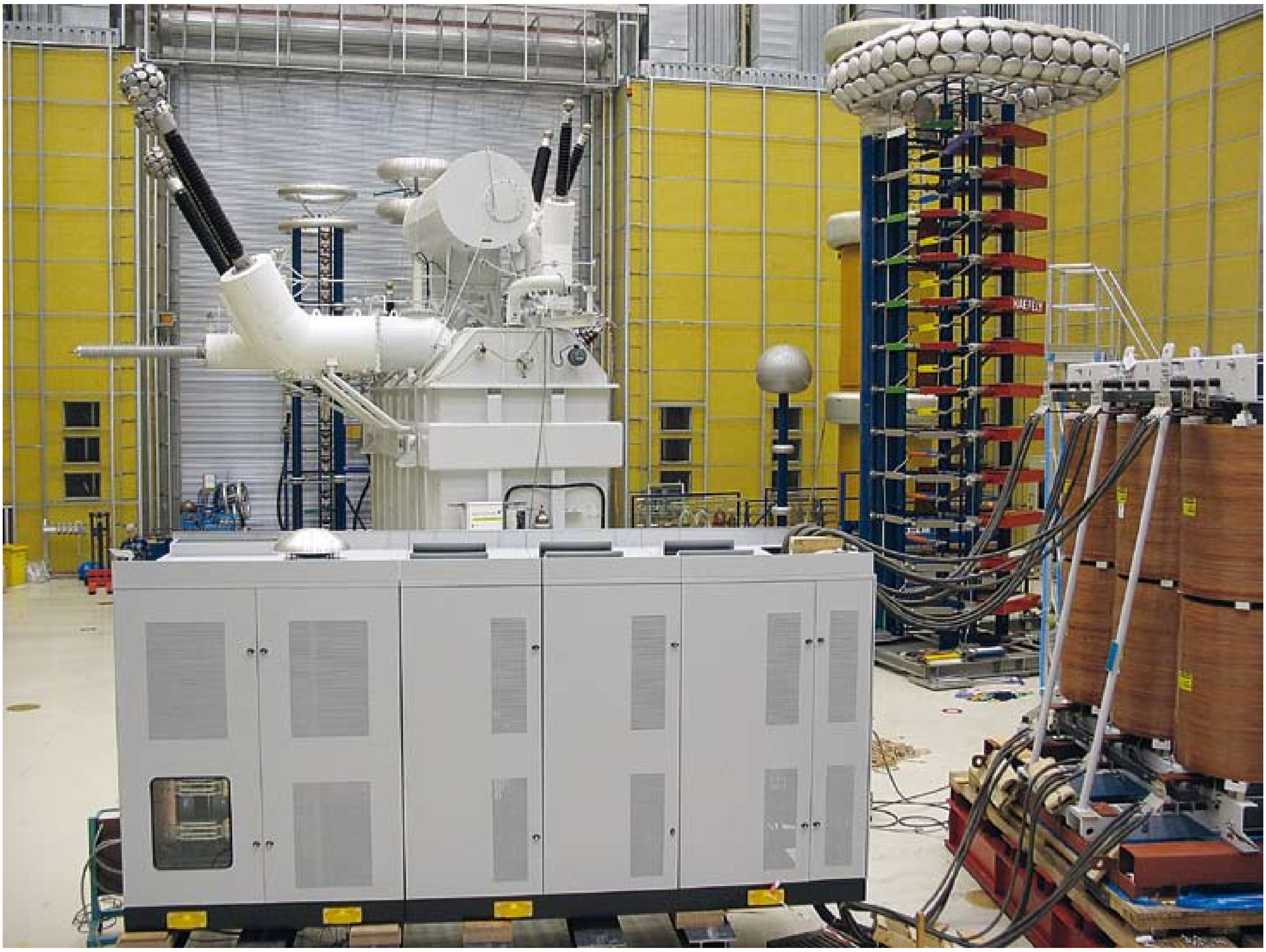
The rectifier-transformer set is protected against short circuit at the DC output by MV circuit breaker. It is the main protection of the unit.
Protection against overload is provided by external protective relay which is a part of MV breaker. This device protects transformer as well as rectifier. As an additional protection an overtemperature relay could be used. The rectifier is equipped with two level (ALARM and TRIP) overtemperature relays, which supervise heatsink's temperature. These devices could be considered as an additional overload protection. Moreover the rectifier could be equipped with an internal air temperature indicator as an option.
Protection against overvoltages is provided by RC circuit connected to the output terminals. As an option the surge arrester (metal-oxide arrester POLIM series) could be installed in the rectifier.
Protection against internal short circuit is also provided by MV circuit breaker. If there is no Ultra Rapid (UR) DC breaker between the rectifier and DC line, fuse topology of the rectifier has to be chosen to avoid supplying of shorted rectifier by other units connected to the same DC line.

