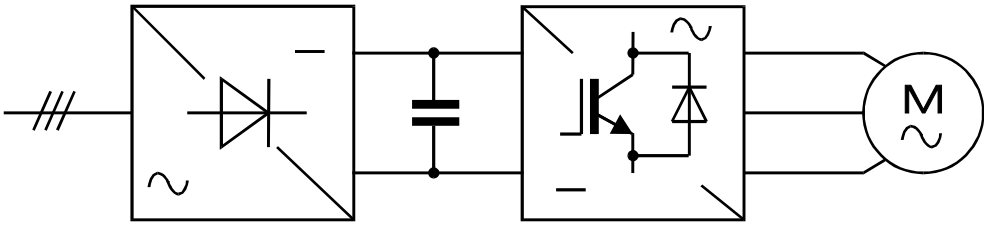
ZAKŁAD ENERGOELEKTRONIKI

mgr inż. MICHAŁ TWERD



FREQUENCY CONVERTER

type

MFC 311

The description

ZAKŁAD ENERGOELEKTRONIKI
MGR INŻ. MICHAŁ TWERD
UL. KONWALIOWA 30
87-100 TORUŃ
TEL. +48 56 6546091, TEL/FAX +48 56 6546908
87-100 TORUŃ

WWW: http://www.twerd.pl
E-mail: twerd@twerd.pl

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1. GENERAL INFORMATIONS

MFC 311 series frequency converters (hereinafter FC) are designed for speed control of 1,1 –15 kW, 380V asynchronous 3 – phase motors.
FC is a complex electronic device for converting 50 Hz supply – line voltage into a.c. voltage with a regulated amplitude and frequency.
A power circuit is made of the newest integrated power modules IPM (Intelligent Power Module) containing 7 IGBT transistors (6 of them are for 15 kW) and their control circuit with a short-circuit and thermal protection system. Pulse-width modulation (PWM) of output voltage is programmed by the 80C196KC (INTEL) microcontroller.
FC employs PWM of the so-called "field orientated control" to make a perfect use of the FC features.
The device operates in the U/F linear or square-law characteristic mode.
The device electronics is powered with fixed voltages from a power unit connected to a low-pass filter. The power unit keeps normal operation at phase supply voltage within 90-250V.
Since the FC electronics is powered with constant current, a stable operation of the system is ensured at line voltage fluctuations and momentary (short-time) line voltage failures.
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FC control terminals are conductively isolated from processor circuits and power circuits. Absolute conductive isolation of the processor from both power circuits and input circuits
provides better noise immunity of the microprocessor system.

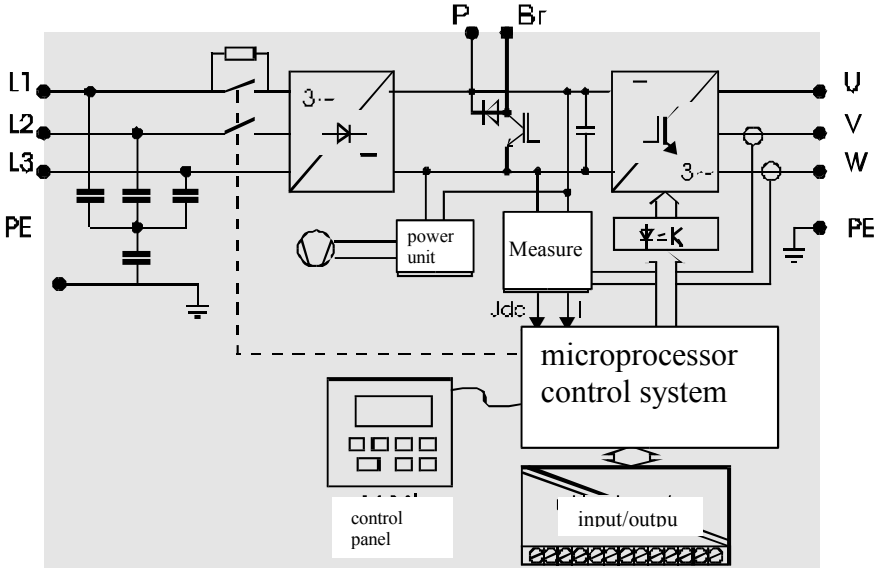


Fig. 1.1. FC block-diagram

FC is operated (controlled) by 0(2) – 10V or 0(4) – 20 mA.
In a floating zero operating mode a decrease of an input level below 2V or 4mA interrupts FC operation.
The system is equipped with an expanded system of diagnostics and interlock circuits (lockouts) to protect FC and the powered unit against fault conditions .

