RECTIFIERS

CITY ELECTRIC TRANSPORT ■
RAILWAYS ■ METRO
ABOUT COMPANY

PrJSC “Pluton” is one of the largest manufacturers of electrotechnical equipment on the territory of Ukraine. The company’s products are supplied to many countries around the world. PrJSC “Pluton” holds key position in electrical industry and has been successfully working for over 20 years, realizing the strategy of intensive growth, development and continuous improvement of products quality and services.


PrJSC “Pluton” uses materials with minimal impact on environment in its production. The materials are safe not only during operation, but also at the end of product life. We have confirmed compliance of our management principles with Environmental Safety ISO 14001:2004 international standard requirements.

RECTIFIERS FOR TRACTION SUBSTATIONS

We have vast experience in designing, manufacturing and commissioning of rectifiers. Our solutions are successfully used in city transport, metro and railway systems in Ukraine, Russian Federation, Republic of Belarus, Republic of Kazakhstan, Republic of Uzbekistan, Latvia, Sweden, Republic of Azerbaijan and other countries.

We provide a full range of services starting with recommendations on switchgear components optimum choice and design, and up to installation and commissioning of the supplied equipment on operation site.

We provide the following after rectifiers start-up:
• personnel correct and safe operation and maintenance training;
• warranty and post-warranty maintenance;
• spare parts supply.

APPLICATION AREA

Rectifiers are manufactured for the following output voltage:

<table>
<thead>
<tr>
<th>Voltage class</th>
<th>600 V</th>
<th>750 V</th>
<th>825 V</th>
<th>1500 V</th>
<th>1650 V</th>
<th>3000 V</th>
<th>3300 V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tram</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trolleybus</td>
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<tr>
<td>Light Rail</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metro</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Railways</td>
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</tr>
</tbody>
</table>
Pluton offers fixed and withdrawable rectifiers. The latest achievements of world technology are applied during development and manufacturing of our rectifiers. This applies both to design of the cabinet and converter power part, as well as rectifier software, protection, diagnostics and control systems, electrical installation, technological solutions, maintenance and repair technology.

As a rule, we supply rectifier with Resibloc® windings dry transformer. Transformers can also be cast resin, supplied with epoxy glass cloth laminate sheet windings.

**RESIBLOC® Dry Transformer:**
- reliability and high safety level,
- environmental protection,
- fire safety,
- overvoltage and short-circuit currents resistibility,
- long lifetime.

**Rectifier:**
- protection, diagnostics and control system,
- innovative schematic and technological solutions,
- minimum maintenance,
- long lifetime,
- low maintenance charges.
FIXED RECTIFIERS

Rectifiers are manufactured with 12-pulse and 6-pulse «bridge» rectification circuits (according to EN 50238: 2003, Table 4, connections 8,9,12).

COMPLIANCE WITH INTERNATIONAL STANDARDS

Rectifiers manufactured by PrJSC “Pluton” were successfully type-tested for compliance with International standards in test center IPH Institut (Berlin, Germany).

Switching surge protection

Power semiconductor devices are protected against internal and external switching surges. Diodes are protected against internal switching surges with RC-circuits and against external switching surges combined with RC-circuits and varistors.

Power Diodes

Pill power diodes manufactured by VISHAY (formerly International Rectifier) are applied. Two diodes in series are connected in each arm of rectifier.

Contact Connections Stabilizing

Power part of rectifier is manufactured applying maintenance-free contact connections.
Transformer

Modern dry transformers with RESIBLOC® windings, capacity from 630 kVA, with various combinations of high (HV) and low (LV) voltages are supplied as traction transformer. RESIBLOC® Traction Transformers are successfully applied in transport systems of many countries.

Transformer with RESIBLOC® windings provides compliance with the following requirements:
- fire safety;
- environmental compatibility;
- "cold" start with maximum load;
- high resistance to dynamic loads under overloads and short circuits;
- overvoltage resistibility;
- minimum maintenance;
- reliable operation under conditions of high pollution, high humidity, low temperatures.

Transformers have original design of HV and LV winding made of wire and foil. Windings are shrouded with epoxy-impregnated fiberglass string.

High content of fiberglass (approximately 80 %) and combination of lateral and longitudinal reinforcement makes winding with a very high lateral and longitudinal strength. Transformer windings mechanical strength is 650-750 N/mm².

