PLUTON TURN ON THE FUTURE

# REGENERATORS, SERIES I-PTE

METRO

## REGENERATORS I-PTE

Converter sections, series I-PTE, produced by PLUTON together with dry-type transformers, manufactured by RESIBLOC® technology are applied as regenerators for metro traction substations.

### Advantages of regeneration

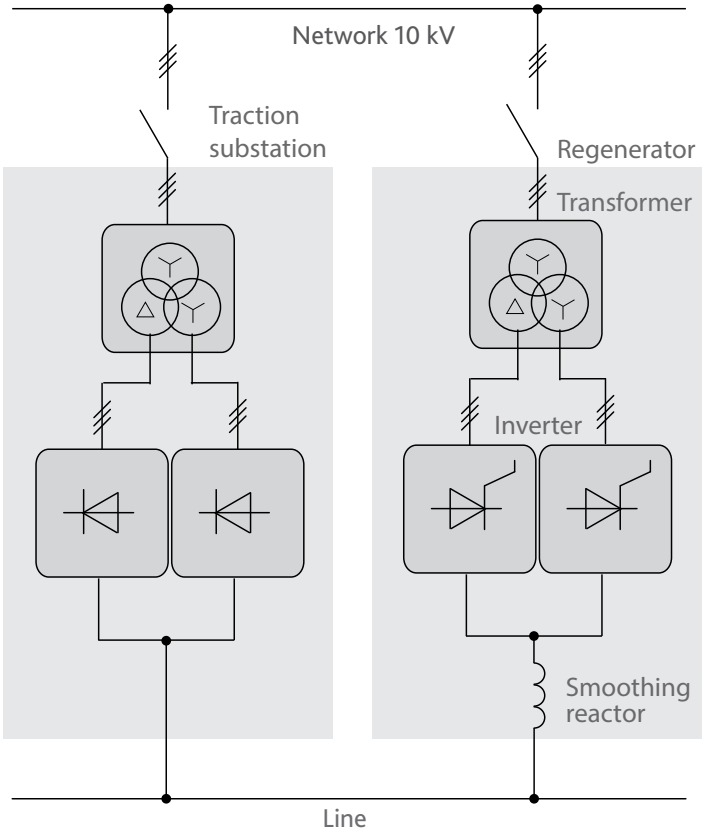
Application of regenerators allows to:

- improve metro energy indicators by regeneration of energy released during train braking (having regenerative braking mode in electric rolling stock);
- reduce overvoltage level occurring during regenerative braking;
- facilitate metro ventilation modes (studies show that application of dynamic braking dissipating the braking energy as heat in resistors leads to a marked increase of power required for metro ventilation);
- save up to 30 % of electricity consumed by rolling stock, depending on the terrain.

Thus, application of regenerators allows to regenerate braking energy back to network and reduce power consumed by ventilation system; this reduces metro overall power consumption.

Regeneration may be done by connection of additional converter regenerating energy back to network.

In this case regenerator – grid-controlled inverter with its converter transformer is added to the existing traction substations.




▲ Simplified diagram of regenerator connection

Smoothing reactor can be switched on, or converter transformer power can be increased to eliminate circulating currents on DC side.

Advantages of this option:

- possibility to regenerate any power back to network by increasing the number of regenerators;
- traction transformers are not loaded with regeneration current;
- flexibility of technical solutions related to selection of installation sites and choosing the power of equipment for regeneration.

