# INTRODUCTION

This 'User's Manual' is intended for studying the converters series ПНТ1М, hereinafter referred to as 'converters', and ensuring their correct operation. It is intended for maintaining personnel who have undergone special training in operating and maintaining semiconductor equipment.

Reliability and longevity of the converters is provided not only by the quality of the converters themselves, but also by correct operation, therefore observance of all the requirements stated in the present document is obligatory.

The schematic circuit diagrams of the component parts of the converters are compiled as a separate diagram album in accordance with the list ГЛЦИ.656121.498 ОП.

## 1. DESCRIPTION AND OPERATION OF CONVERTERS

### 1.1 Application

The converters are intended for construction of d.c. drives employing motors with electromagnetic or permanent magnet excitation.

### 1.2 Delivery Set and Converter Code Explanation

1.2.1. The converters comprise:

- converter unit БПНТ1М - 1 item

- high-speed fuses (according to the inquiry sheet depending on the number of feeding mains phases) - 2 or 3 items

1.2.2. Converter Code Explanation

ПНТ 1 М-3.010 Е УХЛ 4

- УХЛ 4 — Climatic modification and location category: **УХЛ4** – cold and moderate; **04** – tropical
- Е — Feedback type: **Е** – e.m.f. feedback; **С** – speed feedback
- 010 — Rated current: **005** – 5A; **010** – 10A; **020** – 20A
- 3 — Rated feeding mains voltage: **2** – 220V; **3** – 380V
- М — Modified
- 1 — Development №
- ПНТ — Non-reversible Transistor Converter

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  **УХЛ4** – cold and moderate
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  **2** – 220V; **3** – 380V
- М – Modified
- 1 – Development №
- БПНТ – Non-reversible Transistor Converter

**1.3. Specifications**

1.3.1. The converters are intended for operation in the following conditions:

- Ambient temperature should be within 5-45 °C, and from 45 to 55 °C with reduction of the rated current by 10% per every 5 °C;
- Altitude should not exceed 1000 m. In case of altitude exceeding 1000 m up to 4300 m ambient temperature should be reduced by 0.6 °C per every 100 m;
- Environment should not be saturated with conductive dust and water vapors as well as explosive or corrosive gases or vapors in concentrations that may corrode metal and insulation.

1.3.2. As for the influence of external mechanical factors, the converters comply with the requirements of operating conditions standard M8 with severity degree II.

1.3.3. Operating position of the units is vertical with deviation to either side of no more than 5°.

1.3.4. Protection degree – IP00.

1.3.5. The converters are powered from single- or three-phase mains with a frequency of 50 or 60 Hz and voltage of 230 or 380 V (depending on the voltage modification) directly or via a matching transformer, in case of mains voltage of 400, 415, 440 and 500 V – only via a step-down transformer or an autotransformer.

Maximum permissible deviations of feeding mains voltage are from +10 to −15% of the rated value and of frequency – from +2 to −2% of the rated value.

1.3.6. The main technical parameters of the converter units are given in Tables 1.1 and 1.2.

1.3.7. Electric drives based on the converters with speed feedback ensure technical characteristics according to Table 1.3, and those with e.m.f. feedback – according to Table 1.4.

1.3.8. The rated operating mode of the converter is continuous. Operation in short-term (S1) and intermittent (S3) modes is also permitted. The diagram of overload capacity ($I/I_{rat}$) as a function of time for S2 mode at a speed of 0.25 of the rated is shown in Fig. 1.1.

1.3.9. Converter Protections, Interlocks and Alarms

1.3.9.1. The converter units have the following protections:

– overcurrent protection ($I>I_{max}$);

**Table 1.1**

| Converter unit type | Feeding mains voltage, V | Converter rated current, A | Maximum output voltage, V, at rated feeding mains voltage | |
|---|---|---|---|---|
| | | | Single-phase | Three-phase |
| БПНТ1М-2.005 | 220 | 5 | 178 | 267 |
| БПНТ1М-2.010 | 220 | 10 | 178 | 267 |
| БПНТ1М-2.020 | 220 | 20 | 178 | 267 |
| БПНТ1М-3.005 | 380 | 5 | 307 | 460 |
| БПНТ1М-3.010 | 380 | 10 | 307 | 460 |
| БПНТ1М-3.020 | 380 | 20 | 307 | 460 |

**Table 1.2**

| Converter unit type | Torque efficiency factor for | | Excitation winding supply unit | |
|---|---|---|---|---|
| | Single-phase mains | Three-phase mains | Current in continuous mode, A | Output voltage |
| БПНТ1М-2.005 | 0.78 | 1 | 1.5 | 110-440 |
| БПНТ1М-2.010 | 0.78 | 1 | | |
| БПНТ1М-2.020 | 0.78 | 1 | | |
| БПНТ1М-3.005 | 0.78 | 1 | | |
| БПНТ1М-3.010 | 0.78 | 1 | | |
| БПНТ1М-3.020 | 0.78 | 1 | | |

**Table 1.3**

| Speed of rotation | Rotation speed error, no more | |
|---|---|---|
| | At load change, % | Total, % |
| $n_{rat}$ | 1.0 | 2.5 |
| 0.1 $n_{rat}$ | 2.0 | 5.0 |
| 0.01 $n_{rat}$ | 5.0 | 7.5 |
| 0.001 $n_{rat}$ | 10 | 15 |
| 0.0005 $n_{rat}$ | 15 | 25 |

**Table 1.4**

| Speed of rotation | Rotation speed error, no more | |
|---|---|---|
| | At load change, % | Total, % |
| $n_{rat}$ | 2.5 | 4.5 |
| 0.1 $n_{rat}$ | 7.0 | 10.0 |
| 0.05 $n_{rat}$ | 10.0 | 15.0 |
| 0.02 $n_{rat}$ | – | 35 |
| 0.015 $n_{rat}$ | – | 40 |