Fuse and fuseless topology

The rectifier solution provides output short circuit immunity for at least 10 periods of supply network (200ms for 50Hz and 167ms for 60Hz). This time is long enough to break short circuit current by the circuit breaker on a primary side of transformer. For that reason the main circuit is made as a fuseless solution. This solution increases reliability of the rectifier significantly, because the rectifier is able to withstand many short circuits, which appear during normal operation at DC supply line (the third rail) without any deterioration of the rectifier's components. Obviously the solution with fuses is also available on request.

Redundancy

ABB offers two possible solutions of redundancy: by fuses or by additional serial diode.
The redundancy by fuse consists of two or more diodes (maximum four) in each arm of the bridge in parallel connection and each of them is provided with UR fuse.
The faulty (shorted) diode is selectively separated by fuse so the rectifier remains in operation. If only one diode fuse is blown

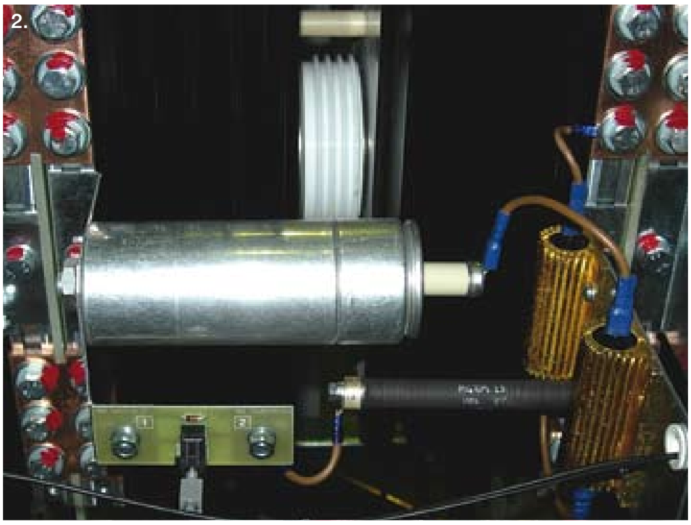


Test Field for non standard combined test of transformer and rectifier groups

(in one arm), the rectifier shall still be able to meet the rating specified at nominal plate. The operation of the fuse is transferred by potential free contact to rectifier's diagnostic system.

The redundancy by additional serial diode consists in serial connection of two or more diodes in each arm of the bridge.
In case of diode failure (internal breakdown) its resistance is close to zero in both directions so it can be considered as a conductor. The rectifier remains in operation if other diodes in arm have big enough reversal voltage strength. Obviously this solution causes higher losses during normal operation (higher voltage drop across arm) however it can be economically motivated in 3.3kV DC rectifiers (high voltage fuses are very expensive).

750V, 4000A rectifier with DC out through the top



1. Magnetic field sensor | 2. Voltage sensor and RC circuit details | 3. Diagnostics main board for voltage sensors

Diagnostics

The main task of the diagnostics circuit is monitoring of diodes. It helps staff to find faulty diode without additional measurement. Obviously this circuit is also able to generate the trip command to the superior system (or directly to the MV circuit breaker) however the rectifier-transformer unit has to be protected by MV circuit breaker independently from diagnostics.

The diagnostics sensors solution applicable in the rectifier depends on rectifier topology. If there is no serial connection of diodes in one arm, the magnetic field sensors are used. If arm of the rectifier bridge is created by two or more diodes connected in series, the reversal voltage across diode is monitored. In case where the fuses are used, the fuses micro-switches work as sensors.

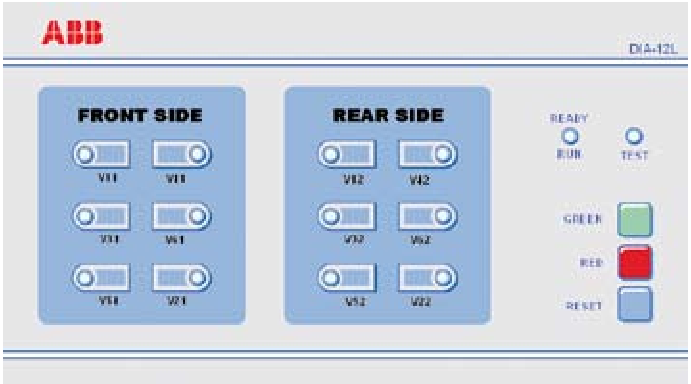
The magnetic field sensors detect direction of current flow. If pulsating current in at least one sensor doesn't appear in correct direction when output current exceeds certain level of nominal current (10-20% depending of rectifier's power), an alarm signal is generated within 200ms. If a current appears in wrong direction in at least one sensor, trip signal is generated immediately independently from the level of output current. Sensors are mounted directly on the diode's busbars. In one non dismountable enclosure are placed two single directional field sensors and testing coil. This solution provides galvanic insulation from the main circuit and also allows testing of all diagnostics devices (sensors, wires, boards and displays).

The reversal voltage diode sensors are mounted directly at the heat-sink of the monitored diode. They generate pulse signal when appropriate reversal voltage appears. If these pulses disappear, it means that monitored diode is shorted. To avoid unexpected operation of diagnostics when the main circuit supply voltage is off, additional supply voltage sensor is used. To provide appropriate insulation level between main and control circuit the fibre optics are used. Each voltage sensor is connected to the main control board of diagnostics panel via individual fibre optic.