▲ Regenerator converter section

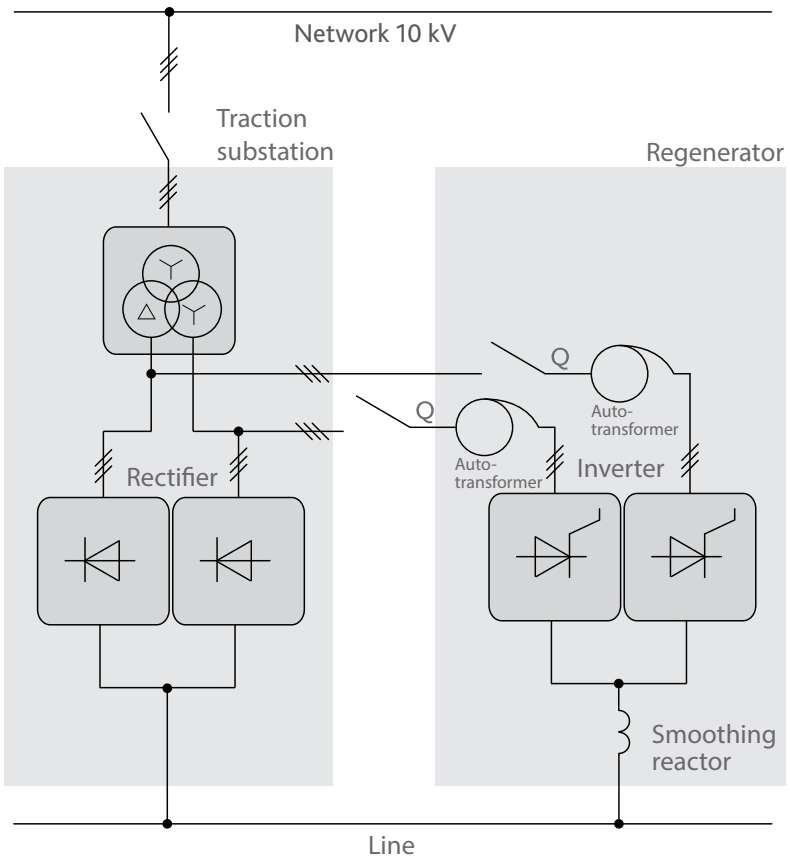
Autotransformer circuit can be applied as another version of additional converter switching on. In this case, inverter is connected to the actual traction transformer via AT autotransformer. Disconnector (Q) allows taking regenerator out of operation without rectifier tripping if required. Number of disconnectors and autotransformers should be doubled for the 12-pulse version. This version can be recommended upon modification of actual substation under limited space conditions.

Benefits of this version:

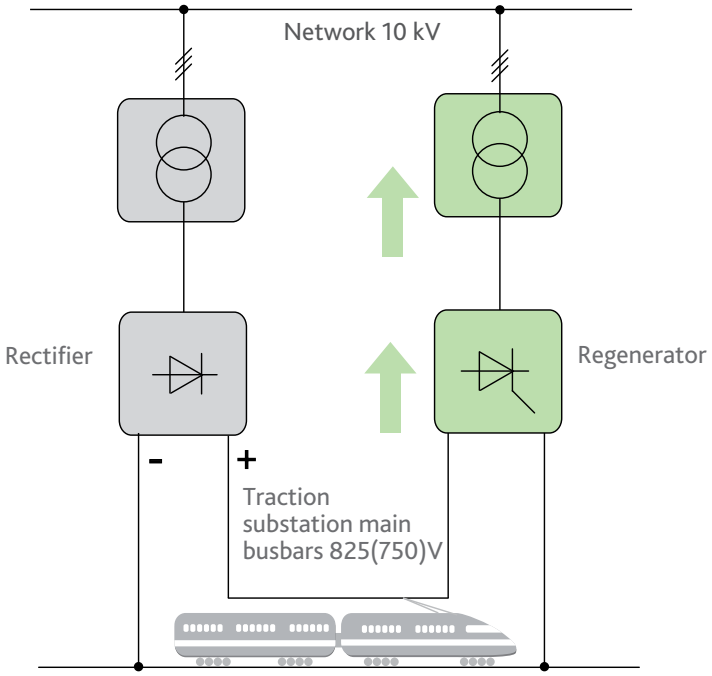
- no separate medium voltage switchgear;
- cost saving on transformer.

Disadvantages:

- regenerator capacity is limited by traction transformer capacity;
- no possibility to switch traction rectifier with inverter connected to its transformer to the "backup" mode.




▲ Autotransformer diagram of regenerator connection




▲ Energy flow during regenerator operation

Figure on the left shows switching and the ways of energy regeneration. Any time braking energy can be given via regenerator to medium voltage network, transferred over long distances and used by different consumers both auxiliaries (escalators, lighting, ventilation) and others.

The latest developments in converter technology were used in design and manufacturing of regenerators, series I-PTE. This applies to the design of cabinet, converter power part, electrical installation, regenerator protection systems, diagnostics and control circuit design and technological solutions, as well as maintenance and repair technologies.

## CONVERTER SECTION

Converter section (hereinafter "CS") is a thyristor six-valve bridge, rated current 800 A. 12-pulse inversion circuit is traditionally used, i.e. two sections of 800 A each, switched with a shift of 30 electrical degrees. Total current of two sections is 1600 A.