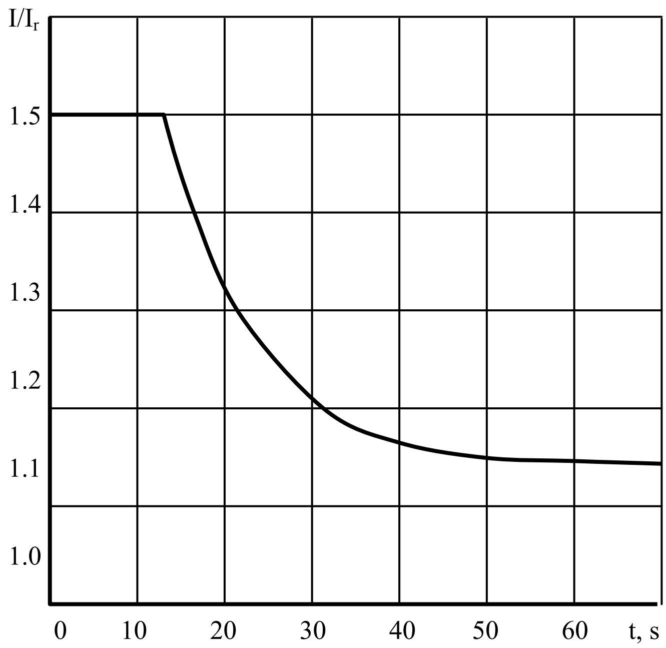


Fig.1.1 – Converter overload capacity diagram

– time-current protection in the event of short-term current overload of the converter;

– protection from tachogenerator circuit failure (in the modification with speed feedback).

Operation of every kind of protection brings about blocking of the power transistor and indication on the face panel of the converter.

1.3.9.2. The converter units have a light alarm indicating readiness for operation, converter operation and protection operation.

1.3.9.3. The converter units provide interlocking of operation on removal of signal "operation allowed".

1.3.10. The case of the converter has a bolt for grounding.

1.3.11. Indices of Reliability of Converter Units:

– total operation time – 10000 hours;

– average life – 15 years;

– warranty term is 2 years since the beginning of duty but no more than 2.5 years since the date of manufacture;

– average restoration time is no more than 8 hours, if using reserve units – no more than 0.5 hours.

**1.4. Design and Action of Converters and Drives Based Thereon**

1.4.1. The schematic circuit diagram of the converter is shown in drawing ГЛЦИ.656121.478Э3.

Three-phase power mains voltage of 220 or 380 V depending on the voltage modification (for direct connection or via a matching transformer) is supplied to terminals X1.1-X1.3 (L1-L3) through the protecting fuses included into the delivery set. In case of single-phase mains the feeding wires are to be connected to any two terminals of L1-L3. The single-phase voltage of 220 or 380 V of the same (or another) mains for feeding the control circuit and ventilator (if installed) is supplied to terminals X1.4 and X1.5. In the converter modifications with a ventilator a jumper is installed between terminals X1.4 and X1.7 if the voltage of the ventilator corresponds to that on terminals X1.4, X1.5. If the latter are supplied with a voltage of 380 V, an additional resistor ($R_{доп}$) with resistance of 2.7 kΩ and capacity of no less than 25W is installed between X1.4 and X1.7.

The power voltage is rectified by diodes VD1–VD3 and filtered by capacitors C1, C2 as well as the capacitors of the protecting RC-circuits unit (E1.2). Rectified and filtered voltage $U_d$ via current transformer TT and power transistor VT1 is connected to terminals X1.8 ($+U_{motor}$) and X1.9 ($-U_{motor}$) with the d.c. motor armature connected thereto.

Voltage $U_{motor}$ is PWM-regulated within 0–0.9$U_d$ by the transistor and high-frequency diode VD4. When transistor VT1 is open, $U_{motor}=U_d$ and the motor armature current rises and energy is accumulated in the armature circuit inductance. When transistor VT1 is closed, the armature current continues to flow due to the energy accumulated in the inductance decreasing in value, whereas the circuit is closed through diode VD4.

Units E1 and E5 have RC-circuits reducing overvoltage peaks and suppressing radio interference.

1.4.2. Control of the converter is performed by the regulating system represented in drawing ГЛЦИ.656111.383 Э3 (control unit N1).

The control system consists of:

– PI-controller of speed based on operational amplifier DA2, on whose input command voltage $U_{com}$ and tachogenerator voltage $U_{BR}$ or the motor e.m.f. pick-off voltage are summated;

– PI-controller of current based on operational amplifier DA6;

– generator of saw-tooth reference voltage based on operational amplifier DA9. PWM-regulation of the motor armature voltage is performed with the aid of this voltage;

– relay element with a narrow hysteresis loop based on operational amplifier DA8 with positive feedback via resistor R42;

– motor current pick-off, based on operational amplifiers DA3, DA5, DA7 constituting simplified models of the motor current circuit (DA5) and of the converter (DA3), controlled by the voltage derived from resistor R8 that represents the load of a.c. transformer T1, whose primary winding is inserted into the circuit of the motor armature and power transistor;

– motor e.m.f. pick-off based on operational amplifiers DA1 (motor voltage pick-off) and DA4;

– power transistor control unit based on optical coupler VD21 and transistors VT10, VT11.

The voltage on the output of the PI speed controller (motor current command signal) is limited to a level of no more than 7.5 V by variable resistor R16 when positive and by zener VD6 when negative. The former limitation sets the maximum possible armature current in transient modes (cut-off current), whereas the latter prevents an undesirable negative impulse of the controller voltage thereby reducing the speed drop at load discharge. The PI-controller output voltage in the absence of the command and feedback signals is set close to zero with resistor R72.

The parameters of the PI-controller are set with changeable elements R11 and C3. With the aid of changeable resistor R7 the normalized speed feedback signal in point ”8” at the maximum motor speed and maximum speed command is set to +7.5 V. It is recommended to assume $U_{com}= -10V$.

The voltage on the output of the PI-controller of current is limited by changeable resistor R35 when negative and by diode VD12 when positive. The said limitations are necessary for correct operation of the PWM motor voltage control system, excluding the mode with constantly open transistor wherein the use of a simple and interference-immune a.c. transformer as a motor current pick-off is impossible.

