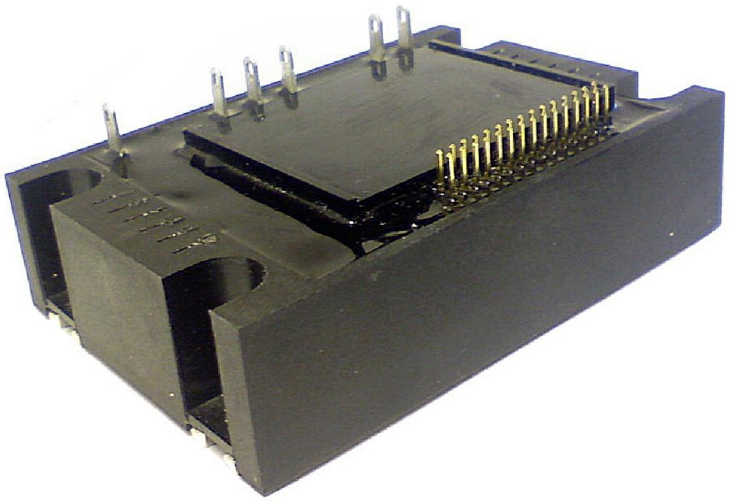
THREE-PHASE BRUSHLESS DC DRIVE MODULE MODERNIZED – 3PHBLDCDMM

USER'S MANUAL



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CONTENTS

1 DESCRIPTION AND FUNCTIONS

The modernized three-phase brushless DC drive module (hereinafter - 3PHBLDCDMM or module) is intended for three-phase electric AC motor controlling on constant magnets with rotor position converter. 3PHBLDCDMM is performed on the basis of modern power electronics, microelectronics, digital-to-analogue integrated circuits and controllers of digital and analogue signal processing with the integral PWM schemes.

3PHBLDCDMM supports the following functions and performances:

- Controllable start/stop of engine;
- Motor shaft rotation direction change;
- Rate control;
- Speed hold when change of motor supply voltage;
- Electric motor protection against current overload and short-circuit;
- Protection against pulse current surges;
- Current protection pickup setting;
- Overheating protection;
- Protection against simultaneous turn-on of top and lower inverter arm transistors;
- Protection against incorrect combination of signals from rotor position transducer;
- External signaling about an accident;
- Internal voltage control;
- Module power from the power circuit;
- Allows supplying the external circuits with its own stabilized voltage +5 V and +15 V with protection against current overload;
- Connection of AC voltage without rectification (3PHBLDCDMM with radiator type “3”);
- Smooth charge of filter capacity without additional charge resistor and charge control circuits (3PHBLDCDMM with radiator type “3”).

3PHBLDCDMM provides operation and protection of the engines with the power up to 15 kW. 3PHBLDCDM produced with different control options which allow using the module as solution to common industrial problems and solutions for special cases.

2 MODULE TYPES

3PHBLDCDMM are produced with different control options and for different inverter currents. In section 5 and 6 the recommended module connection circuits depending on version are represented.

3PHBLDCDMM are produced at 5, 10, 20, 30, 50, 70 and 100 A. The current in module name indicates the maximum inverter current control circuit which allows normal operation; the maximum transistor current exceeds the specified one in the product name. The current protection will trigger at higher current and inverter current will be limited. The current specified in the product name is the protection operation current at the average current. Meanwhile the protection current can be regulated but only to the lower side (see section 5). The peak voltage designed in the module name indicates collector-emitter voltage capability of transistors used in the module. 3PHACDMM is available for 100, 200, 600 and 1200V that correspond to the values of 1, 2, 6 and 12 in the name of the module. Meanwhile peak supply voltage is lower for the module, that it is indicated in the name (see section 4), that conditioned on security measures when operation of the module power transistors.

Modules for 100 V are produced at 5, 10, 20, 30, 50, 70 and 100 A;
Modules for 200 V are produced at 5, 10, 20, 30, 50 and 70 A;
Modules for 600 V are produced at 5, 10, 20, 30 and 50 A
Modules for 1200 V are produced at 5, 10, 20, 30 and 50 A;

Variation of power assembly:

«4» - only inverter.

«3» - inverter and rectifier bridge. This version of the radiator contains controlled thyristor-diode rectifier bridge which allows the module to operate directly from the AC voltage. The control chart of the rectifier bridge thyristors provides a smooth (within 300 ms) filter capacity charge, which, in turn, allows managing without the current-limiting resistor.

With power assembly type “3” the module of 1, 2, 6-th class at currents 5 and 10 A are produced that is 3PHBLDCDMM-5-1-x3, 3PHBLDCDMM-10-1-x3, 3PHBLDCDMM-5-2-x3, 3PHBLDCDMM -2-x3, 3PHBLDCDMM-5--6x3, 3PHBLDCDMM-10-6-x3. All other types of 3PHBLDCDM are produced only with power assembly type “4”.

Control option:

"A" - standard with the PWM. Digital-to-analog control using all standard control module outputs with integral PWM generator circuit.

"B" – simplified with PWM. The control option, with built-in PWM-oscillator scheme which allows choosing operation enable/disable and motor shaft rotation direction with one switch, that is convenient, in particular, using the module in lifting and traction mechanisms.

"C" – bipolar with PWM. Controls with built-in PWM-oscillator scheme, is carried out on one input or with DAC or with help a variable appropriately connected resistor. Control voltage is in the range -10 … +10 V with the braking range -0.5 … +0.5 V. The rotation speed meanwhile is determined by the voltage amplitude, and the rotation direction of its polarity.

“D” – digital with PWM. DAC forms a part of the module. DAC allows carrying out the speed control with a digital code; meanwhile the module can be controlled by the standard control scheme (type “A”);
the control option choice is carried out with availability or deficiency of the jumper (see section 5). The module has an internal PWM-oscillator.

“E” – standard without PWM. The control algorithm is not differed from the type “A”, except that the module does not include PWM-oscillator. For module operation it is necessary the external connection of timing chain for PWM-oscillator, feedbacks connection. The module options without internal PWM-oscillator can be convenient for decision of complicated particular problems and for realization of specific speed feedbacks.

"F" – simplified without PWM.
"G" – bipolar without PWM.
"H" – digital without PWM.

All control options are applicable to all types of power assemblies, regardless of the current and of the voltage.
Figure 2.1 shows the decoding of the module names series 3PHBLDCDMM.

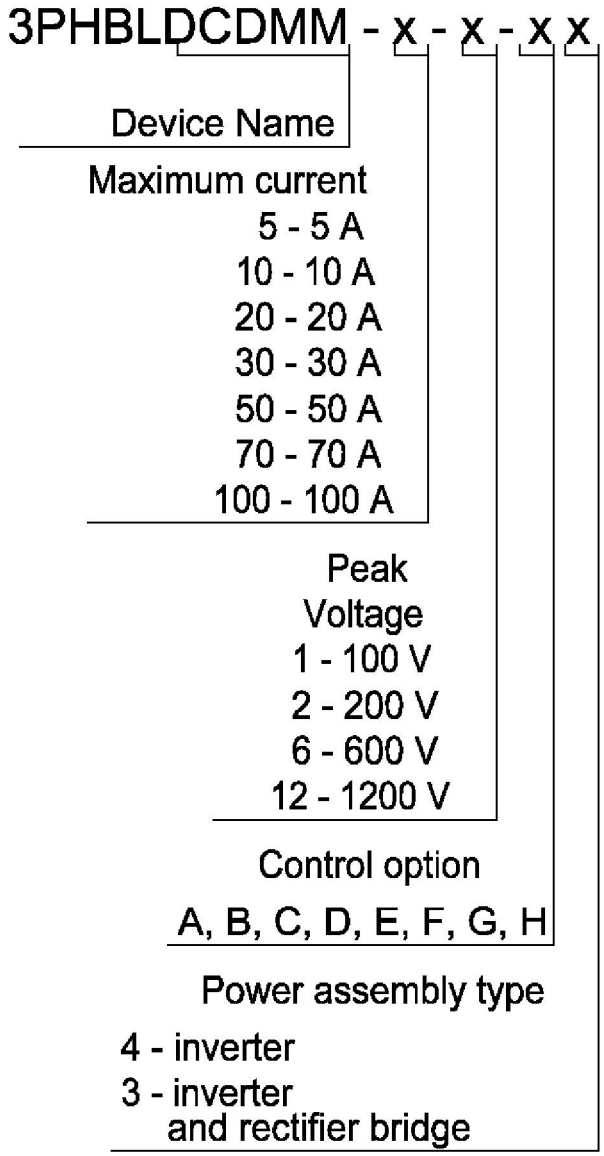

Figure 2.1 – Module name explanation

For instance, the module 3PHBLDCDMM-30-12-B4: brushless motor control module with maximum inverter current 30 A, peak inverter voltage 1200V, with control option «B», power assembly – only inverter.

3 GENERAL MODULE DESCRIPTIONS

Module 3PHBLDCDMM is an assembly of control thyristors module M31 and control module 3phBLDCCM. The structural circuit of 3PHBLDCDMM is shown at Figure 3.1.