Such circuit has an advantage in comparison with traditional 6-pulse inversion circuit in terms of harmonic composition of inverted current and voltage. 12-pulse circuit (m=12) will have the following harmonics:
n=1, 11 (9 % of the first), 13 (7.6 % of the first), etc. There are no 5th and 7th harmonics compared to 6-pulse circuit.

It is known that network transformer additionally improves (due to switching processes) the spectrum of current consumed from network. Content of the 11th and 13th harmonics is reduced by at least by 2 %.

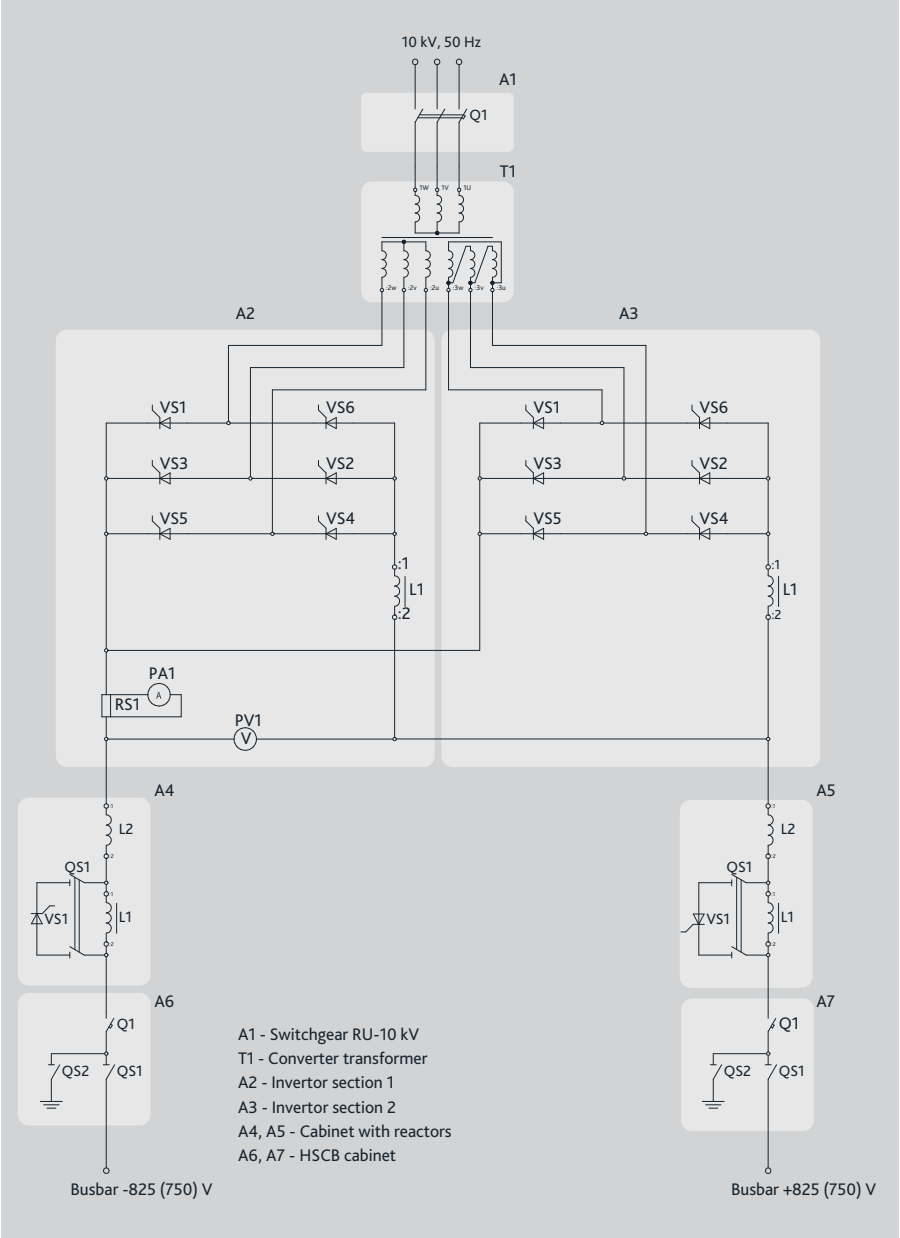
As a result, current harmonic values at converter transformer input will be as follows:
- for the 11th harmonic - 7 % of the first one;
- for the 13th harmonic - 5.6 % of the first one.
Inverted current harmonic distortions do not exceed the allowed values for medium-voltage networks according to international standard IEEE STD 519-1992 HARMONIC LIMITS, and do not exceed the distortions of 6-pulse diode rectifiers operation. Hence, there is no need to apply additional network filter-compensating devices. Existing devices for 6-pulse rectifiers are enough, if they are installed.