The voltage of the current controller (point “25”) should never exceed the saw-tooth reference voltage formed in summating point “2” of amplifier DA9 whereas the time of switched-off state of the power transistor should not be shorter than 0.1 of the period of saw-tooth voltage.

The parameters of the current controller are set by Manufacturer for an averaged d.c. motor with electromagnetic excitation. When using other types of d.c. motors the parameters of the current controller have little influence over the quality of transients due to high-speed performance of the controller.

The motor current pick-off operates as follows. Voltage proportional to the motor voltage is applied to the input of amplifier DA7 through resistor R17 and diode VD7. Voltage proportional to the motor e.m.f. but opposite by sign is applied to the same input via resistor R12. The difference between the said voltages proportional to the voltage drop on the armature resistance of the motor is amplified by amplifier DA5, filtered with the help of feedback elements R21, C5 and compared with the voltage on resistor R8. Due to the high amplification factor of DA3, when the armature current rises, the voltage on the output of DA5 follows the voltage on resistor R8 proportional to the motor current. When the current decreases (the power transistor is closed and the voltage on R8 is zero due to action of cut-off diode VD3), the output voltage of DA5 falls under the influence of the voltage in point “8” proportional to the motor e.m.f. according to the time constant T=R21*C5 that should be equal to the armature circuit time constant $T_a=L_a/R_a$.

Time constant T may be adjusted by the User for a concrete motor with changeable resistor R21. A normalized signal (average value) of +2V (at the rated motor current) or +3V (at the cut-off current $I_{cut\text{-}off}= 1.5I_{rat}$) on the output of DA5 is set with resistor R8.

The motor e.m.f. pick-off is based on the solution of the voltages balance equation for the motor armature circuit:

$$U_M = E+I_aR_a+L_a\, dI/dt \qquad (1.1)$$

In operator format this equation can be written as follows:

$$E =U_M -I_aR_a -I_aRT_a\, p \qquad (1.2)$$

This equation is solved with operational amplifier DA4, where $U_{DA4}$ stands for value E in a certain scale, voltage $U_{DA1}$ – for $U_M$ and $U_{DA5}$ – for the value $I_aR_a$.

The voltage on the output of DA4 (without consideration of influence of capacitor C4):

$$U_{DA4}=U_{DA1}R_{18}/R_{14}-U_{DA5}R_{18}/R_{13}-U_{DA5}C_2R_{18}p \qquad (1.3)$$

Capacitor C4 filtrates the output voltage of amplifier DA4, thereby reducing interference in the regulating circuit.

The power transistor control unit provides application of positive voltage to the base of the power transistor if current flows through the input circuit of optical coupler VD21 (transistor VT7 is open by the positive potential on the output of DA8), and of negative voltage – in the absence of current in the input circuit of VD21 (transistor VT7 is closed). Resistor R65 and diodes VD26, VD27 provide reduction of the power transistor base current to the minimum level, necessary for keeping the power transistor in an open state, by "pumping out" a part of transistor VT10 base current to the collector circuit of the power transistor.

1.4.3. The Protection, Alarm and Interlock System

consists of:

-overcurrent protection;

-time current protection (protection from long overloads);

-protection from speed feedback circuit (tachogenerator) failure;

-indicator of readiness for operation (green LED VD24 "ГР");

-indicator of switched-on state of power transistor (green LED "Работа");

-indicator of protection operation (red LED "Авария");

-speed controller interlock unit;

-unit producing signal «ГР» ("Readiness for operation").

All the protections are based on the protection flip-flop, employing transistors VT3, VT4 forming a circuit analogous to a thyristor. In case of operation of any protection the transistors open, shunting the input circuit of optic coupler VD21 with the result that the power transistor control unit applies negative voltage to the base of the transistor thereby closing it.

Overcurrent protection is provided by applying a signal proportional to the current in the power circuit derived from resistor R8 (point "9") to the base of transistor VT4 via resistor R32.This signal is compared with the constant signal coming from the stabilized source −15V through resistor R34. When the current in the power circuit exceeds the rated value by more than (60−80)% transistor VT4 opens and the protection flip-flop switches.

The time-current protection is based on operational amplifier DA10 and transistor VT6. The signal from the output of amplifier DA5, proportional to the converter output current, comes to the input of amplifier DA10 via resistor R27 and the parallel-series chain comprising resistors R31, R38 and diodes VD10−VD14 that constitutes a non-linear resistor with approximately quadratic dependence on voltage. Thanks to resistor R45 and capacitor C12 in the feedback circuit of the amplifier, its output signal is proportional to the value $I^2t$ and correspondingly to the temperature of overheating of the motor and power transistor cooler. This signal comes to the protection flip-flop input via the threshold element based on transistor VT6. The response level of this protection is determined by the relation between the resistances of R46 and R52. The dependence of response time of this protection on the current is shown in Fig. 1.1.

The protection against the tachogenerator circuit failure is based on comparison of the tachogenerator signal with a signal proportional to the motor e.m.f. In case of normal operation these signals are approximately equal and operation of the drive is permitted. In case the tachogenerator circuit is open or there is a short-circuit between its terminals, the difference between the said signals becomes larger than a preset threshold level and operation of the drive will be prohibited. The signal from the output of DA4 proportional to the motor e.m.f. is applied to the base of VT2, whereas the normalized speed signal (the voltage on capacitor C1) is applied to the emitter. In case of disappearance of the normalized speed signal or its impermissible decrease transistor VT2 opens causing transistor VT3 to open and the protection flip-flop to switch.

The readiness for operation signaling unit and the unit producing signal "ГР" employ transistors VT8, VT9, VT12 and VT14. When feeding voltage +15V appears capacitor C14 begins to charge. As soon as the voltage on this capacitor reaches the threshold value of zener VD19 transistor VT8 will open and transistor VT9 – close, permitting the power transistor control unit to operate on condition that the protection flip-flop is switched off. The current flowing from source +15V through resistors R50 and R61 opens transistors VT12 and VT14. Green LED VD24 lights up and signal "ГР" appears. Transistor VT14 might be used for switching on an intermediate relay in an upper level device to perform commutations necessary in connection with the appearance of the signal that the drive is ready for operation.