Transformers operate under condition of 100% humidity, water vapor condensation, and chemical pollution. Transformers can be equipped with low noise radial fans. Forced cooling system allows to increase transformers rated capacity up to 40 %.
Rectifiers are equipped with microprocessor control and diagnostics system. This system issues the following criteria information about state of each diode on visualization panel: «normal operation», «parameters derating», «breakdown», as well as diodes temperature. Monitoring of each diode parameters is made dynamically, during rectifier operation.

Diagnosis of the mentioned criteria can significantly increase the period of rectifier trouble-free operation.

In case of diode parameters changing to critical for this circuit level, the power diode can be replaced without its breakdown. In case of one diode breakdown, the rectifier continues operation.

Visualization power panel is a modular type industrial controller PP65 with color LCD screen produced by Bernecker & Rainer (Austria).

Industrial controller PP65 has significant processing power, high efficiency and compact size.

Information about state of the rectifier and its elements can be observed on visualization panel or computer monitor using special program.

Mnemonic symbols of rectifier diodes, graphs of reverse voltage distribution between diodes and arms temperature is displayed.

The following data is displayed on visualization panel:
• rectifier single-line diagram;
• events log;
• diodes temperature;
• diodes temperature diagram;
• voltage distribution between two diodes in series;
• signals:
  - transformer overheating;
  - doors condition;
  - rectifier overheating;
  - diode parameters derating.

The rectifier is connected with medium voltage switchgear protection devices and SCADA system.
### Main technical parameters of fixed rectifiers

<table>
<thead>
<tr>
<th>Name of parameter</th>
<th>Unit</th>
<th>Rectifier rated voltage arrangement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>750 V, 825 V</td>
</tr>
<tr>
<td>Rated voltage</td>
<td>V</td>
<td>750*</td>
</tr>
<tr>
<td>Rated current</td>
<td>A</td>
<td>1600…4000*</td>
</tr>
<tr>
<td>Auxiliaries network voltage</td>
<td>V</td>
<td>~110/220</td>
</tr>
<tr>
<td>Rectification circuit</td>
<td></td>
<td>Bridge</td>
</tr>
<tr>
<td>Number of connection circuit</td>
<td>-</td>
<td>8, 9, 12</td>
</tr>
<tr>
<td>Rectifier cooling type</td>
<td></td>
<td>Natural, forced</td>
</tr>
<tr>
<td>Duty class (acc. to EN50328)</td>
<td>-</td>
<td>V1*</td>
</tr>
<tr>
<td>Maximum ambient temperature</td>
<td>°C</td>
<td>40*</td>
</tr>
<tr>
<td>Altitude</td>
<td>m</td>
<td>1000</td>
</tr>
<tr>
<td>IP class (acc. to IEC60529)</td>
<td>-</td>
<td>IP21</td>
</tr>
</tbody>
</table>

* other values – upon request

Rectifiers are manufactured for both indoor and outdoor arrangement. In case of outdoor arrangement control and diagnostic system is located separately and installed indoors or in a cabinet with regulated environment.

Rectifiers are manufactured with air natural and forced cooling. Forced air cooling is actually combined natural air and forced air. Rectifier operates with natural cooling under loads lower or close to rated ones. In case of risk of overheating under overloads, fans are switched on and forced cool diodes. Fans switch off automatically some time after overload disappearance.
OVERALL DIMENSIONS OF FIXED RECTIFIERS

Rectifier 750 V (825 V); 1600 A, with natural cooling, VI duty class acc. EN 50328

Rectifier 750 V (825 V); 2500 A, with natural cooling,
Rectifier 750 V (825 V); 4000 A with forced cooling,
VI duty class acc. EN 50328
Rectifier 1650 V; 3150 A with natural cooling
Rectifier 1500 V (1650 V, 3300 V); 4000 A with forced cooling
VI duty class acc. EN 50328