Failures displayed on the control panel screen

- short-circuit or overcurrent at FC output
- overvoltage in the DC circuit
- undervoltage in the DC circuit
- heatsink excess temperature
- motor thermal protection
- no-power phase condition

2. SAFETY REQUIREMENTS

2.1 Warning

- After FC power-up in-circuit elements (except in /out terminals [In/Out]) are energized. Contact is dangerous!
- When power is applied to FC, the U, V, W terminals are at dangerous voltage even if the motor is inoperative.
- When FC power is off, its elements are still at dangerous voltage within 3 minutes.

Instructions for safety operation

- No connections are allowed when FC is powered on.
- It is not allowed to apply supply voltage to U, V, W output terminals.
- It is not allowed to measure permissible voltage on any device elements.
- To measure cables insulation one should disconnect them from FC.
- It is not allowed to touch (contact) integrated circuits to avoid static discharge damage.
- One should make sure that power capacitors are not connected to the motor cables.

2.2 Precautions against electric shock.

A ground wire must be connected to the PE earth terminal of the terminal block. Earth fault protection safeguards only the system, but does not protect against an electric shock injury.

3. SPECIFICATIONS

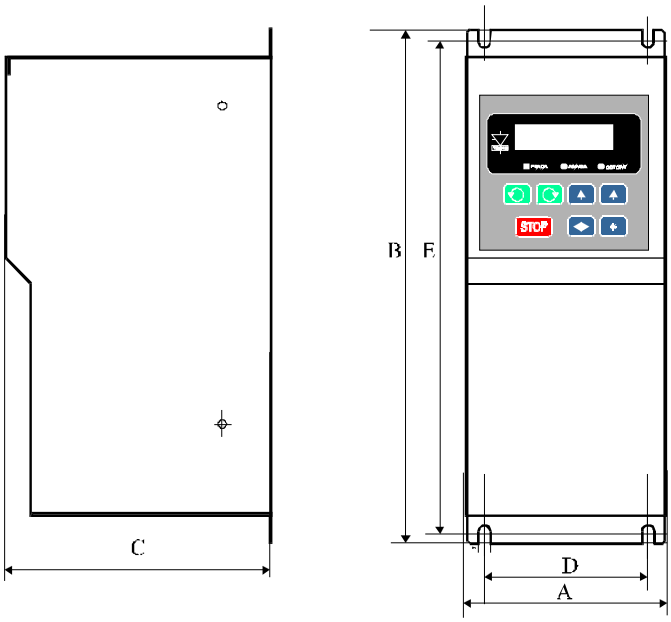


Table 3.1 FC power rating and overall dimensions.

FC type	Motor power rating, kW		Rated output current, A		Overload current, 60s each 10 min., A	Dimensions, mm				
	Even moment	Pumps, ventilators	Even moment	Pumps ventilators		A	B	C	D	E
MFC311-1,1	1.1	1.5	3.5	4.0	5.25	107	265	150	80	258
MFC311-1.5	1.5	2.2	4.0	5.5	6.0	107	265	150	80	258
MFC311-2.2	2.2	3.0	5.5	7.8	9.0	107	265	150	80	258
MFC311-3.0	3.0	4.0	7.8	9.0	11.7	107	265	150	80	258
MFC311-4.0	4.0	5.5	9.0	12	13.5	124	318	162	100	305
MFC311-5.5	5.5	7.5	12	17	18	124	318	162	100	305
MFC311-7.5	7.5	11	18	24	27	166	336	188	110	326
MFC311-11	11	15	24	30	36	166	336	188	110	326
MFC311-15	15	18	30	37	45	166	336	188	110	326