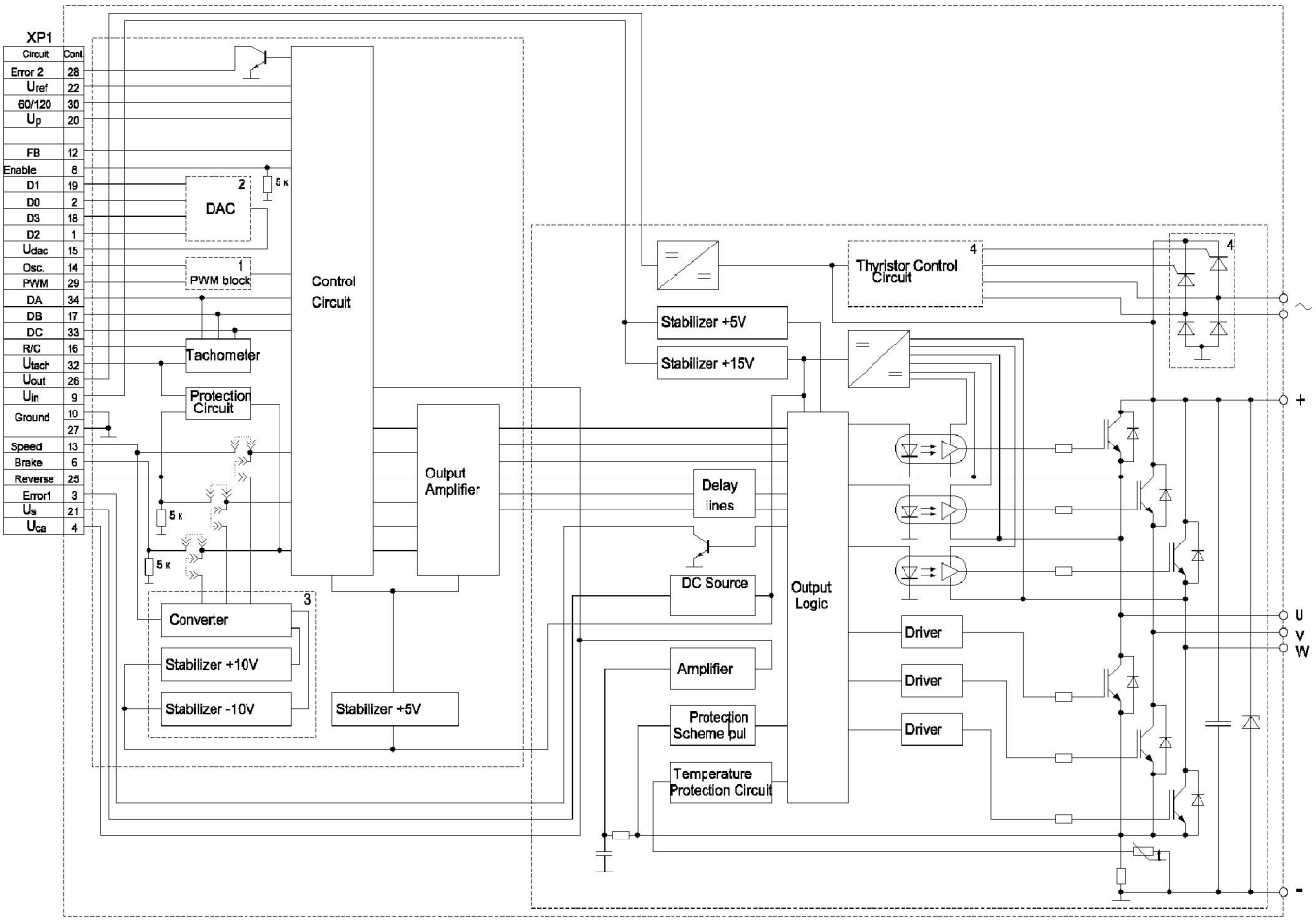

Figure 3.1 – Structural circuit of 3PHBLDCDMM

«1» - internal PWM generator scheme, installed for control options «A», «B», «C» and «D».

«2» -internal DAC, installed for control options «D», «F»

«3» - conversion circuit for bipolar connection, being a part of 3PHBLDCDMM for control options «B» and «G».

«4» - rectifier bridge circuit, providing smooth filter capacity charge and capability of module operation from AC voltage. The scheme is a part of 3PHBLDCDMM with power assembly type "3".

Connector XP1 is two rows of contacts PLS-17 with the response part of the type PBS-17. The connector is intended for module controlling. Power contacts or tips (for modules at currents 5 and 10 A), or tread contacts for screw M8 (see overall drawings). Outputs assignment of connectors XR1 and power outputs are represented in Table 3.1. In the columns "Control" the sign "+" denotes that the output is used for this control type, the sign "-" denotes that the output is not used.

Table 3.1 – Module outputs assignment

Number	Symbol	Description
1	D2	The second discharge of digital speed control input
2	D0	The null discharge of digital speed control input
3	Error 1	Signaling output of current and temperature overload
4	U_{ca}	Amplifier output of Bypass Current
5		Not involved
6	Brake	Braking Control Input
7		Not involved
8	Enable	Operation Enable/Inhibit Input
9	U_{in}	Internal voltage stabilizer Input
10	Ground	Ground
11		Not involved
12	FB	Speed Feedback Input
13	Speed	Rotation Speed Control Input
14	Osc.	Connection Input of pulse-time frequency elements of PWM Oscillator
15	U_{dac}	Digital Speed Control Input
16	R/C	Tachometer RC-chain output
17	DB	Sensor Connection Input of phase V
18	D3	The third discharge of digital speed control input
19	D1	The first discharge of digital speed control input
20	U_p	Protection Operation Current Control Output
21	U_s	DC Source Output +15 V
22	U_{ref}	Reference Voltage Source
23		Not involved
24		Not involved
25	Reverse	Control Input of Motor Shaft Rotation Direction
26	U_{out}	Internal DC/DC – converter Output
27	Ground	Ground
28	Error 2	Signaling Output of Operation Inhibit
29	PWM	Inverting PWM Comparator Input
30	60/120	Control Input of phasing mode
31		Not involved
32	U_{tach}	Tachometer Signal Output
33	DC	Sensor Connection Input of phase W
34	DA	Sensor Connection Input of phase U
	+	Power Supply Connection Output «+»
	U	Connection Output of Phase A
	V	Connection Output of Phase B
	W	Connection Output of Phase C
	-	Power Supply Connection Output «-»
	~	AC Voltage Connection Output (only for modules with rectifier bridge)

For easy connection of control circuits schematic external connectors XP1 of 3PHBLDCDMM are shown at Figures 3.2 – 3.2.7.

1									10								17
		Er.1	U_{oy}		Brake		Enable	U_{in}	Ground			Speed				DB	
		U_p	S.	U_{ref}			Rev	U_{out}	Ground	Er.2		60/120		U_{tach}	DC	DA	
18									27								34

Figure 3.2 – Appearance of connector XP1 with control A.

1									10								17
		Er.1	U_{ca}		Brake		Enable	U_{in}	Ground			Speed				DB	
		U_p	S.	$U_{оп}$			Reverse	U_{out}	Ground	Er.2		60/120		U_{tach}	DC	DA	
18									27								34

Figure 3.2.1 – Appearance of connector XP1 with control B.

1									10								17
		Er.1	U_{ca}				Enable	U_{in}	Ground			Speed				DB	
		$U_з$	S	U_{ref}				U_{out}	Ground	Er.2		60/120		U_{tach}	DC	DA	
18									27								34

Figure 3.2.2 – Appearance of connector XP1 with control C.

1									10								17
D2	D0	Er.1	U_{oy}		Brake		Enable	U_{in}	Ground			Speed		U_{dac}		DB	
D3	D1	U_p	S	U_{ref}			Reverse	U_{out}	Ground	Er.2		60/120		U_{tach}	DC	DA	
18									27								34

Figure 3.2.3 – Appearance of connector XP1 with control D.

1									10								17
		Er.1	U_{ca}		Brake		Enable	U_{in}	Ground		FB	Speed	Osc.		R/C	DB	
		U_p	S	U_{ref}			Reverse	U_{out}	Ground	Er.2	PWM	60/120		U_{tach}	DC	DA	
18									27								34

Figure 3.2.4 – Appearance of connector XP1 with control E.

1									10								17
		Er.1	U_{ca}		brake		Enable	U_{in}	Ground		FB	Speed	Osc.		R/C	DB	
		U_p	S	U_{ref}			Reverse	U_{out}	Ground	Er.2	PWM	60/120		U_{tach}	DC	DA	
18									27								34

Figure 3.2.5 – Appearance of connector XP1 with control F.

1									10								17
		Er.1	U_{ca}				Enable	U_{in}	Ground		FB	Speed	Osc.		R/C	DB	
		U_p	S	U_{ref}				U_{out}	Ground	Er.2	PWM	60/120		U_{tach}	DC	DA	
18									27								34

Figure 3.2.6 – Appearance of connector XP1 with control G.

1									10								17
D2	D0	Er.1	U_{ca}		Brake		Enable	U_{in}	Ground		FB	Speed	Osc.	U_{dac}	R/C	DB	
D3	D1	U_p	S	U_{ref}			Reverse	U_{out}	Ground	Er.2	PWM	60/120		U_{tach}	DC	DA	
18									27								34

Figure 3.2.7 – Appearance of connector XP1 with control 3

Basic electric characteristics and maximum allowable electric characteristics of the modules 3PHBLDCDMM at 25 ^{0}C are represented in Table 4.1.