Blocking of the speed controller is performed by shunting the output of operational amplifier DA1 with transistor VT1 in the absence of signal "PP" ("Operation Permitted") from an external device. The said blocking is performed with the aid of "a dry contact" (or transistor) short-circuiting terminals 8 and 7 of connector X1.

If the contact is made (signal "PP" is present) transistor VT1 is closed and operation of the converter is permitted.

If the contact is open the speed controller is interlocked. Simultaneously, the power transistor is blocked (transistor VT7 is closed) with the aid of transistor VT5.

In case of operation of any of the protections transistor VT14 closes, LED VD24 goes out, transistor VT13 opens and LED VD25 "Авария" ("Failure") lights up. Signal "Readiness for operation" is removed.

The protection flip-flop can be reset with the aid of contacts "Сброс" ("Reset") and "Общий" ("Common").

1.4.4. The internal circuits are powered from intermediate transformer T1 installed in control unit

N2 (ГЛЦИ.656111.384Э3).

The voltage regulators for +15V and −15V are based on transistors VT1 and VT2 and zeners VD10, VD15. They are intended for powering the regulating system, protection and alarm system with stabilized voltage decoupled from the power voltage.

The voltage regulators for +6V and −6V are based on transistors VT3, VT4 and zeners VD12, VD13. They are intended for powering the power transistor control unit and control circuits of the excitation winding power source that are conductively coupled with the power circuit.

The protection of the power sources is performed by fuses F1 and F2.

1.4.5. The excitation winding power source (ГЛЦИ.656111.385 Э3) is also installed in control unit N2. It is based on a PWM voltage regulator with negative current feedback.

The high-voltage power transistor, VT1, type KT839A is controlled with low-voltage transistor VT2 type KT819Б installed into its emitter circuit.

The unit is powered with rectified voltage $U_d$ from the intermediate d.c. circuit of the converter.

The current pick-off comprises two low-impedance resistors R2 and R3 connected in parallel. The voltage from this resistors comes to the input of operational amplifier DA1.1 (current controller).

The voltage drop on resistor R70 is used as a current command signal. The said resistor is connected to terminals "$R_{OB}$1" and "$R_{OB}$2" and installed in control unit N1 to provide convenience of adjustment. The current through this resistor is determined by the voltage of zener VD4 and resistance of R7.

The output voltage of the current controller is compared with the saw-tooth voltage formed on capacitor C4 by amplifier DA1.2. Amplifier DA1.2 having positive feedback via resistor R11 switches with a frequency of about 1−2 kHz thereby performing PWM-regulation of the output voltage. This voltage comes to the base of transistor VT2 through common-collector amplifier VT3 and resistor R12.The average current of the motor excitation winding can be adjusted by rotating the slider of variable resistor R70, but the current should not exceed the maximum value stated in Table 1.2.

## 2. MOUNTING AND OPERATION

### 2.1 Location and Mounting

The converter unit is installed into a control cabinet, on a control board or into a niche of a lathe or another industrial mechanism providing the clearances according to Fig. 2.1 are observed. The protection degree is IP00.

The overall and mounting dimensions of the converter unit are represented in Figs 2.2–2.4. The external view of the unit face panel is shown in Fig. 2.5.

The converter has the following external circuits (on connector X1):

– power voltage connection circuit (terminals X1.1 (“L1”), X1.2 (“L2”), X1.3 (“L3”));

– circuit to connect the voltage for powering the control circuits and ventilator (terminals X1.4, X1.5 (“~$U_{\text{п}}$”));

– circuit for connecting a jumper or an additional ballast resistor, $R_{\text{ДОП}}$, for matching the feeding mains voltage with the ventilator voltage (terminals X1.4 and X1.7);

– circuit for connecting the motor armature (terminals X1.8 (“+$U_{\text{ДВ}}$”) and X1.9 (“–$U_{\text{ДВ}}$”);

– circuit for connecting the excitation winding (terminals X1.8 (“+$U_{\text{ОВ}}$”) and X1.6 (“–$U_{\text{ОВ}}$”);

– circuit for connecting an additional smoothing capacitor $C_{add}$ (terminals X1.8 (“+$U_{\text{ДВ}}$”) and X1.10 (“–$U_d$”);

– grounding circuit.

On connector X1 of control unit N1:

– circuit for connecting the speed pick-off (tachogenerator) (terminals “$U_{BR}$” and “общий PC”);

– circuits for connecting an external control device (terminals “$U_{\text{ЗАД}}$” [speed command, $U_{com}$], “Общий PC” [Common of PC], “–15V”, “PP”, “ГР”, “Общий” [Common], “Сброс” [Reset]).

CAUTION! The ventilator installed in ПНТ1М-3.020… does not have a modification for 380 V. Therefore the terminals “~$U_{\text{П}}$” can be connected to the mains of 220 V only.

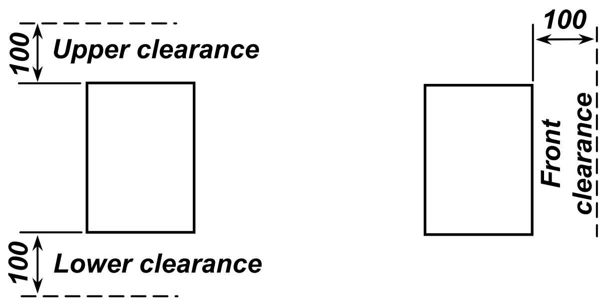


*Fig. 2.1 – Clearances*

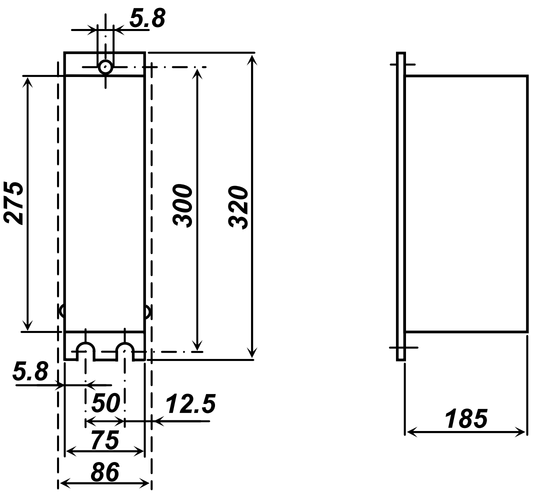


*Fig. 2.2 Overall and mounting dimensions of converters ПНТ1М-2.005… and ПНТ1М-3.005…*