Table 3.2. Technical data, common for all MFC 311 series FC types

Power	Supply voltage, U in	380V – 15% -+ 10%
	Supply (voltage) frequency	45-66 Hz
Output	Output voltage	0 – 380 V
	Output frequency	0,5-200Hz
	Frequency error	0,05Hz
Control system	Modulation mode	Field orientated control
	Frequency control for power transistors	2,5 or 5 kHz
	Frequency setting	11 bit analog, accuracy 1% Control panel (resolution 0,1Hz)
Control inputs/ outputs	Analog inputs	Two inputs: 0(2)-10Vor 0(4)-20mA
	Digital inputs	Six inputs, 15-24V
	Analog output	8-bit +-1% 0(2)-10V, 0(4)-20mA
	Digital output (with an open collector)	100mA, 24V
	Relay output	AC (alternating current) 250V DC (direct current) 24V,8A
Protection	Overcurrent protection	Instantaneous value 3,6 I_{nom} Effective value 2,55 I_{nom}
	Overvoltage protection in the d.c. circuit	1,47 x U in (Uin=380V) (Udc>750V)
	Undervoltage protection in the d.c. circuit	0,65 x Uin
	Termal protection	T>75^{0}C
	Check of communication with the control panel	
	Check of analog inputs level	
	Motor thermal protection	

4. CONNECTION

4.1. Power circuits connection

MFC 311 FC is powered with 3-phase 3x380V current. It is recommended to use a shielded quadwire (3 phases and a grounded wire). A heavy current connection diagram is shown in Fig.4.1. The wire cross-section and nominal values of protection devices must be selected depending on the system output current.
Recommended values are shown in Table 4.1. A mains choke is required at power exceeding 7,5 kW.

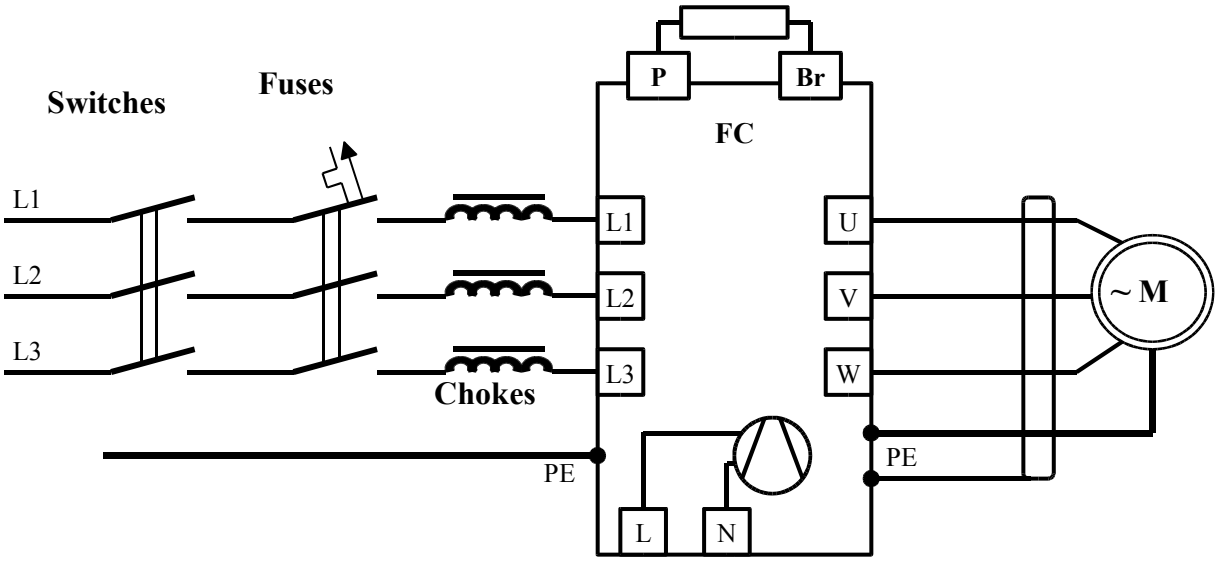


Fig.4.1. Power circuit connection
Mains chokes are required when power exceeds 5,5 kW