Table 4.1 – Basic electric characteristics and maximum allowable electric characteristics of 3PHBLDCDMM

Title	Unit	Rate			Note
		min	typ.	max	
Supply characteristics					
Supply Voltage (power from power circuit)*	V	40		60	1-st class
		40		160	2-nd class
		40		350	6-th class
Current Consumption	mA			40	Supply from power circuit U_s=350 V
Supply Voltage	V	15		20	External Supply
Current Consumption	mA		200	250	External Supply
Input Characteristics					
Output Current Consumption	mA			1	
Current Consumption on outputs «DA», «DB», «DC»	mA			5	U=15 V
Control Voltage Range	V	-0.3		5.2	
Lower Level Input Voltage	V	-0.3		0.5	For logic inputs
High Level Input Voltage	V	2.4		5.2	For logic inputs
Closedown Voltage	V		0.5		
Maximum Speed Voltage	V		4.5		
PWM oscillator characteristics					
PWM oscillator Frequency	kHz	15		25	
Maximum Peak Tooth Voltage	V	4.2		4.6	
Minimum Peak Tooth Voltage	V	1.0		1.2	
Electric Tachometer Characteristics					
Output Voltage	V	3.6		4.2	
Positive Pulse Duration	ms		1		
Output Signal Pulse Duration Instability	μs			250	
Output characteristics					
Maximum Voltage on Output «Error»	V			20	
Maximum Current on Output «Error»	mA			20	
Voltage on Output «U_{ref}»	V	6.25	6.5	6.75	No load
Maximum Load Current on Output «U_{ref}»	mA			10	
Voltage on Output «U_s»	V		15	16.5	No load
Maximum Load Current on Output «U_s»	mA			50	
Current Protection Operation Voltage «U_{ca}»	V		1.0		

Protection Characteristics					
Protection Operation Current at average Current	A		5		5 A
			10		10 A
			20		20 A
			30		30 A
			50		50 A
			70		70 A
			100		100 A
Current Protection Speed	µs			100	
Protection Operation Current at Pulse Current	A		20		5 A
			40		10 A
			70		20 A
			120		30 A
			200		50 A
			250		70 A
			350		100 A
Protection Speed at Pulse Current	µs			3	
Protection Turn-on Frequency against Braking with anti-connection	Hz			4	
Turn-on Temperature of Temperature Protection	^{0}C	90		100	
Turn-off Temperature of Temperature Protection	^{0}C	50		60	
Temperature Protection Speed	ms			1	
Output Operation Delay «Error»	µs			2	

* the control circuit can not be supplied from power voltage for modules of the 12-th class

Table 4.2 – Basic and maximum permissible electric characteristics of power circuits for modules of 1-st class (3PHBLDCDMM-xx-1-xx)

Title	Unit	Rate			Note
		min	type	max	
Power switches characteristics					
Drain-Source Maximum Voltage	V			100	
DC Link Peak Voltage	V			60	
Power Transistor Maximum average current at 100^{0}C	A			12	5 A
				23	10 A
				30	20 A
				40	30 A
				68	50 A
				97	70 A
				107	100 A
Power Transistor Maximum Pulse Current at 25^{0}C	A			60	5 A
				110	10 A
				140	20 A
				230	30 A
				380	50 A
				550	70 A
				600	100 A
Loss Power at Maximum Load	W			5,5	5 A
				11	10 A
				36	20 A
				52	30 A
				75	50 A
				105	70 A
				200	100 A
Power Circuit Closed Transistor Leakage Current	µA			100	

Isolation characteristics					
Isolation Voltage Module Outputs – housing base	V	1000			DC, 1 minute

Table 4.3 – Basic and maximum permissible electric characteristics of power circuits for modules of 2-nd class (3PHBLDCDMM-xx-2-xx)

Title	Unit	Rate			Note
		min	type	max	
Power switches characteristics					
Peak Voltage Drain-Source	V			200	
DC Link Peak Voltage	V			160	
Power Transistor Maximum average current at 100 ^{0}C	A			11	5 A
				17	10 A
				32	20 A
				44	30 A
				66	50 A
				76	70 A
Power Transistor Maximum Pulse Current at 25 ^{0}C	A			70	5 A
				90	10 A
				180	20 A
				260	30 A
				380	50 A
				420	70 A
Loss Power by Maximum Load	W			10	5 A
				25	10 A
				55	20 A
				55	30 A
				125	50 A
				270	70 A
Power Circuit Closed Transistor Leakage Current	µA			100	
Isolation characteristics					
Isolation Voltage Module Outputs – housing base	V	2000			DC, 1 minute

Table 4.4 – Basic and maximum permissible electric characteristics of power circuits for modules of 6-th class (3PHBLDCDMM-xx-6-xx)

Title	Unit	Rate			Note
		min	type	max	
Power switches characteristics					
Collector-Emitter Peak Voltage	V			600	
DC Link Peak Voltage	V			400	
Power Transistor Maximum Average Current at 100 ^{0}C	A			11	5 A
				16	10 A
				30	20 A
				60	30 A
				60	50 A
Power Transistor Maximum Pulse Current at 25 ^{0}C	A			35	5 A
				60	10 A
				105	20 A
				240	30 A
				240	50 A
Loss Power at Maximum Load	W			20	5 A
				45	10 A
				80	20 A
				90	30 A
				280	50 A

Power Circuit Closed Transistor Leakage Current	μA			100	
Isolation characteristics					
Isolation Voltage Module Outputs – housing base	V	4000			DC, 1 minute

Table 4.5 – Basic and maximum permissible electric characteristics of power circuits for modules of 12-th class (3PHBLDCDMM-xx-12-xx)

Title	Unit	Rate			Note
		min	type	max	
Power switches characteristics					
Collector-Emitter Peak Voltage	V			1200	
DC Link Peak Voltage	V			700	
Power Transistor Maximum Average Current at 100 ^{0}C	A			10	5 A
				15	10 A
				24	20 A
				60	30 A
				60	50 A
Power Transistor Maximum Pulse Current at 25 ^{0}C	A			40	5 A
				60	10 A
				90	20 A
				240	30 A
				240	50 A
Loss Power at Maximum Load	W			25	5 A
				65	10 A
				160	20 A
				90	30 A
				280	50 A
Power Circuit Closed Transistor Leakage Current	μA			100	
Isolation characteristics					
Isolation Voltage Module Outputs – housing base	V	4000			DC, 1 minute

5 MODULE CONTROL

In dependence on module control type we recommend the following turn-on schemes (Fig.5.1 – 5.4).

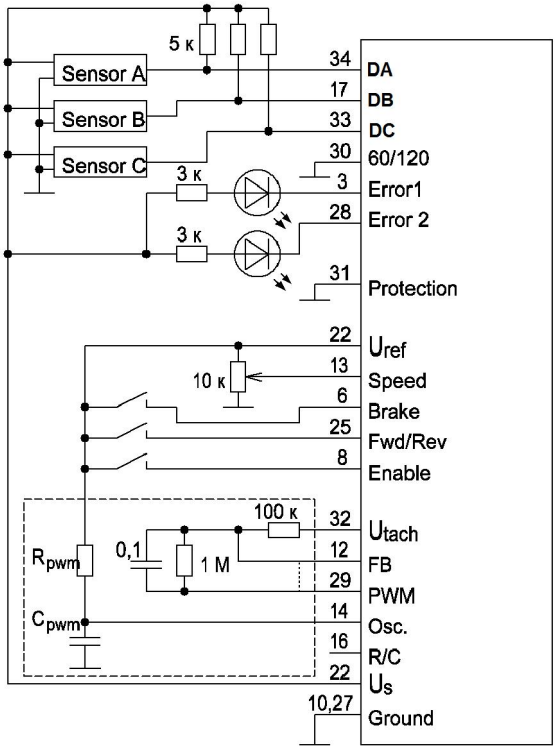

Figure 5.1 – Turn-on schemes of Control Circuits 3PHBLDCDMM «A» and «E»

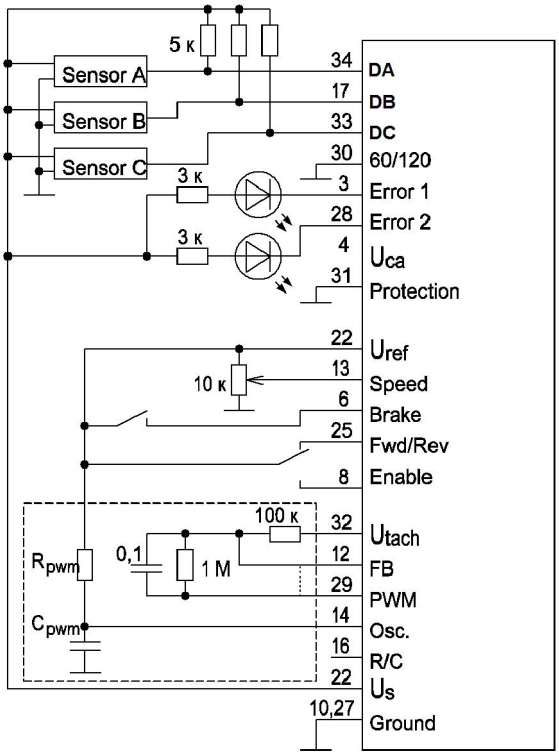

Figure 5.2 – Turn-on schemes of Control Circuits 3PHBLDCDMM «B» and «F»