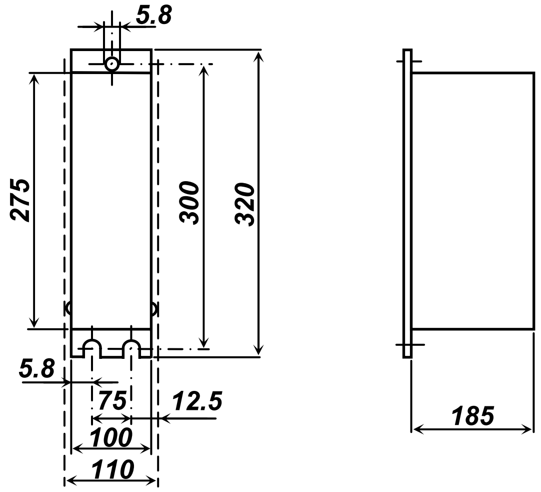


*Fig. 2.3 Overall and mounting dimensions of converters ПНТ1М-2.010… and ПНТ1М-3.010…*

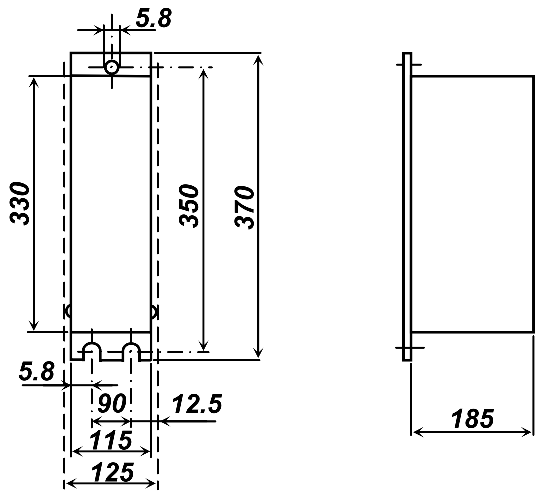


*Fig. 2.4 Overall and mounting dimensions of converters ПНТ1М-2.020… and ПНТ1М-3.020…*

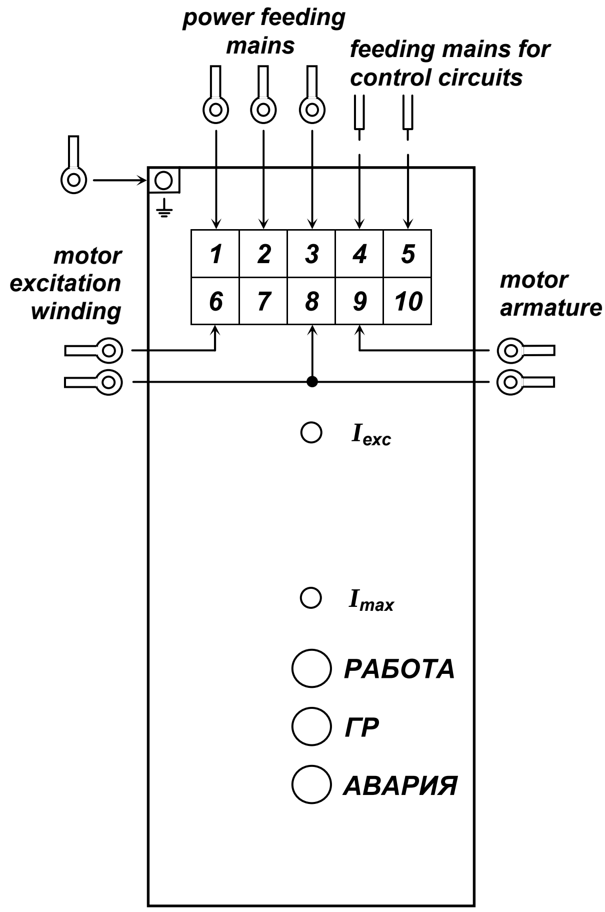


*Fig. 2.5 – Connection Diagram of Converters Series ПНТ1М…*

If the User has difficulty in obtaining a voltage of 220 V it is possible to connect a voltage of 380 V to terminals “$U_{\text{П}}$” (correspondingly the modification of unit N2 should be for 380 V) having installed a ballast resistor $R_{\text{ДОП}}$ with resistance of 2.7 kΩ and capacity of no less than 25 W between terminals X1.4 and X1.7.

The cross-sections of the wires for connecting the power feeding mains voltage and motor armature are given in Table 2.1. The wire cross-sections for the grounding circuits should be at least the same as that for the phases of the power mains voltage. The cross-section for the other circuits should be at least 0.2 mm$^2$. The circuits for connection of signals “$U_{\text{зад}}$” (“$U_{com}$”), “$U_{BR}$”, “Сброс” (“Reset”), “РР”, “ГР” should be made of wires with a length of no more than 0.5 m and separated (distance between the bunches - at least 0.3 m) from the power circuits. In case of longer wires it is necessary to use wires twisted in pairs with a step not exceeding 10 mm (desirably screened). The screen should be connected to contact “Общий” (“Common”).