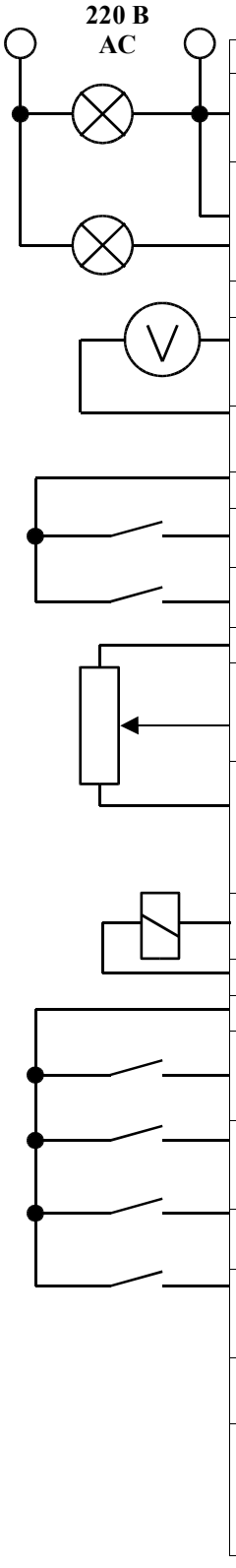
Table 4.1. Nominal values for fuses; mains wires

FC type	Rated current, A	Fuse, A	Wires, mm^2	Choke
MFC 311-1,1	3	6.3	3*1.5+ 1.5	
MFC 311-1.5	4	6.3	3*1.5+1.5	
MFC 311-2,2	5,5	10	3*1,5+1,5	
MFC 311-3,0	8	16	3*1,5+1,5	
MFC 311-4,0	9,5	16	3*2,5+1,5	
MFC 311-5,5	12	16	3*2,5+1,5	3*16A 1 mH
MFC 311-7,5	18	20	3*4+4	3*24A 0,7 mH
MFC 311-11	24	25	3*4+4	3*24A 0,7 mH
MFC 311-15	30	32	3*4+4	3*32A 0,6 mH

It is recommended to shield a motor feed wire to eliminate interference from FC.
These wires must run (be laid) as far away as possible from other wires. Interference from motor feed wires is reduced using a choke on the motor side. In this case one should take account of a motor voltage decrease (less torque).
The length of motor shielded feed wires must be less than 50 metres.

4.2. Control circuits connection.

Table 4.2. Control wires connection (factory setting)



№	Designation	Description	Factory setting
1 2 3		Programmed relay output 1	"OPERATION"
4 5 6		Programmed relay output 2	"EMERGENCY" (FAILURE)
7			
8	Out A	Analog output Output (signal) level 0(2)-10V or 0(4) –20mA	0-10V – proportional to output frequency, at 10V – FC output frequency is max
9	GND	Common terminal for analog outputs	
10	24V	24V – voltage (d.c.) max. 100mA	
11	In C1	Programmed digital inputs	START/STOP
12	In C2		LEFT/RIGHT
13	GND	Common terminal for analog inputs	
14	In A1	Analog input 1 Input signal level 0(2)-10V or 0(4) –20mA	Frequency setting for control via channel B
15	U ref	Potentiometer supply voltage 10VDC (max.10mA) Pot. 1 kOhm<R<10kOhm	
16	Out C	Programmed output (open collector)	Excess of preset frequency
17	24V		
18	24V		
19	In C3	Programmed digital inputs	External failure N/A Selection of specified frequency
20	In C4		Selection of preset frequency
21	In C5		
22	In C6		
23	GND	Common terminal of analog outputs	
24	In A2	Analog input 2. Input signal level 0(2)-10V or 0(4)-20mA	N/A