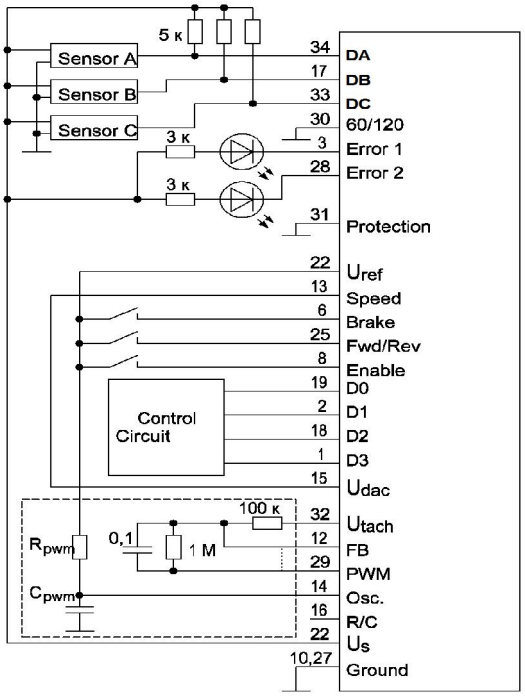

Figure 5.3 – Turn-on schemes of Control Circuits 3PHBLDCDMM «D» and «H»

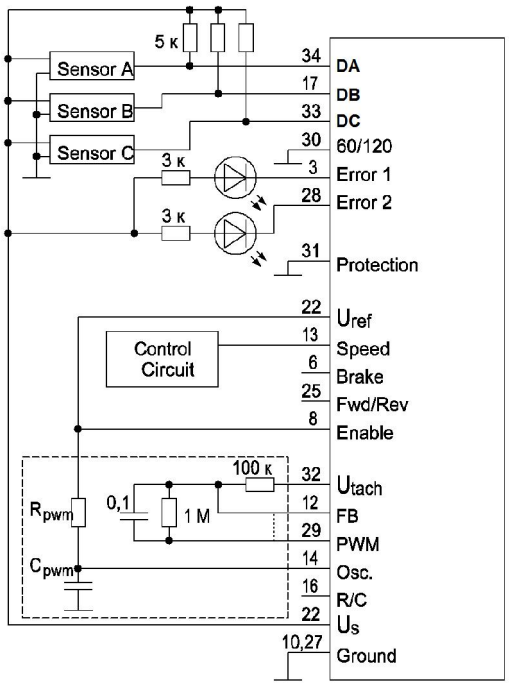

Figure 5.4 – Turn-on schemes of Control Circuits 3PHBLDCDMM «C» and «F»

Dotted lines represent a part of the scheme that is necessary for turn-on of the modules without internal PWM generator (options «E», «F», «G», «H»). For modules with internal PWM oscillator the indicated outputs should be unactuated.

The turn-on scheme of the module with control option «B» or «F» with common switch to “Forward Reverse” and “Enable” is shown at Figure 5.2. Module operation inhibition will be only in case of switch breaking with both contacts. Control options “B” and “F” can be also controlled on option circuits “A” and “E”.

It is allowed to use the logic TTL-level control instead of the switches.

The motor control by means of 3PHBLDCDM is carried out with help of following outputs:

«Enable». TTL-level input giving inhibition or enable to control scheme operation. “Log.1” corresponds to enable, “log.0” – to disable. When operation inhibiting, output transistor “Error” will be open (see Table 1).

«Brake». TTL-level input turning on and off the braking mode. If there is “log.0” the braking will be absent. When “log.1” is given to this input all lower inverter transistors will be open, and the motor will go into dynamic braking (see Table 5.1).

«Forward Reverse». TTL-level input giving motor shaft rotation direction. When rotation changing the dynamic brake will operate which will be kept to shaft rotation decrease to 1….3 kHz, after that the changes to side opposite will begin. With giving of short-time pulse on input “Reverse” or with return of signal reference level before motor shutdown, the dynamic brake will all the same operate and acceleration will begin from 1…3 Hz.

«60/120». TTL-level input rating phasing mode. «Log.1» on input «60/120» settle phasing mode of 60 (300) electrical degrees; «log.0» – phasing mode of 120 (240) electrical degrees (see Table 5.1).

Algorithms 60° and 300° or 120° and 240° are symmetrical but rotor shaft rotation direction is reverse for them. For instance, when RPS signals are given on inputs «DA», «DB», «DC» with phasing algorithm 60° or 120°, the module gives current control signals by the motor for forward rotation, and when RPS signals are given with phasing algorithm 240° or 300° – for reverse rotation.

The sensors’ status depending on rotor position varies in accordance with the diagram is showed at Figure 5.5.

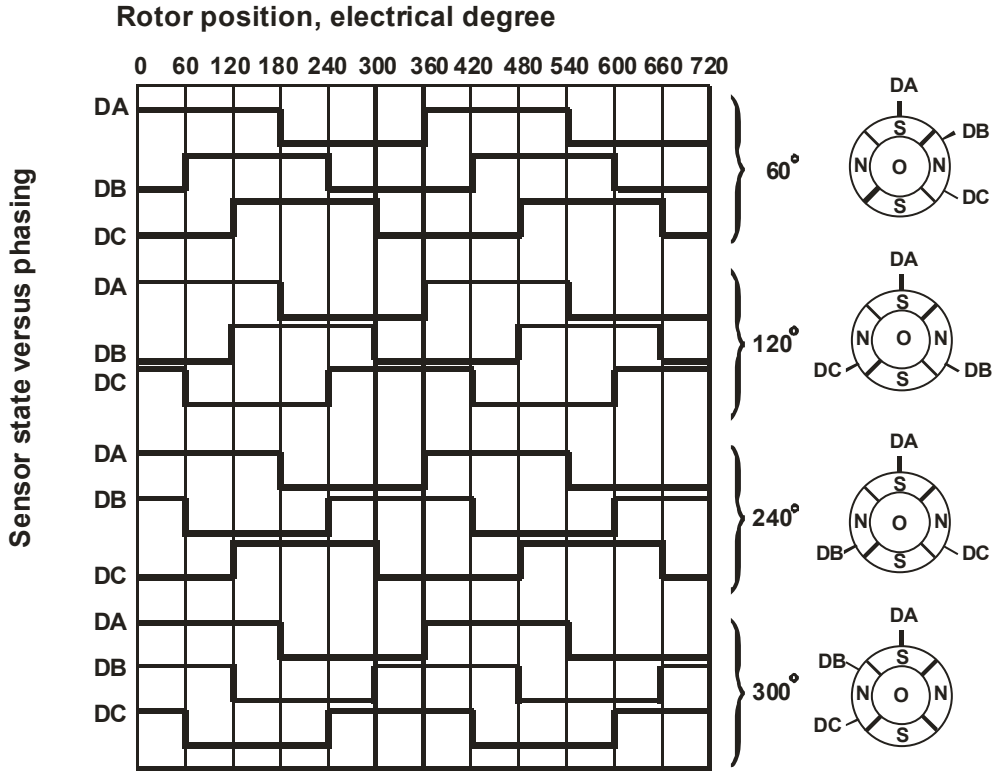

Figure 5.5 – Diagram of position sensors statuses

«Speed» Input of motor shaft rotation velocity demand. The module exercises motor shaft rotation speed hold when the supply voltage amplitude varies. If the set rotation speed is less than 50% of the maximum the speed varies no more than ± 5 %, when the supply voltage is differed ± 50 %. By maximum speed the regulation is carried out only supply voltage amplitude increase the speed differs no more than + 5 %, when amplitude increase no more than + 50 %). Speed control mode is within 0.5…4.5 V for control options «A», «B», «C», «E», and for the other options with the introduction feedback in the external control circuit (see Fig.5.1 - 5.4). If the feedback for control options "E", "F", "G", "H" is absent (the jumper is installed, as indicated by the dotted line on Fig.5.1 - 5.4), then the speed control range will be in the range 1.5 ... 4.5 V. The motor shaft rotation speed versus the input voltage "Speed" is presented at Fig. 5.6 and 5.7 (for control options, "C" and "D").

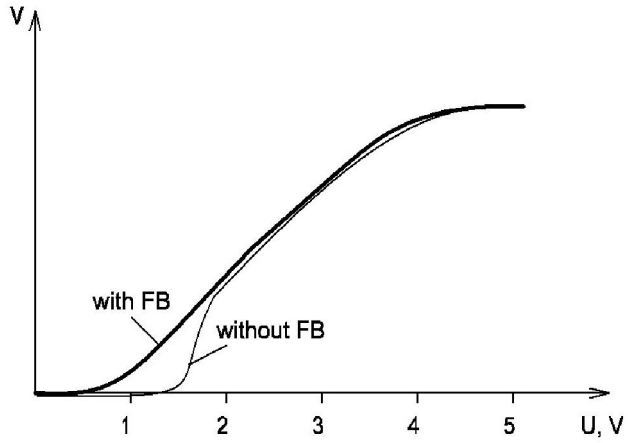

Figure 5.6 – Motor Shaft Rotation Speed versus Output Voltage «Speed» with feedback circuit and without it

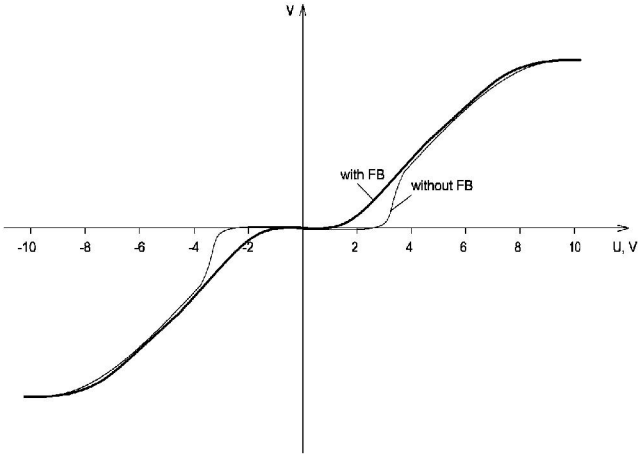

Figure 5.7 – Motor Shaft Rotation Speed versus Output Voltage «Speed» with feedback circuit and without it for control options «C» and «G»

For options «C» and «G» the motor control is carried out only on output «Speed»; outputs «Forward Reverse» and «Brake» are unactuated. Output «Enable» can be connected to «U_{ref}», then this output will not affect the module operation, if the output «Enable» to «U_{ref}» through the switch, then the control on this output will be carried out as well as for the other control options.