<table>
<thead>
<tr>
<th>Rated output voltage, V</th>
<th>Rated output current, A</th>
<th>Rectification circuit acc. EN 50328</th>
<th>Rectifier cooling type</th>
<th>W (Width), mm*</th>
<th>H (Height), mm*</th>
<th>D (Depth), mm*</th>
</tr>
</thead>
<tbody>
<tr>
<td>750, 825</td>
<td>1600</td>
<td>8</td>
<td>natural</td>
<td>1000</td>
<td>2200</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9</td>
<td>natural</td>
<td>1200</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2500</td>
<td>8</td>
<td>natural</td>
<td>2000</td>
<td>2200</td>
<td>600</td>
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<td></td>
<td></td>
<td>9</td>
<td>natural</td>
<td>2000</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>4000</td>
<td>8</td>
<td>natural</td>
<td>4800</td>
<td>2200</td>
<td>800</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9</td>
<td>forced</td>
<td>2400</td>
<td>2200</td>
<td>800</td>
</tr>
<tr>
<td>1500, 1650</td>
<td>2000</td>
<td>8</td>
<td>natural</td>
<td>1400</td>
<td>2200</td>
<td>800</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9</td>
<td>natural</td>
<td>2400</td>
<td>2200</td>
<td>800</td>
</tr>
<tr>
<td></td>
<td>3150</td>
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<td>natural</td>
<td>2400</td>
<td>2200</td>
<td>800</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9</td>
<td>forced</td>
<td>2400</td>
<td>2200</td>
<td>800</td>
</tr>
<tr>
<td></td>
<td>4000</td>
<td>8</td>
<td>natural</td>
<td>4800</td>
<td>2200</td>
<td>800</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9</td>
<td>forced</td>
<td>2400</td>
<td>2200</td>
<td>800</td>
</tr>
<tr>
<td>3000, 3300</td>
<td>2000</td>
<td>12</td>
<td>natural</td>
<td>2400</td>
<td>2200</td>
<td>800</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12</td>
<td>natural</td>
<td>2400</td>
<td>2200</td>
<td>800</td>
</tr>
<tr>
<td></td>
<td>3150</td>
<td>12</td>
<td>natural</td>
<td>4800</td>
<td>2200</td>
<td>800</td>
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<td></td>
<td>12</td>
<td>forced</td>
<td>2400</td>
<td>2200</td>
<td>800</td>
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<td>4000</td>
<td>12</td>
<td>natural</td>
<td>4800</td>
<td>2200</td>
<td>800</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12</td>
<td>forced</td>
<td>2400</td>
<td>2200</td>
<td>800</td>
</tr>
</tbody>
</table>

* frame
Rectifier 3300 V, 2000 A, with natural cooling.
Rectifier 3300 V, 3150 A, with forced cooling.
VI duty class acc. EN 50328
12-pulse rectification circuit. Outdoor installation

Rectifier diagnostics cabinet
6-pulse 750 V (825 V); 1600...2000 A

12-pulse 750 V (825 V); 2500...4000 A
POWER PART CIRCUITS OF FIXED RECTIFIERS

A - galvanic isolation board

12-pulse 1500 V (1650 V); 2000...4000 A

SA - Surge arrester

12-pulse 1500 V (1650 V), 3000 V (3300 V); 2000...3150 A
WITHDRAWABLE RECTIFIERS

Withdrawable rectifiers include fixed cabinet and withdrawable power unit connected by contacts system. Withdrawable rectifiers are characterized by high power in a compact size.

Power fuse is connected in series with each diode.

Main technical parameters of withdrawable rectifiers

<table>
<thead>
<tr>
<th>Name of parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated output voltage</td>
<td>V</td>
<td>600, 750, 825</td>
</tr>
<tr>
<td>Rated output current</td>
<td>A</td>
<td>3000</td>
</tr>
<tr>
<td>Duty class (acc. to EN50328)</td>
<td>-</td>
<td>VI</td>
</tr>
<tr>
<td>Overload</td>
<td>sec</td>
<td>1.0 – continuous</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.5 – 7200 sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.0 – 60 sec</td>
</tr>
<tr>
<td>Auxiliaries network voltage</td>
<td>V</td>
<td>110/220 or on requesty</td>
</tr>
<tr>
<td>Rectification circuit</td>
<td>-</td>
<td>Bridge</td>
</tr>
<tr>
<td>Number of connection circuit</td>
<td>-</td>
<td>8, 9</td>
</tr>
<tr>
<td>(acc. to EN 50328)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rated input frequency</td>
<td>Hz</td>
<td>50</td>
</tr>
<tr>
<td>Rectifire cooling type</td>
<td>-</td>
<td>Natural, forced</td>
</tr>
<tr>
<td>Power factor (calculated), minimum</td>
<td>%</td>
<td>0.95</td>
</tr>
<tr>
<td>Efficiency factor (calculated), minimum</td>
<td>%</td>
<td>98</td>
</tr>
<tr>
<td>Maximum ambient temperature</td>
<td>°C</td>
<td>40</td>
</tr>
<tr>
<td>Altitude</td>
<td>m</td>
<td>1000</td>
</tr>
<tr>
<td>IP class (acc. to IEC60529)</td>
<td>-</td>
<td>IP20</td>
</tr>
</tbody>
</table>

Control and protection system

The main control device in the rectifier is a modular microprocessor control and protection system based on microcontrollers produced by Microchip.