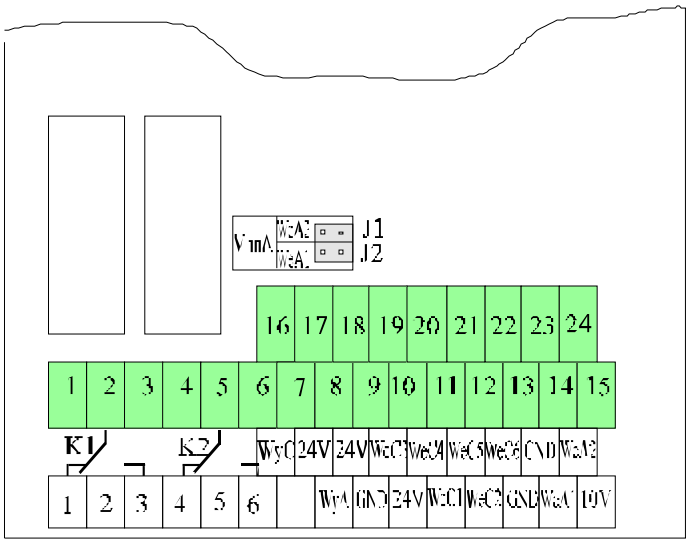


Fig.4.3. Sockets and switches layout

Cross –section area of control circuit wires must be 0,5-1,0 mm^2. It is recommended to use shielded wires especially when their length exceeds 20m. Control circuit wires must be placed (laid out) far away from power circuits.

Table 4.2. shows specified parameters and control circuits connections (factory settings).

- Input InC3 is programmed to operate in case of an external failure. A closed contact stops FC and displays an external failure message. It can be used, for example, as a motor thermal protection relay contact (input).
- Input InC4 is programmed to select a control site –remote/local. An open contact means keyboard control, a closed contact – external elements control.
- Inputs InC5 and InC6 enable selecting of preset (specified) fixed frequencies.

The use of internal relays K1-K2 is given as an example. They can control a circuit powered from the 24VDC inner power supply (100mA) or any other power supply source of not more than 220 V AC.

5. CONTROL PANEL DESCRIPTION

5.1. General description

Using the control panel it is possible to control the system (start/stop, selection of a direction, selection of a control method), to specify the parameters, to control the parameters and an operating mode.