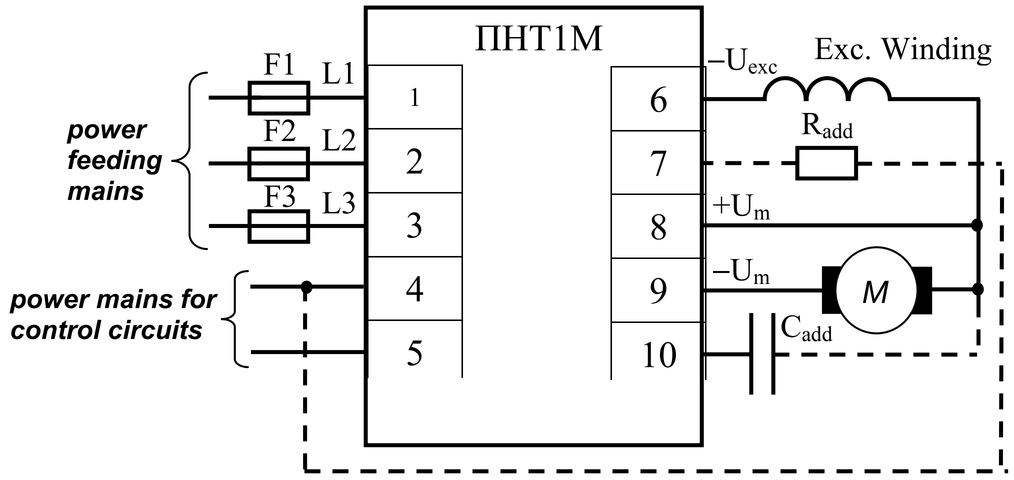


***Fig. 2.6 – Connection Diagram of Power Circuits***

**2.2 Preparation of Converters for Operation**

2.2.1. The schematic diagram for connection of the converter unit to the mains and motor is represented in Fig. 2.6.

It is possible to use the converter as a single-phase one with connection via any pair of the input power terminals. The control system can also be connected to the power mains with the exception of drive ПНТ1М-3.020…, whose ventilator and control system voltage is 220 V. The said connection is performed before fuses F1…F3 (see Fig. 2.6).

**Table 2.1**

| **Converter type** | **Wire cross-section, mm$^2$** | | **Fuse type** |
|---|---|---|---|
| | **Power voltage connection** | **Motor armature connection** | |
| ПНТ1М-2.005…-3.005 | 0.75 | 1.0 | ПП24-25-3723 Пл.вст. 6.3 A |
| ПНТ1М-2.010…-3.010 | 1.0 | 1.5 | ПП24-25-3723 Пл.вст. 16 A |
| ПНТ1М-2.020…-3.020 | 2.5 | 2.5 | ПРС-63 Пл.вст. 40 A |
| Note: use of fuses of other types with analogous parameters is also possible | | | |

2.2.2. The converters ПНТ1М are intended for being powered from low-inductance power mains. If the inductance of the mains is considerable or a matching power transformer (or autotransformer) is used, it is necessary to connect an additional non-electrolytic capacitor to the intermediate d.c. circuit (terminals X1.8 and X1.10). Its capacity is

$$C = AL_{fm} - B \ \text{[F]} \qquad (2.1)$$

where $L_{fm}$ – feeding mains inductance [H], A, B – coefficients shown in Table 2.2.

**Table 2.2.**

| Converter type | ПНТ1М-2.005… | ПНТ1М-2.010… | ПНТ1М-2.020… | ПНТ1М-3.005… | ПНТ1М-3.010… | ПНТ1М-3.020… |
|---|---|---|---|---|---|---|
| A | 0.0065 | 0.026 | 0.11 | 0.003 | 0.012 | 0.05 |
| B | $1.5*10^{-6}$ | $1.5*10^{-6}$ | $8*10^{-6}$ | $1.5*10^{-6}$ | $1.5*10^{-6}$ | $8*10^{-6}$ |

2.2.3. In case of the necessity for reduction of the level of radio interference created by the operating converter it is recommended to connect capacitors type K25-24 with capacity of at least 4 μF (or analogous in parameters capacitors of other types) connected in star to terminals "L1", "L2", "L3" of connector X1. Their common point must be grounded.

2.2.4. The diagram for connecting the signal circuits is shown in Figs. 2.7 and 2.8.

2.2.5. Sequence of Calculation of Speed Controller Parameters

a) calculate the resistance value of R7 in order to provide normalized speed feedback signal $U_{OCH}$=7.5V at $n_{max}$ in point "8":

$$R_7 = \frac{U_{BR\max} - U_{OCH}}{U_{OCH}\left(\frac{1}{R_{10}} + \frac{1}{R_{12}}\right)} = \frac{U_{BR\max} - 7.5}{1.75 \cdot 10^{-3}}, [\Omega] \quad (2.2)$$

where $U_{Brmax}$ is the tachogenerator voltage at maximum motor speed $n_{max}$.

In this case the maximum value of the command voltage should be:

$$U_{COMmax} = U_{дн} R_6 / R_{10} = 7.5 \times 10 / 7.5 = 10, \text{ [V]} \quad (2.3)$$

b) determine the speed feedback factor:

$$k_{oc} = \frac{U_{осн}}{\omega_{\max}} = \frac{9.55 U_{осн}}{n_{\max}} = \frac{71.62}{n_{\max}}, \text{ [Vs/rad]} \quad (2.4)$$

c) determine the voltage amplification factor of the converter:

$$k_{П} = \frac{U_{d,rat}}{U_{ПМ}} = \frac{U_{d,rat}}{5}, \quad (2.5)$$

where $U_{d,rat}$ is the rated voltage in the intermediate d.c. circuit. At feeding mains voltage of 220 V $U_{d,rat}$=300 V and at feeding mains voltage of 380 V $U_{d,rat}$=520 V. $U_{ПМ}$ is the peak-to-peak amplitude of the saw-tooth voltage in the PWM-regulator, $U_{ПМ}$=5 V.

d) determine the current pick-off gain:

$$k_{ДТ} = \frac{U_{R8} R_{30}}{I_r R_{26}} = \frac{2 \cdot 10}{I_r \cdot 3.9} = \frac{5.13}{I_r}, \text{ [V/A]} \quad (2.6)$$

where $U_{R8}$ = 2 V is set with resistor R8 at the rated current of the converter $I_r$.

$$R_8 = \frac{U_{R8} w_2}{I_r w_1} = \frac{2 \cdot 1000}{20} = 100, [\Omega] \quad (2.7)$$