Regenerator capacity can be expanded by connection of two additional sections to the existing two. It will provide rated current of 3200 A.

Further expansion of capacity makes no sence, because modern metro substations do not need more powerful regenerating units.

CS series I-PTE, were developed and manufactured using the most modern technologies, materials and components from leading world manufacturers. CS are based on power pill thyristors 2760 A, class 28, produced by Dynex. CS cooling is natural or forced air, depending on CS operating conditions.

CS power part is made using maintenance-free contact connections technology. Special compensating devices produced in Germany are used to fix clamping on contact joints, irrespective of temperature and thermal daily and seasonal oscillations. Power semiconductors in CS are protected against internal and external switching overvoltage. Protection is provided by RC-circuits against internal switching overvoltage, and against external switching - in combination by: RC-circuits and varistors (overvoltage protection panel).




▲Regenerator simplified diagram

## CONTROL SYSTEM

Control system is based on MC-40 microprocessor module developed by PLUTON. This module fulfills control, diagnostic and protection functions of regenerator.

Each CS has the following protections:

- against internal short circuits;
- against external short circuits;
- input current limit by discrete-configurable setting;
- time-current protection;
- against invertor triggering;
- against network voltage slump;
- against power thyristors overheating;
- against overvoltage on power thyristors;
- against unequal phase sequence of network voltage;
- against control pulses dump;
- against input overvoltage;
- against transformer overheating.

CS has measuring instruments for input voltage Ud, input current Id and regenerated energy meter.

## RESIBLOC® TRANSFORMER

Modern dry transformers manufactured by RESIBLOC® technology, with different combinations of HV and LV (up to 45 kV) are supplied as converter transformer. RESIBLOC® transformers are certified in Europe and most of CIS countries, as well as in many other countries. Transformers have original design of primary and secondary windings made of copper wire and aluminum foil.

RESIBLOC® transformers are able to withstand maximum temperature fluctuations without damage of epoxy surface and formation of microcracks.

Transformers operate under conditions of 100% humidity and water vapor condensation, as well as under conditions of chemical pollution.
Transformer protection degree - IP00, IP21, IP23, IP54.

It is recommended to connect rectifier and inverter sections to one transformer during construction of new substations. In this case the rectifying sections are connected to the taps of transformer secondary windings.

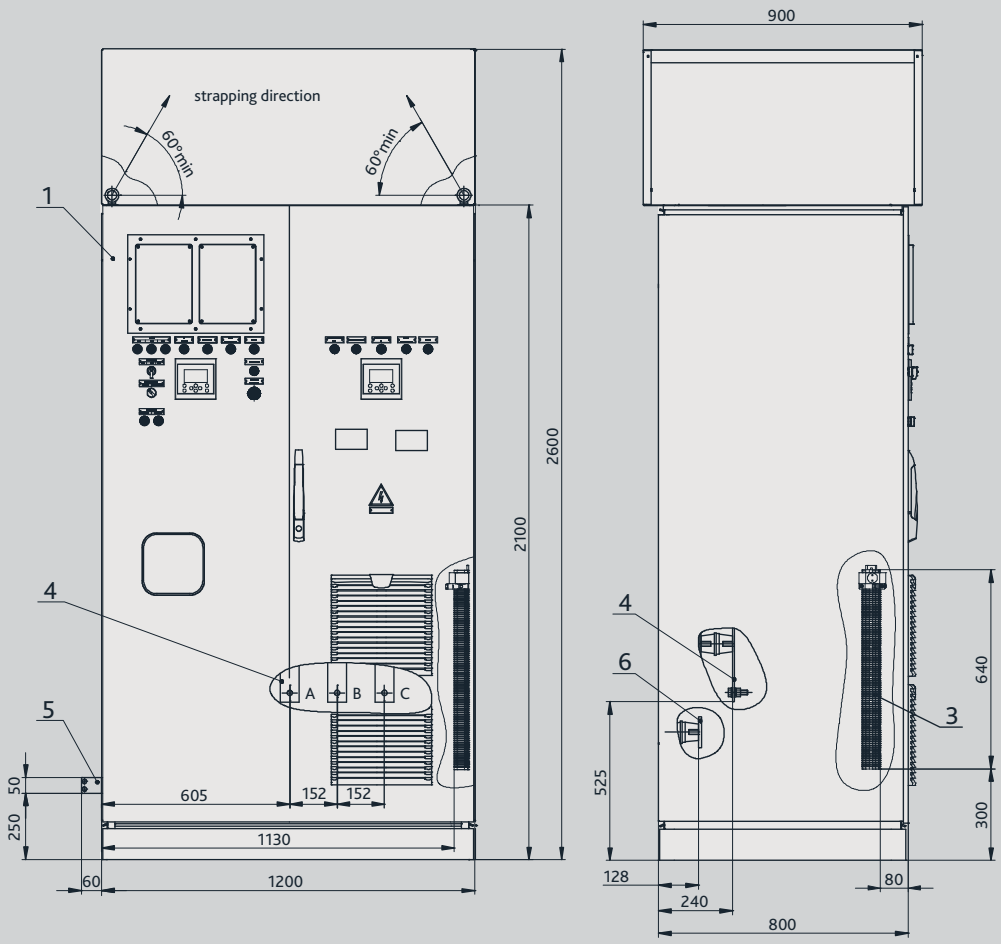
This substantially saves basic costs and shortens the payback period for braking energy regenerators.