Diagnostics panel

The main board of diagnostics contains microprocessor based logical circuit, which collects data from all sensors and stores information about the failed element into memory, which has to be cleared manually. This board provides self-test feature, which generates FAULT signal in case of internal malfunction.

The diagnostics display consists of two color LED diodes (one diode belongs to one power diode), which show condition of power semiconductors. Three pushbuttons also exist on panel surface: two to check diagnostics in both directions and one to reset information about reason of failure from memory.



Diagnostics panel

The rectifier and transformer selection

To choose appropriate rectifier and transformer, correct input data has to be known:

– rated requested DC power (or current),
– rated requested DC voltage,
– requested overload ability,
– requested topology (serial or parallel, fuse or fuseless)
– ambient conditions (IP requirements).

Having these data please contact the nearest ABB representative and the most suitable rectifier will be selected by our staff as soon as possible. In case of non standard requirements ABB is ready to prepare tailor-made design also to fit to customer's requirements.

The table below shows main technical data of PD rectifiers.

Rated DC voltage	**[V]**	up to 750[1]	1500÷1650	3000÷3300
Max. output voltage	**[V]**	900	1900	3800
Rated current	**[A]**	800÷4800	800÷3000	300÷3000
Overload class		VI according to EN50328/IEC60146		
Efficiency	**[%]**	>99.5 >99.2 serial conf.	>99.7	>99.7
Max. ambient temp.	**[°C]**	40 (up to 55 with derating)		
Min. ambient temp.	**[°C]**	0 (up to -20 as an option)		
Max. installation altitude	**[m.a.s.l.]**	1000 (up to 4000 with derating)		
IP class (IEC60529)		IP20÷IP21, IP30÷IP32, IP40÷IP45		
Rated insulation voltage	**[kV]**	0.9÷1.8	2.3÷3.0	3.6÷6.5
Power frequency withstand voltage	**[kV]**	2.8÷4.6	5.5÷9.2	11.5÷23
Width [2]	**[mm]**	830÷2400	1054÷2800	1054÷2800
Depth [2]	**[mm]**	852÷1452	1054÷1452	1054÷1452
Height	**[mm]**	2022÷2200 [3]		
Weight [4]	**[kg]**	420÷2800	450÷1900	450÷1900

1) 825VDC available as an option.
2) Dimensions of rectifiers without redundancy.
3) Dimension of IP20, in case of higher IP class – up to 2600.
4) Weights refer to IP20.

The rectifier type code

1/2	P D –	**Product Type** PD-diode rectifier			
3/4	1 6	**Current Rating** in hundreds of amperes (rounded to full hundreds)			
5	S /	**Bridges Topology S**-serial, **P**-parallel, **R**-parallel with output inter-phase reactor, **V**-six pulse rectifier			
6-8	7 5 0 –	**Nominal DC Voltage** in volts (above 1kV in kV separated by dot eg. **3.3**)			
9	0	**Redundancy**			
		0-no redundancy without fuses 1-no redundancy with fuses	2-redundancy by add. serial diode 3-redundancy with fuses		
10	0	**Diagnostics**			
		0-no diagnostics 1-diagnostics with magnetic field sensors	2-diagnostics with voltage sensors 3-diagnostics with fuses microswitches		
11	0	**Measuring instruments**			
		0-no meters 1-ammeter	2-ammeter and voltmeter 9-version		
12	0 –	**Auxiliary supply**			
		0-no aux. voltage needed 1-110VAC/DC	2-230VAC 3-230VAC/220VDC 9-version		
13	2	**IP protection class** (first digit – protection against solid objects)			
14	0	**IP protection class** (second digit – protection against liquids)			
15	1	**AC input bars/cables terminals**			
		0-top entry (typically IP-X0) 1-upper part sidewall entry	2-bottom entry 9-version		
162	2	**DC output bars/cables terminals**			
		0-top entry (typically IP-X0) 1-upper part sidewall entry	2-bottom entry 9-version		
17	0 –	**Enclosure Finish**	(0-standard, 9-version)		
18	0	**Non standard equipment**			
		0-no additional equipment 1-overtemperature protection 2-interior heater controlled by thermostat 3-internal lamp 4-door limit switch	A-(1+2) B-(1+3) C-(1+4) D-(2+3) E-(2+4)	F-(3+4) G-(1+2+3) H-(1+2+4) G-(1+3+4) H-(2+3+4)	J-(1+2+3+4) 9-version

Output characteristic and energy recovery

In some applications it is necessary to have U=f(I) characteristic other than natural characteristic offered by transformer and diode rectifier unit. In such cases ABB suggests to use thyristor rectifiers to create U=f(I) according to customer requirements. Such rectifiers are available in ABB's portfolio for all voltage levels mentioned in this catalogue.

If it is reasonable to send energy from braking trains to AC supply network, ABB offers also thyristor inverters. These inverters could cooperate with thyristor or diode rectifiers.

Example of 12-pulse thyristor rectifier (inverter) for traction purposes.

Contact us

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