Control and protection system provides:
- diodes fuses operation control;
- fuses operation control on input and output protection panels;
- temperature control inside the cabinet (on request);
- control of transformer heating to warning and alarm levels;
- visualization of all the necessary information on a color touch screen display: rectifier state (on/off), high-voltage and high-speed circuit breakers state, rectified voltage and current values, temperature, warning and alarm messages. Moreover, the display provides control over the power unit rolling in / out, as well as visual control of its position;
- events logging;
- communication with the upper level (SCADA system).
MAIN FEATURES

Optimal dimensions
Rectifier dimensions are optimal for use in a panel with DC cubicles.

Design features
Power unit can have three specific positions against fixed cabinet:
- **operating position** – power contacts are closed;
- **test position** - power unit is 100 mm rolled out from the cabinet, power contacts are opened and separated with the gap, ensuring insulation;
- **servicing position** - power unit is completely rolled out on the substation floor.

Maintainability
Power unit moving between operation and test positions (in and out of the main contacts) is mechanized and require no manual effort of staff.

Power unit test position is an additional visual indicator of the device off-state.

Serviceability and handling safety
Service position provides maximum ease of access to rectifier power unit and in busbar compartment. However, direct accidental contact of personnel with live parts of busbar compartment is mechanically impossible in this position.

Protections
**Overvoltage protection:**
- Damping capacitor is installed in parallel with each power diode for overvoltage protection.
- Rectifier is equipped with RC-filter on DC side for protection against overvoltage from the side of traction network.
- Varistor panel protects against overvoltage from the side of supply network.

**Short circuit protection:**
- The rectifier is designed to withstand external short circuit without damage up to medium voltage circuit breaker tripping.
- Power fuses installed in series with each diode protect against internal short circuits. Rectifiers are produced for various semiconductor failure modes (T, F and R modes) in accordance with EN 50328.
OVERALL DIMENSIONS OF WITHDRAWABLE RECTIFIERS

Rectifier 600 V (750 V, 825 V); 3000 A, 6-pulse rectification circuit, with natural cooling
VI duty class acc. EN 50328

Rectifier 600 V (750 V, 825 V); 3000 A, 12-pulse rectification circuit, with natural cooling
VI duty class acc. EN 50328
POWER PART CIRCUITS OF WITHDRAWABLE RECTIFIERS

12-pulse rectification circuit
6-pulse rectification circuit
IMPLEMENTED PROJECTS

Metro

Almaty Metro (Republic of Kazakhstan)
Supply of 20 rectifiers

Baku Metro (Republic of Azerbaijan)
Supply of 17 rectifiers

Kiev Metro (Ukraine)
Supply of 56 rectifiers

Kharkov Metro (Ukraine)
Supply of 12 rectifiers

Yekaterinburg Metro (Russian Federation)
Supply of 6 rectifiers

Tashkent Metro (Republic of Uzbekistan)
Supply of 18 rectifiers

St. Petersburg Metro (Russian Federation)
Supply of 4 rectifiers

Moscow Metro (Russian Federation)
Supply of 18 rectifiers

City Electric Transport

Russian Federation
Supply of rectifiers for Moscow, St. Petersburg, Rybinsk, Volgograd, Ufa, Khimki, Tomsk, Lipetsk city electric transport traction substations (more than 100 rectifiers)

Supply of rectifiers for Moscow monorail traction substations and first phase depot (14 rectifiers)

Republic of Belarus
Supply of rectifiers for Minsk, Grodno, Gomel, Brest, Vitebsk, Mogilev, Bobruysk city electric transport traction substations (more than 70 rectifiers)

Latvia
Supply of rectifiers for Riga city electric transport traction substations (more than 30 rectifiers)

Ukraine
Supply of rectifiers for Kiev, Odessa, Krivoy Rog city electric transport traction substations (more than 150 rectifiers)

AR of Crimea
Supply of 3 rectifiers for 2 Kerch city electric transport substations

Sweden
Supply of 5 rectifiers for Stockholm city electric transport traction substations

Railways

Ukrainian Railways (Ukrzaliznytsya) (Ukraine)
Supply of 4 rectifiers for main railway line substations

“Magnitogorsk Iron and Steel Works” (Magnitogorsk, Russian Federation)
Supply of 16 rectifiers for 3 substations of 1.65 kV DC industrial railway

OJSC “Orenburg Minerals” (Yasniy, Russian Federation): Supply and commissioning of 3 rectifiers for 1.65 kV DC industrial railway traction substations modernization