## MAIN TECHNICAL PARAMETERS OF REGENERATORS

| Name of parameters | Unit | Value | | |
|---|---|---|---|---|
| Type of regenerator | - | I-PTE-800-825-50-6 | I-PTE-1.6к-825-50-12 | I-PTE-3.2к-825-50-12 |
| Rated output voltage | kV | 6.3 , 10 , 35( ±10 %) | | |
| Output voltage frequency | Hz | 50 (60) ±1 | | |
| Number of output voltage phases | - | 3 | | |
| Number of inputs | - | 1 | | |
| Operation mode | - | Intermittent S3, RC = 40 % | | |
| Rated input voltage | V | 825 (750) | | |
| Regeneration setting adjustment range | V | 810…950 (725...850) | | |
| Rated inverted current | A | 800 | 1600 | 3200 |
| Maximum ratio of current overload | - | 1.5 | | |
| Overload time | s | 30<br>1 time per 10 min, wherein current RMS value for each 15 min should not exceed rated current value | | |
| Type of cooling | | Natural or air combined | | |
| Efficiency coefficient, minimum | % | 96 | | |

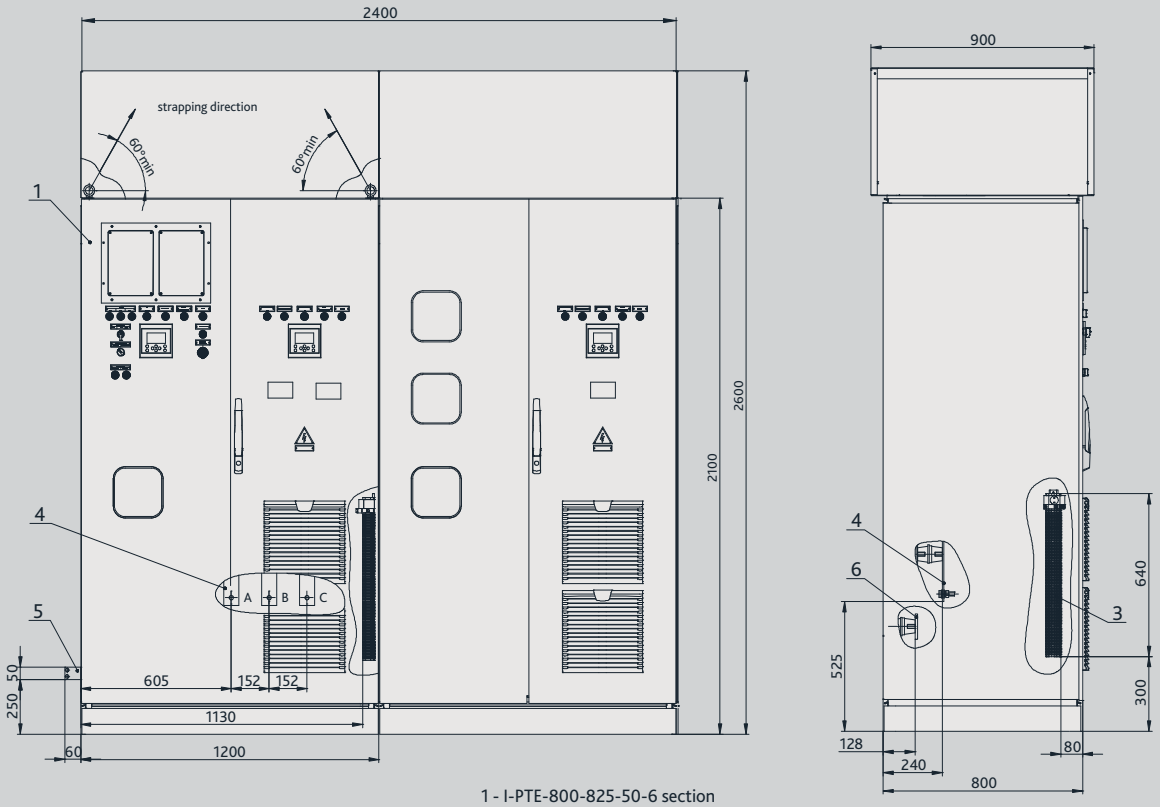
* - cooling method, which uses natural air cooling of thyristors, and the installed in sections fans switch on automatically for a short time, when temperature rises to the set level, and switch off when the temperature decreases.