Motor rotation direction is selected in agreement with signal polarity on output «Speed», the control voltage -0.5…+0.5 V corresponds to braking mode (all lower switches are open), the rotation speed is regulated with voltage level (-10…+10 V). The diagram with explaining the module operation with control option «B» and «E» is shown at Figure 5.8.

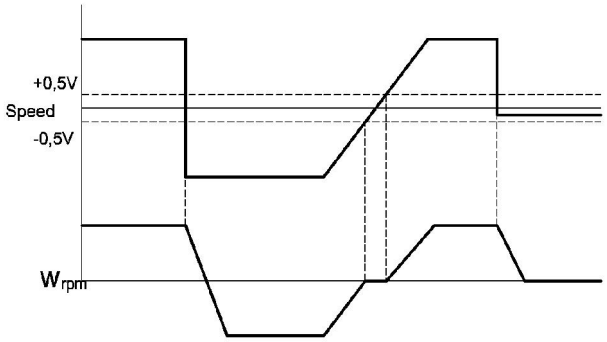

Figure 5.8 – Module control with option «C» и «G»

«DA», «DB», «DC». Inputs of rotor position sensors (RPS). As RPS transducers of any type with output voltage +5…20 V can be used. When connecting the RPS you must take into account that the outputs «DA», «DB» and «DC» are not pulled up to supply voltage, therefore the sensor output is an open collector, this outputs should be connected to supply voltage output the resistors as it is indicated at Fig. 5.1 – 5.4.

Below there is a table of module statuses when three-phase six-step brushless DC module control.

Table 5.1 – Options of module statuses when three-phase six-step brushless DC module control.

Inputs									Protection	Outputs				Note
60º/120º=1			60º/120º=0			Fwd/Rev	Enable	Brake		U	V	W	Error 2	
DA	DB	DC	DA	DB	DC									
1	0	0	1	0	0	1	1	0	0	1	-	0	1	
1	1	0	1	1	0	1	1	0	0	-	1	0	1	
1	1	1	0	1	0	1	1	0	0	0	1	-	1	Fwd/Rev=1
0	1	1	0	1	1	1	1	0	0	0	-	1	1	(p.1; p.2)
0	0	1	0	0	1	1	1	0	0	-	0	1	1	
0	0	0	1	0	1	1	1	0	0	1	0	-	1	
1	0	0	1	0	0	0	1	0	0	0	-	1	1	
1	1	0	1	1	0	0	1	0	0	-	0	1	1	
1	1	1	0	1	0	0	1	0	0	1	0	-	1	Fwd/Rev=0
0	1	1	0	1	1	0	1	0	0	1	-	0	1	(p.1; p.2)
0	0	1	0	0	1	0	1	0	0	-	1	0	1	
0	0	0	1	0	1	0	1	0	0	0	1	-	1	
1	0	1	1	1	1	X	X	0	X	-	-	-	0	p.3
0	1	0	0	0	0	X	X	0	X	-	-	-	0	
1	0	1	1	1	1	X	X	1	X	0	0	0	0	p.4
0	1	0	0	0	0	X	X	1	X	0	0	0	0	
V	V	V	V	V	V	X	1	1	X	0	0	0	1	p.5
V	V	V	V	V	V	X	0	1	X	0	0	0	0	p.6
V	V	V	V	V	V	X	0	0	X	-	-	-	0	p.7
V	V	V	V	V	V	X	1	0	1	-	-	-	0	p.8

p.1	On outputs «U», «V», «W» high level (1) signifies connection to «+», low level (0) – connection to «–» (ground minus).
p.2	High level (1) on input «60º/120º» installs the phasing mode of 60 electric degrees, low level (0) – phasing mode of 120 electric degrees
p.3	With wrong combination on inputs «DA», «DB», «DC», low level (0) on input «Brake» - outputs «U», «V», «W» are disconnected; output «Error 2» built on the circuit with open collector has an active low level (0)
p.4	With wrong combination on inputs «DA», «DB», «DC», high level (1) on input «Brake» - outputs «U», «V», «W» are connected to «-» (ground minus), motor windings are closed between each other, thus, the braking electromagnetic force is generated (dynamic brake); on output «Error 2» - low level (0)
p.5	With true combination on inputs «DA», «DB», «DC», high level (1) on inputs «Enable» and «Brake» - outputs «U», «V», «W»» are in dynamic braking mode; on output «Error 2» - high level (1)
p.6	If on input «Enable» is low level (0), and on input «Brake» high level (1) – outputs «U», «V», «W» are in dynamic braking mode; output «Error 2» - low level (0)
p.7	If on the inputs «Enable» and «Brake» is low level (0) – outputs «A», «B», «C» are disconnected; on output «Error 2» - low level (0)
p.8	At the current level consumed by the motor from an external source of specified limit above – outputs «U», «V», «W» are disconnected; on output «Error 2» - low level (0).

Where X – any state on input, V – any true state on sensory input corresponding to the phasing of 60º or 120º.

«U_p». Output of current protection pickup. With unactuated output «U_p» the protection will operate on maximum current of 3PHBLDCDMM; with connection of outputs «U_p» and «Ground» The protection will operate on the level 10…20% of the maximum current. For protection pickup demand it is necessary to connect the resistor R_{ch} to this output as shown at Fig. 5.1 - 5.2. The nominal of this resistor should be chosen proceeding from the following graph (see 5.9).

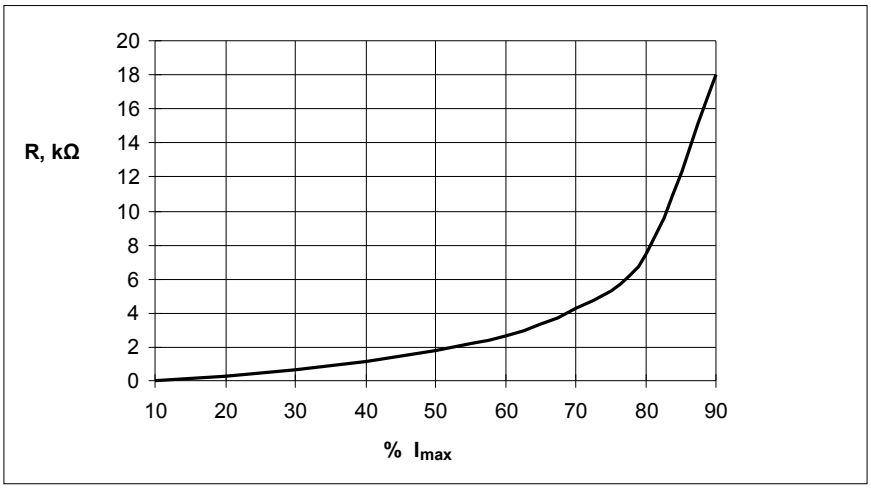

Figure 5.9 - Protection Operation Current versus Protection Resistor Value.

Thus, if, for instance, resistor of 2.7 kΩ will be connected to 3PHBLDCDMM of 10A, then the protection will operate at current of 6A. For easy calculation there is Table 5.1 of adjustable protection current percentage against protection over-current.

Table 5.2 - Percentage of probable protection current versus maximum protection current

%	Maximum current specified in product name, A						
	5	10	20	30	50	70	100
20	1	2	4	6	10	15	20
40	2	4	8	12	20	30	40
60	3	6	12	18	30	40	60
80	4	8	16	24	40	55	80
100	5	10	20	30	50	70	100

«U_{ca}». Inverter current amplifier output (motor current). To the maximum module current corresponds to 1.1 V on amplifier output regardless of current nameplate value supported by the module. The dependence of the voltage on output «U_{ca}» on motor current is linear one.

«Error 1». Output signals the incidents which is a result of current overload or overheating, being an open transistor collector of protection circuit.

«Error 2». The output signaling about module operation inhibits («log.0» on output «Enable» and "log. 1" on output "Protection"), wrong combination on outputs of rotor position transducers, being an open transistor collector of protection circuit. The explanation of this output operation is shown in Table 5.1.

«U_{ref}». Reference voltage source output (6.5V±5%) with maximum output current of 10 mA. When connecting this output you should be careful to avoid current overload or short circuit, because in this case the module can fail.

«U_s». Source output of DC voltage +15V with current limiting at level 50 mA. When connecting the external circuits it is recommended to supply them from this output because even in the event of short current or overload the module will not break.

«$U_{in\ ss}$». Internal supply stabilizer +15 and +5V, being necessary for operation of control and protection circuits. For consistent module operation the voltage at this input must be +16…20V; current consumption is no more than 200 mA without external load.

«U_{out}». Output of internal DC/DC–converter designed for conversion of power circuit voltage 40…600V in stabilized voltage +18V with load capability up to 250 mA. In the event that the module is supplied from the external voltage source, connected to output «U_{in}», this output must be unactuated.

It is recommended to use the external supply at running voltage of power circuit not less than 40V. It is tolerated the module supply of power voltage with stabilizer setting at 16…20V. If it is provided for module supply from the power voltage through the internal DC/DC-converter, then the outputs «U_{in}» and «U_{out}» must be connected.