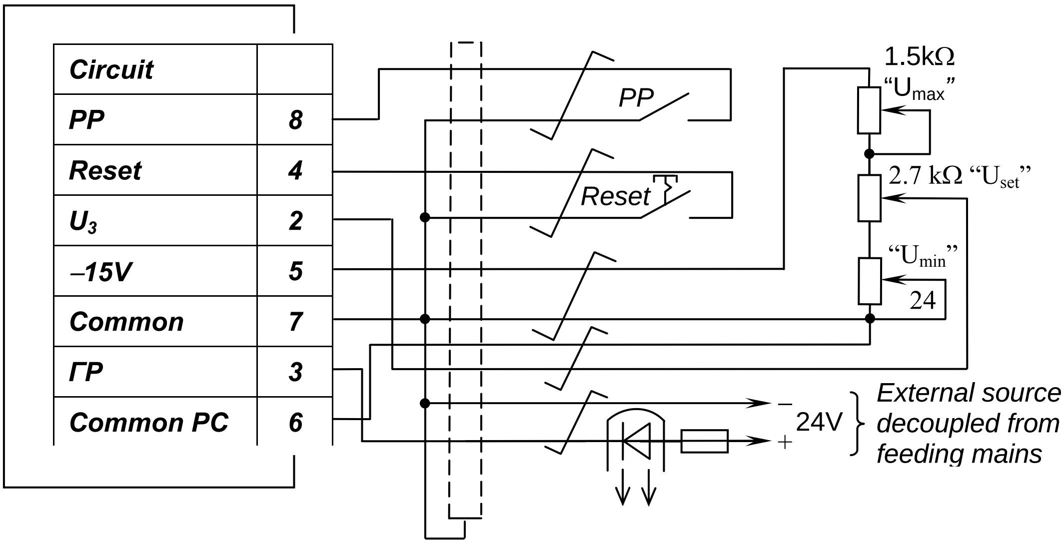


*Fig. 2.7 – Connection of Signal Circuits of Converter with E.M.F. Feedback*

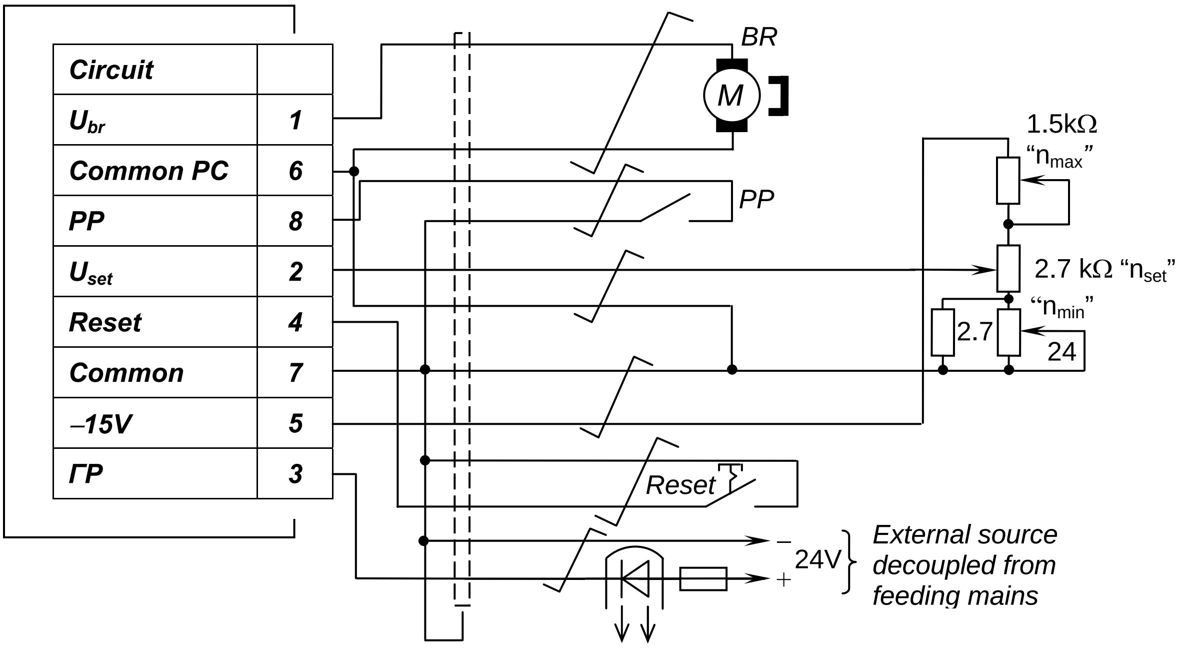


*Fig. 2.8 – Connection of Signal Circuits of Converter with Speed Feedback*

where $w_2 = 1000$ is the wind count of the secondary winding of the current transformer, $I_r$ is the rated current of the converter, $w_1$ is the wind count of the primary winding. The product $I_r w_1$ always equals 20 (1 wind for a rated current of 20 A, 2 winds - for 10 A and 4 winds - for 5 A).

e) determine the time constant of the motor armature circuit, $T_a = L_a/R_a$, where $L_a$ is the inductance of the armature circuit and $R_a$ is the resistance of the armature circuit. The said parameters can be taken from the data on the motor. $L_a$ can also be found by experiment at the minimum speed of the drive according to the expression:

$$L_a = U_{d,rat}\frac{\Delta t}{\Delta I_a}, \text{[H]} \tag{2.8}$$

where $\Delta I_a$ is the armature current increment during the time $\Delta t$ that are determined using the oscillogram of the voltage on resistor R8.

f) determine the cutoff frequency of the current closed loop:

$$\omega_{ci} = \frac{k_{П} R_{25} k_{ДТ}}{L_a R_{29}} \tag{2.9}$$

At $R_{25}=R_{29}$

$$\omega_{ci} = \frac{k_{П} k_{ДТ}}{L_a} = \frac{k_{П} k_{ДТ}}{T_a R_a}, \text{[rad/s]} \tag{2.10}$$

g) choose the cutoff frequency of the speed closed loop, $\omega_c$, basing on the required response speed of the drive and the interference level in the regulating loop and observing the condition $\omega_c<2\omega_{ci}$. It is recommended to choose $\omega_c$ within 50–250 rad/s. The higher is the interference level, the lower should be the cutoff frequency.

h) calculate the value of changeable resistor R11 :

$$R_{11} = \frac{\omega_c k_{ДТ} J R_{10}}{C_M k_{OC}}, [\Omega] \tag{2.11}$$

where $J$ is the total moment of inertia on the motor shaft, [kg×m],

$$C_M = \frac{M_r}{I_{mot,r}} = \frac{P_{mot,r}}{\omega_{mot,r} I_{mot,r}} = \frac{9.55 P_{mot,r}}{n_r I_{mot,r}}, \text{[N×m/A]} \tag{2.12}$$

where $P_{mot,r}$ is the rated capacity of the motor, [W],

$n_r$ is the rated speed of the motor, [r.p.m].