## OVERALL DIMENSIONS OF CS I-PTE-800-825-50-6



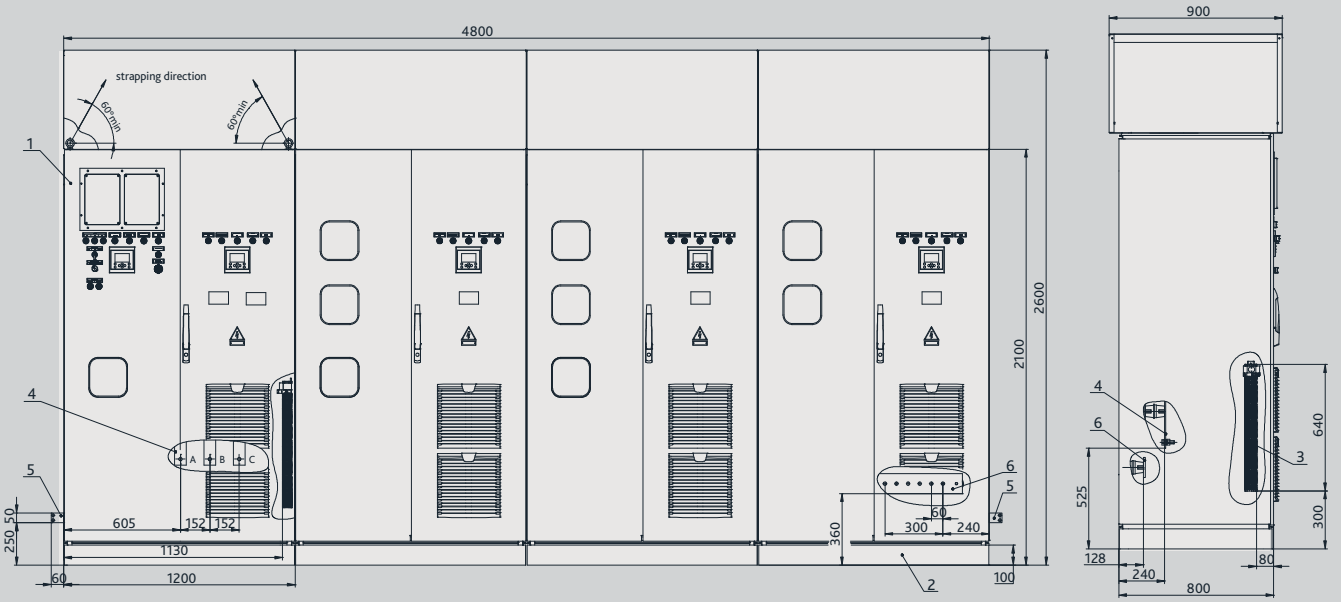

1 - I-PTE-800-825-50-6 section
2 - Base
3 - Control circuits terminal block
4 - Power cables connection busbar
5 - Earthing busbar
6 - DC outputs

## OVERALL DIMENSIONS OF CS I-PTE-1.6K-825-50-12




1 - I-PTE-800-825-50-6 section
2 - Base
3 - Control circuits terminal block
4 - Power cables connection busbar
5 - Earthing busbar
6 - DC outputs

## OVERALL DIMENSIONS OF CS I-PTE-3.2K-825-50-12




1 - I-PTE-800-825-50-6 section
2 - Base
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5 - Earthing busbar
6 - DC outputs

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