«U_{tach}». TTL-level output of internal module tachometer. With motor shaft rotation on output «U_{tach}» there must be the pulses with duration of 1 ms and duty factor changing in dependence of motor shaft rotation speed.

For measure of motor speed it is recommended to connect to this output RC-circuit smoothing the ripples. In this case, with motor shaft rotation acceleration the duty cycle on output «U_{tach}» will be decreased and on output RC-filter the signal amplitude will be increased. It is rational to use this output for speed display or speed feedback.

«R/C». Serviceability control input of internal module tachometer. In normal tachometer operation, on this output should be the pulses with amplitude of 3 … 5 V and duty cycle depending on the motor shaft rotation speed, the leading edge should be considerably longer than the rear one.

«Osc.». The input meant for timing chain connection for internal PWM oscillator. The recommended connection scheme of this input is represented at Figure 5.1 – 5.4. The frequency giving by external RC-chain, should be within 15…50 kHz. The frequency versus resistor nominal and capacitor is shown at Figure 5.10.

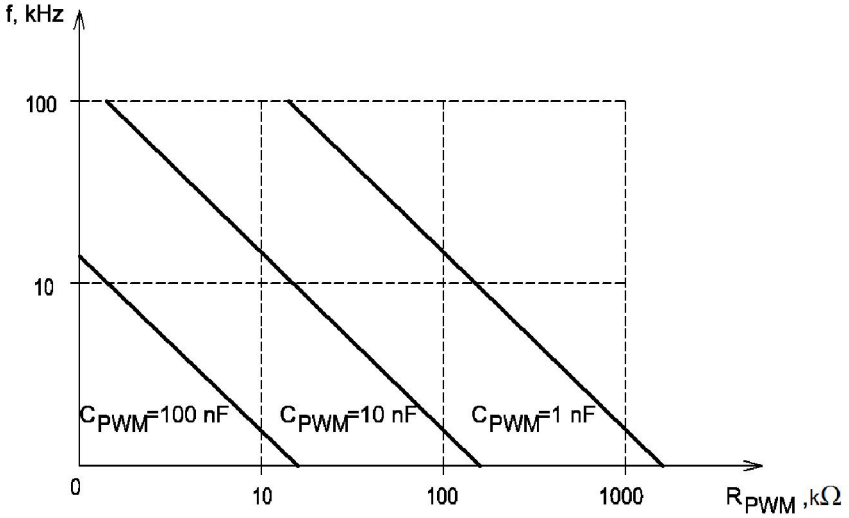

Figure 5.10 - PWM-Frequency versus R_{pwm} and C_{pwm} nominal

For more linear nature of the motor shaft rotation speed change versus control voltage, it is recommended to install the current source 0.5 ... 5 mA instead of R_{PWM} depending on the desired PWM frequency.

The output is involved only for control options «E», «F», «G», and «H».

«PWM» and **«FB».** Stabilization inputs of motor shaft rotation speed. The outputs are enabled only for control options «E», «F», «G», «H»; for control options «A», «B», «C» and "D" the feedback is loaded in module circuit and does not require any adjustments. If the feedback is not required, then these outputs should be connected (Fig.5.1 - 5.4), then the speed will be regulated in control voltage range 1.5…4.5 V. The option of module using in the mode of feedback closed loop is shown at Figure 5.8. The pulse signal which is proportional to speed level (tachometer signal) can be received from any sensor (optical, Hall transducer) with signal level (0…6.5) V.

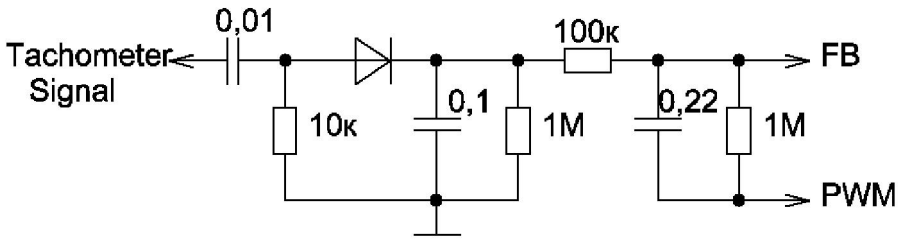

Figure 5.8 – Speed Feedback Connection Scheme

The feedback depth and its operation correctness at different motor shaft rotation speed should be regulated with the capacitor ratio of 0.01 μA and resistor ratio of 10 kΩ, or capacitor ratio of 0.22 μA and resistor ratio 100 kΩ.

«D0», «D1», «D2», «D3». TTL-level inputs of internal DAC. Motor shaft rotation frequency will change from combination corresponding 0.5 V at the DAC output (the output of «U_{dac}») to combination corresponding 4.5 V for the options of internal PWM oscillator, or with the engaged feedback. To control without feedback the speed regulation will be implemented starting with the combination corresponding to 1.5 V. The outputs are involved only for control options "D" and "H".

«U_{dac}». Output of internal DAC. To control connection with DAC you need to connect this output with the output "Speed", as stated in Figure 5.3. The value change of the input code from 0000 to 1001 leads to step change of the speed level from 0% to 90% approximately on 10%. The values of the input code from 1010 to 1111 correspond to 100% of speed level. To provide smoother speed regulation it is recommended to install the capacitance integrator 1…10 kΩ / 0.01…0.1 μF between outputs «U_{dac}» and «Speed» and to supply PWM-signal of 1…20 kHz to one of the digital velocity demand input. Therewith the older the charge the larger range (but and the bigger increment) in which the regulation is carried out: changes 1…1.5 V when signal delivering to output «D3»; changes 0.1…0.2 V when delivering to output «D0».
The outputs are involved only for control options "D" and "H".

Operation features of the module protection.

M31 has four protections: protection on average current, protection on pulse current, temperature protection and protection against the simultaneous turning on of the upper and lower transistor of one phase.

Protection at the average current limits the average current flowing through the windings of the motor. Protection speed – is not more than 100 μs. This protection limits the current to the maximum (if a resistor «R_{ch}» is not installed) for the module level. In the name of the module is specified protection operation current at the average current but limitations current in fact less than the protection operation current that is due to the volatility of current flowing through the windings of the motor; the protection is triggered by bursts of current with a duration of more than 100 μs. The limitation current also depends on the rotation speed of the engine and the nature of the overload (in one phase, two or three). The lower speed and less congested phases, the lower current will limit the module, because with the same amplitude of pulsed current the pulse ratio varies, resulting in a change of the motor average current.

The signaling about protection operation at average current is carried out through the output “Error 1”.

Pulse current protection turns off the power module transistors at a high motor pulse current. Protection speed – is not more than 2 microseconds with operation current exceeding the protection operation current at average current in 3… 4 times.

During normal engine operation, this protection will be triggered only during acceleration and braking under heavy load, limiting the starting and braking currents. As in the case of the protection at the average current on the output "Error 1" a signal corresponding to protection operation will appear. In contrast to the average current protection, protection operation threshold on pulsed current is not regulated.

Temperature protection turns off the power module transistors at housing temperature 90…100 ^{0}C and turns on at temperature 50…60 ^{0}C, providing the hysteresis 30…40 ^{0}C. During temperature protection operation the transistor on output “Error 1” will be opened to housing temperature decreasing to 50…60 ^{0}C.

When temperature protection operation power switch does not reset the protection; the module will start only after lowering of the housing temperature to acceptable level.

Protection against the simultaneous operation of the upper and lower arm of one phase with the switching lock with continuance of 5 μs eliminates the failure of the module on the cross-currents. Including, because of the control circuit failure the power transistors will not go down.

6 POWER OUTPUTS

Depending on the type of module power assembly it is recommended the following diagrams for power circuits' connection (Fig. 6.1 – 6.3).

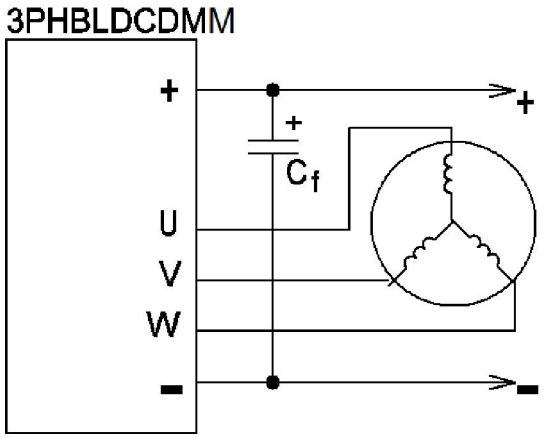

Figure 6.1 – Connection circuit of 3PHBLDCDMM with power assembly type «4»

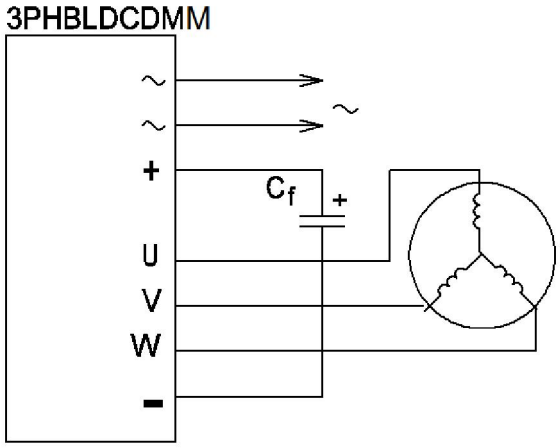

Figure 6.2 – Connection circuit of 3PHBLDCDMM with power assembly type «3»

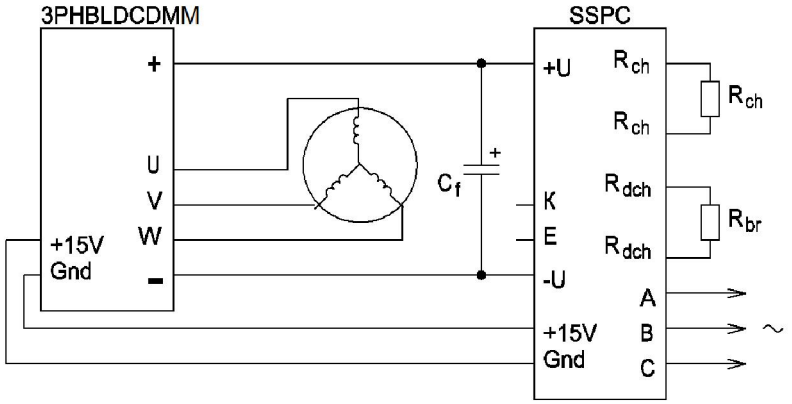

Figure 6.3 – Connection circuit of 3PHBLDCDMM with power assembly type «4» with SSPC

A SSVC (solid state voltage controller) with a rectifier bridge provides smooth capacity charge C_f and provides safe braking, by that allowing getting rid of the additional rectifier bridges, current limit circuits of charge capacity, braking circuits and control voltage schemes. It is recommended to use the SSVC with 3PHBLDCDMM for all 3PHBLDCDMM modules on the power of 380 V and at currents over 20 A.