The value $J/C_M$ can be determined by experiment, the motor being started-up without load (but with the mechanism connected to the shaft).

$$\frac{J}{C_M} = \frac{9.55 I_{start-up} t}{n_{\max}}, \tag{2.13}$$

where $t$ is the time during which the motor reaches the speed $n_{max}$ with the current $I_{start-up}$.

i) the capacity of C3 is determined as:

$$C_3 = \frac{b}{R_{11}\omega_c}, \text{[F]} \tag{2.14}$$

where $b>2$.

The more is $b$, the less is the value of speed overcompensation but the more is the transient duration. It is recommended to assume $b$ within 2–6.

For the modification with e.m.f. feedback the sequence of calculation of the speed controller parameters is the same. In this case it is necessary to provide a normalized signal of 7.5 V in point "8" at the maximum speed by choosing changeable resistor R22.

2.2.6. The sequence of calculation of the e.m.f. pick-off parameters is the following:

- calculate the resistance of R14:

$$R_{14} = \frac{R_9 R_{18} E_r}{U_{E,r}(R_1 + R_3)} = 60E_r \text{, } [\Omega] \qquad (2.15)$$

where $E_r$ is the rated e.m.f. of the motor, $U_{E,r}$ is the voltage on the output of amplifier DA4 corresponding to the rated motor e.m.f;

Subsequently, this resistance is determined more precisely during adjustment to provide $U_{EH}$=8 V at the maximum speed of the motor rotating without load.

- the resistance of R13 is calculated according to the expression:

$$R_{13} = \frac{2(R_1 + R_3)R_{14}}{R_9(I_{mot,r} R_a)} = \frac{138 R_{14}}{I_{mot,r} R_a} \text{, } [\Omega] \qquad (2.16)$$

Subsequently, this resistance is determined more precisely during adjustment so that the voltage on the output DA4 at the stopped motor is zero, the current being within 0.3−1.5 of the rated value.

- the capacity of C2 is calculated with the expression:

$$C_2 = \frac{T_a}{R_{13}} \text{, [F]} \qquad (2.17)$$

- the resistance of R21 is calculated with the expression:

$$R_{21} = R_{12} \frac{2E_r}{U_{E,r} I_{mot,r} R_a} = \frac{R_{12} E_r}{3.75 I_{mot,r} R_a} \text{, } [\Omega] \qquad (2.18)$$

- the capacity of C5 is calculated with the expression:

$$C_5 = \frac{T_a}{R_{21}} = \frac{L_a}{R_{21} R_a} \text{, [F]} \qquad (2.19)$$

If the capacity is different from that mounted on the PCB, it may be corrected by installing an additional capacitor on petals 21, 22 in parallel with resistor R21.

- resistor R22 for the modification with e.m.f. feedback is chosen so that the signal in point "8" is equal to 7.5 V at the maximum speed. In this case resistor R7 should be removed. On the other hand, in the modification with speed feedback resistor R7 is installed whereas resistor R22 is removed. The resistance of R22 is about 285 Ω.

**2.3. Running**

2.3.1. Using commutating apparatuses (are not included into the delivery set), connect the feeding voltage for the control circuits and then – the power voltage. Green LED VD24 "ГР" should light signalizing that the drive is ready for operation.

2.3.2. Close the contact of operation permission, PP.

2.3.3. Connect the command voltage (speed command). The drive should accelerate to the set speed with an acceleration determined by the cutoff current setting and rotate with the set speed. The brightness of glowing of LED VD18 "Operation" will be proportional to the load of the drive and its speed.

2.3.4. Switch off the command voltage. The motor will be coasting, decelerating under the influence of the load torque and mechanical losses. During deceleration the motor does not produce any active torque.

Open contact PP. The converter will be interlocked. Switch off the feeding voltage.

2.4. The list of possible troubles and their remedies is given in Table 2.3.

**Table 2.3**

| Trouble description | Possible cause | Remedy |
|---|---|---|
| 1. Fuse blow-out (F1, F2, F3 in Fig. 2.6) | 1.1 Puncture of one or several diodes in rectifier<br>1.2 Puncture of diode of transistor in power transistor switch | 4.4 Replace faulty diodes<br>1.2 Replace diode or transistor module |
| 2. Feeding voltage is applied but none of LEDs lights up | 2.1 Fuse blow-out in БУ2 (F1, F2) | 2.1 Replace blown-out fuses |
| 3. Protection operates as soon as signal PP is applied | 3. Puncture of diode shunting load of converter. | 3. Replace diode |
| 4. At glowing green LED and applied signal PP there is no current on output of converter regardless of command signal size. | 4.1 Open in circuit of resistor R6 in БУ1<br>4.2 Speed controller and power switch are not unblocked<br>4.3 Signal does not pass through power switch control unit | 4.1 Restore circuit<br>4.2 Make sure that transistors VT1 and VT5 in БУ1 are closed<br>4.3 Check that signal passes through circuit of VD21 and VT10. |

## 3. MAINTENANCE AND SAFETY PRECAUTIONS

Not until the mains voltage is switched off should examination, cleaning, repair or component changes be performed. No connectors should be linked/unlinked until feeding voltage has been removed. Never ground the cases of oscilloscopes when using them during repair and adjustment as they might be conductively coupled with the mains.

Only qualified personnel should be allowed to maintain the units.

The cases of the converter and motor should be grounded with wire whose cross-section is at least 2.5 $mm^2$.