There is a filtering capacitor and voltage limiter of 1.5V between the outputs "+" and "-" of the module.

Table 6.1 shows the maximum-allowable capacitor voltage and the limiter breakdown voltage versus the module class.

Table 6.1 – Capacitor and limiter characteristics of power circuit

Module class	Maximum allowable capacitor voltage, V	Limiter breakdown voltage, V
1	250	80
2	250	165
6	700	450
12	700	800

Average voltage of module power circuit must not exceed the lowest value of the specified one in the table, otherwise the module can fail.

Below is a description of module power outputs.

«U», «V», «W» (**«1»** and **«2»** for «B»). Motor phase connection outputs. The phases must be connected to the corresponding outputs. When wrong connection of phases the motor will operate inconsistent. Below there is a Table 6.2 in which the maximum powers of motors are indicated, supported by modules 3PHBLDCDMM.

Table 6.2 – Maximum allowable module current and brushless motor voltage

Device, 3PHBLDCDMM	Maximum average power supported by module, kW	Maximum motor power on P_{avr}, kW	Maximum starting power supported by module, kW	Maximum motor power on P_l, kW
With mains supply AC 36 V*				
-5-1	0.13	0.12	0.37	0.37
-10-1	0.27	0.25	0.68	0.55
-20-1	0.56	0.55	0.87	0.75
-30-1	0.81	0.75	1.2	1.1
-50-1	1.35	1.1	2.2	2.2
-70-1	1.9	1.8	3.1	3.0
-100-1	2.7	2.2	3.1	3.0
With mains supply AC 110 V*				
-5-2	0.41	0.37	1.1	1.1
-10-2	0.82	0.75	1.6	1.5
-20-2	1.6	1.5	2.7	2.2
-30-2	2.5	2.2	4.0	4.0
-50-2	4.1	4.0	6.0	5.5
-70-2	5.8	5.5	6.0	5.5
With mains supply AC 220 V*				
-5-6	0.82	0.75	2.2	2.2
-10-6	1.6	1.5	4.1	4.0
-20-6	3.3	3.0	5.6	5.5
-30-6	4.9	4.0	9.6	9
-50-6	8.3	7.5	9.6	9
With mains supply AC 380 V*				
-5-12	1.5	1.5	4.1	4.0
-10-12	3.0	3.0	5.8	5.5
-20-12	5.7	5.5	9.2	9.0
-30-12	9.0	9.0	15.2	15
-50-12	15.2	15	15.2	15

* It is necessary an external bridge rectifier.

3PHBLDCDMM of different types can provide the correct operation and the motor protection of power specified in the Table 6.1. The values listed in the table (maximum motor power P_{avr}) are valid if the motor is operating at its full capacity. It is allowed to install a motor with higher wattage, if the motor shaft power will not exceed the maximum average power supported by the module (column 2). However, irrespective of the

power generated by the motor its rated capacity should not exceed the specified in column 5, otherwise the module can be easily damaged by the starting current (P_s).

For example, the engine capacity of 3 kW, powered by a single-phase 220 V. The engine develops the power at the load corresponding to a half of the maximum (1.5 kW). Consequently, it is not necessarily to install the 3PHBLDCDMM-50-6; it is possible to use the module at 3PHBLDCDMM-20-6, as it provides the load 1.5 kW and is able to run engines with rated capacity up to 3.0 kW. At the same time, if the shaft power (for the same engine at 3 kW) is equal to 0.8 kW, the module at 3PHBLDCDMM-10-6 can not be used, although it supports the operation on load up to 0.95 kW, but when you launch the engine of maximum capacity exceeding 2.2 kW it can fail.

Thus, when choosing a module you should focus not only on its rated capacity and the average operating motor current but on its starting current; at that, the difference in the module capacities depending on the engines and their operating conditions can be significant.

"+" and "-". The power supply connection outputs; from the same power the control scheme operates, so the module will not be turned on at the supply voltage below 40 V. To the same outputs the filter capacitance C_f is connected (see Fig. 6.1 - 6.3) which is necessary to half-waves smoothing from the rectifier bridge and to filter the emissions arising during the engine operation. It is recommended to install the capacity C_f, as close as possible to the module outputs. The values of this capacity change depending on engine power, at which operates 3PHBLDCDMM. The following table shows the minimum and recommended values of C_f.

Table 6.3 – Capacity choice to motors of different power.

Motor power, kW	Minimum capacity, μF	Optimal capacity, μF
<0.51	100	300
0.75	200	500
1.1	200	500
1.5	250	750
2.2	400	1000
3.3	700	1500
5.1	1000	2500
7.5	1500	3500
11	2000	5000
15	3000	7000

Permissible capacitor voltage should be not less than 450 V for single-phase circuit and not less than 700 V for three-phase. For three-phase network it is allowed the value of the filtering condenser capacity on the order below those that is indicated. It is allowed to connect capacitors sequentially to increase the maximum allowable voltage, with balancing resistance of 75 kΩ of capacity not less than 1 W.

The condenser capacity should be at least 200 μF per 1 kW of engine power, the optimum - 500 μF to 1 kW of power. Capacity of less than 500 μF should be considered only in cases where the engine is running at constant load without the frequent starting and stops. If it is assumed that the load on the engine will change frequently, or the engine will operate in unstable conditions, it is not recommended to install the condenser when the capacitor is less than 500 μF for 1 kW. The capacity of a nominal value of less than 200 μF for 1 kW should not be installed because the engine will not develop maximum power, and 3PHBLDCDMM can be turned off by failures in the supply voltage.

In that case, if voltage regulator is installed before the module the capacity can be installed less than specified in Table 6.2 (on the order of hundreds μF) but it is not recommended to use 3PHBLDCDMM without connected capacity C_f.

In the modules SSVC and 3PHBLDCDMM with a rectifier bridge are used different principles of charge of the capacitor. SSVC operates on the hysteresis loop, limiting the voltage on the upper and lower limit; 3PHBLDCDMM provides a smooth charge of the capacity for 300 ms (typical). Consequently, during rapid starting engine operation of the low power synchronously with the voltage supply 3PHBLDCDMM engine will be run more smoothly but that does not indicate malfunction of the modules.

If in the 3PHBLDCDMM that is used does not contain a controlled rectifier bridge and SSVC is not connected, it is not recommended to install an unmanaged rectifier bridge and directly behind it the filtering capacitor because the bridge and the capacitor can be easily damaged by charge capacity current. In the simplest case, it is recommended to install a current-limiting resistor, which nominal should be chosen based on the maximum allowable rectifier bridge current or on a stabilizer (if used). More complex but also more acceptable is a variant with the control scheme without allowing current overload during capacity charge.

AC voltage connection outputs are used only for power assembly option "3". When connecting, the phasing does not matter.

7 SERVICE INSTRUCTIONS

Connection to the module

The power circuit is attached to the module with pin contacts or soldering (modules at the current of 10 A inclusive) or with screws M5 (modules at the current over 20 A). The screws should be tightened to the torque (5 ± 0.5) Nm, with a mandatory installation of flat and spring washers which are available with.

Power cables connection must be made through the connectors that have corrosion-resistant coating, purified from extraneous accretions. After tightening the screws (bolts) it is recommended to fix the connection with paint. It is recommended to re-tighten the screws (bolts) after 8 days and in 6 weeks after the start of operation. Subsequently, the delay should be monitored at least 1 time per semester.

Thread section of outside conductors and cables must be not less than 5 mm^2 for currents up to 10 A inclusive, and not less than 10 mm^2 for currents over 20 A.

Module controlled outputs designed for installation in equipment by soldering or by means of detachable connectors. The allowable number of resoldering of module outputs during mounting (assembly) operations is 3. Output soldering must be made at temperature without exceeding 235 ° C. Duration of soldering is not more than 3 s.

When installing and operating it is necessary to take measures to protect the module against exposure of static electricity; when mounting it is obligatory to use by personnel the grounding bracelets and grounding soldering irons of low voltage powered through a transformer.

Module installation

The module is mounted in the equipment to the cooler (chassis, frame systems, metal plates, etc.) in any orientation using the M5 or M6 screws with torque (5 ± 0.5) Nm, with mandatory installation of flat and lock washers. In settings module should be positioned in such a way as to protect it against additional heating of the neighboring elements. It is desirable that the planes of cooler ribs are oriented in the direction of air flow.

The contact surface of the cooler should have roughness not more than 2.5 μm and the flatness tolerance - less than 30 μm. The cooler surface should not have any rough edges, honeycombs. No foreign particles should be between the module and the cooler. To improve the thermal balance the module installation on mounting surface or the cooler should be implemented with the help of heat-conductive pastes or similar in their heat-conducting properties.

When installing it is necessary to ensure uniformity of the pressing of the module base to the cooler. To this end, all screws should be tightened evenly in 2 - 4 methods alternately: first, located on one diagonal, then on the other ones. During module disassembling the screw spinning should be produced in the reverse order.

Not earlier than three hours after the mounting the screws must wheeled, respecting the specified torque, as a part of the heat conductive paste under pressure outflow and fastening can weaken.

It is allowed to install for a cooler some modules without additional layers, under the condition that the power between the outputs of the different modules does not exceed the minimum value of puncture potential of each of them at grounded cooler. Below there is Table 7.1 of conformity 3PHBLDCDMM power loss on it and the necessary cooling area.

Table 7.1 – Necessary cooling area for 3PHBLDCDMM for different types

Device, 3PHBLDCDMM	Loss power on maximum load, max, W	Cooling area without compulsory blow, min, cm^2
-5-1	5	150
-10-1	10	300
-20-1	35	1000
-30-1	50	1500
-50-1	75	2000
-70-1	100	3000
-100-1	200	6000
-5-2	10	300
-10-2	25	750
-20-2	50	1500
-30-2	60	2000
-50-2	130	4000
-70-2	270	8000
-5-6	20	500
-10-6	50	1500
-20-6	80	2500
-30-6	100	3000
-50-6	300	9000
-5-12	25	750
-10-12	70	2000
-20-12	150	4000
-30-12	100	3000
-50-12	300	9000

The small cooling area is assumed in the event that the module operates at less than the maximum load, or, if the forced cooling is provided. The table is given for modules with the power assembly type "4" (only the inverter). If the module includes the rectifier bridge (power assembly type "3"), it is necessary to increase the cooling area to not less than 20% from the shown in Table 7.1.

Requirements for operation

The module should only be used in exposure to mechanical loads in accordance with Table 7.2.

Table 7.2 – Impact of mechanical loads.

Exposure factor	Value of exposure factor
Sinusoidal vibration: - acceleration, m/s2 (g); - frequency, Hz	 100 (10) 1 - 500
Mechanical shock of repeated action : - peak impact acceleration , m/s2 (g); - duration of impact acceleration, ms	 400 (40) 0.1 – 2.0
Linear acceleration, m/s2 (g)	5000 (500)

The module should be used under the influence of climate stresses in accordance with Table 7.3.

Table 7.3 – Impact of climate stresses

Climatic factor	Value of climatic factor
Low temperature of environment: - operating, °C; - absolute, °C	 - 40 - 45
High temperature of environment: - operating, °C; - absolute, °C	 + 85 + 100
Relative humidity at temperature 35 °C non-condensing %, max	98

Safety Requirements

1. Operation with the module should be carried out only by qualified personnel.
2. Do not touch the module power outputs of the supply voltage applied, even if the motor is stopped.
3. Do not connect or disconnect wires and connectors while on the power circuit is energized.
4. When any operations with the module power outputs after stopping the motor, wait at least 1 minute in order to make sure that the filter capacitor is fully discharged.
5. Connect the oscilloscope probe only after removal of the power voltage and discharge of filter capacity.
6. Do not disassemble or modify the module. If it is necessary, please contact the manufacturer.
7. If the radiator is not grounded, it must not touch it, if the module is applied by mains supply.
8. Do not touch the radiator or discharge resistance, because its temperature can be very high.
9. If the module is smoking, smelling or abnormal noises then immediately turn off the power and contact to the manufacturer.
10. Avoid contacting the module with water and other liquids.

Module power circuits are not galvanic isolated from control circuits!
Use caution when operating!

The first launch of the block

1. Connect the module to the motor in accordance with the recommended turn-on circuit.
2. Be sure in lack of short circuit on outputs «U_{ref}», «U_s», and «+15V».
3. Set the minimum speed, disconnect the brake and enable.
4. Give to the output «+» the voltage not less than 35V; be sure that the module current consumption does not exceed the maximum.
5. Launch the module and the motor; be sure in serviceability of outputs “Speed”, “Enable”, “Brake” and “Reverse”.
6. Increase the supply voltage to operating and be sure again in serviceability of the module.

8 RELIABILITY SPECIFICATIONS

Reliability probability of the module for 25000 hours must be at least 0.95.

Gamma-percent life must be no less than 50000 hours by $\gamma = 90$ %.

Gamma-percent service life of the modules, subject to cumulative operating time is no more than gamma-percent life, no less than10 years, when $\gamma = 90$ %.

Gamma-percent storage-ability time of the modules, when $\gamma = 90$ % and storing – 10 years.

9 OVERALL AND CONNECTING MODULE DIMENSIONS

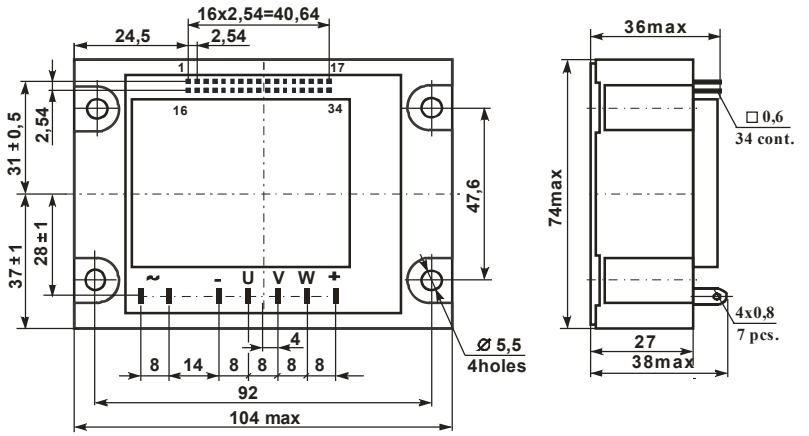

Figure 9.1 – Overall dimensions of 3PHBLDCDMM-5,10-1,2,6 power assembly type «3»

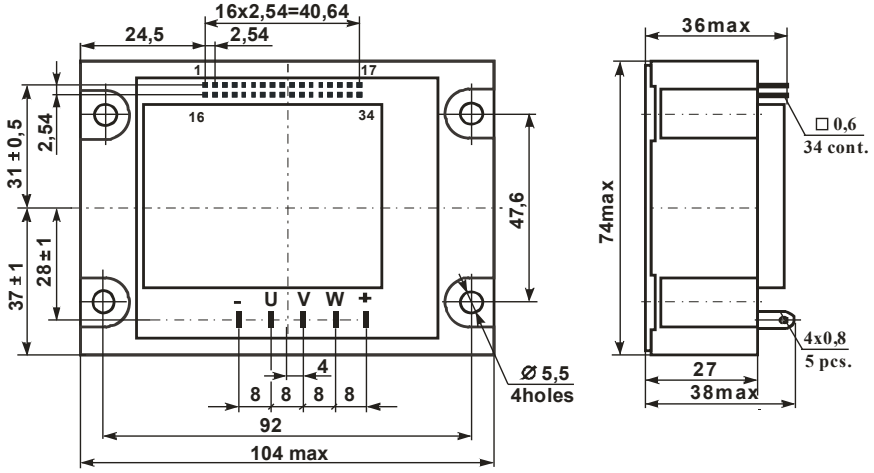

Figure 9.2 – Overall dimensions of 3PHBLDCDMM -5,10-1,2,6 power assembly type «4»

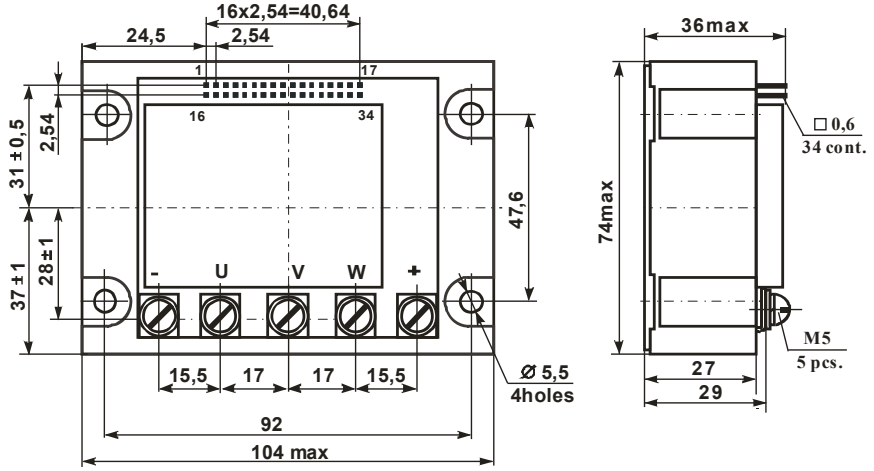

Figure 9.3 – Overall dimensions of 3PHBLDCDMM -20,30,50,70,100-1,2,6 and 3PHBLDCDMM-5,10,20,30,50-12 power assembly type «4»

At customer's request we can supply brackets for installing the module on a DIN-rail. It is recommended to install on DIN-rail the modules with rated current without exceeding 10 A.

Precious metals are not contained.