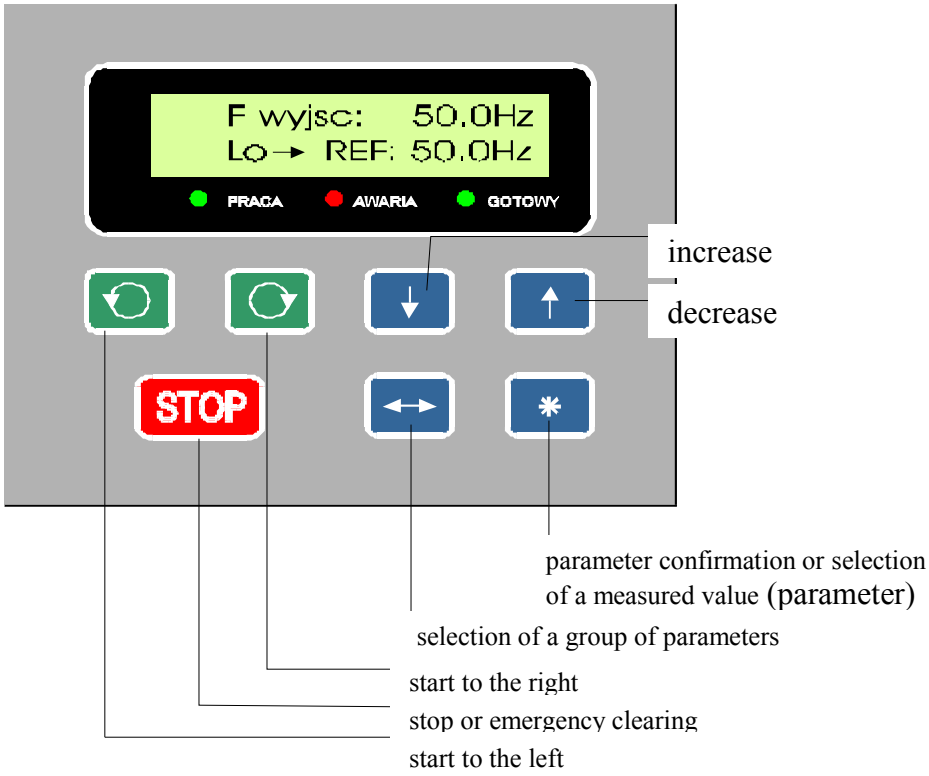


Fig.5.1. Control panel

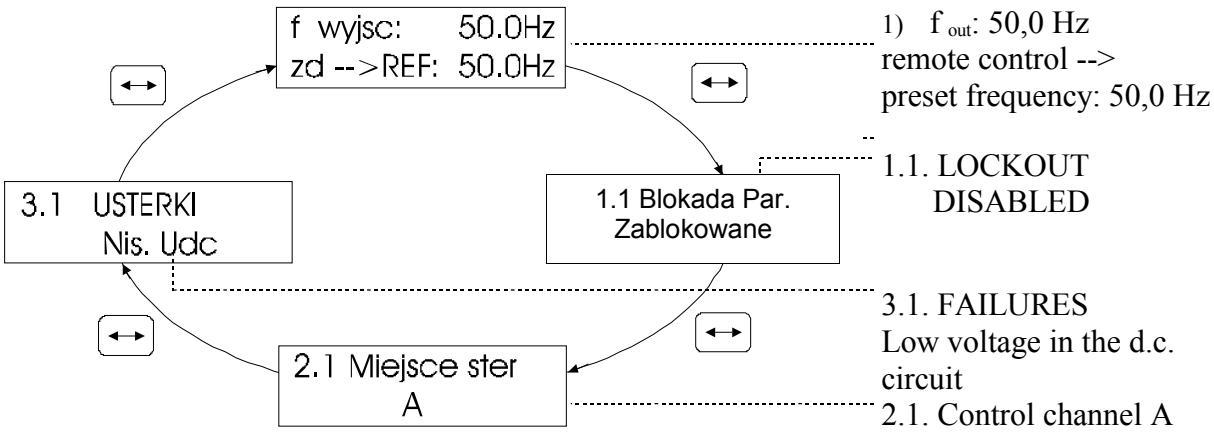


Fig. 5.2. Switch from the operating mode display to 3 groups of parameters display.

5.2. Display of operating (mode) parameters

Operating frequency, direction of rotation, method of control (remote or local), as well as one of the additional parameters listed below are displayed on the control panel.

[REF:] – preset output frequency
[I:] – motor output current
[Udc:] – voltage in the d.c.circuit
[T:] – heatsink temperature

The above mentioned parameters can be scrolled by pressing the " *" button.
The " ↑ " button serves to increase the preset frequency, the " ↓ " button serves to decrease it.

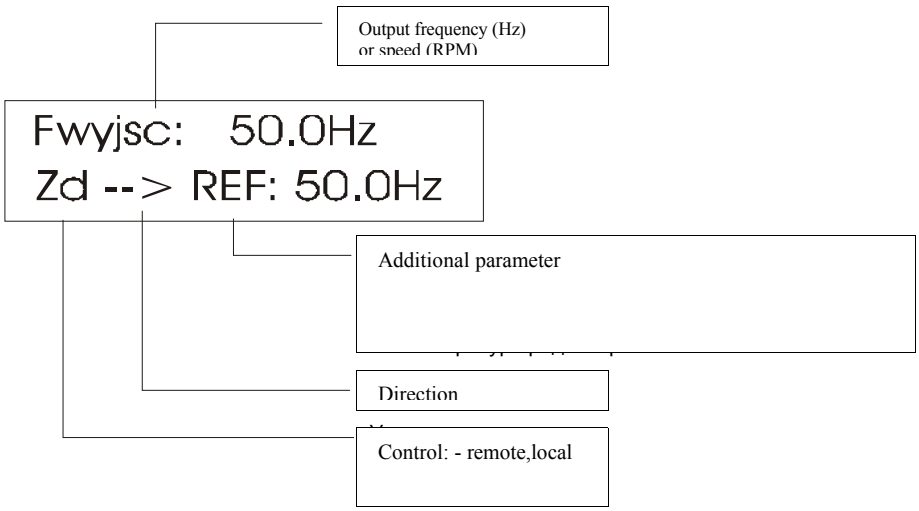


Fig. 5.3. An external view of the alpha-numeric display

When the system is shut-down (stopped), the message "FC stopped" is displayed, as well as one of the four additional parameters.

5.3. Scrolling and setting parameters.

Parameters are arranged in 3 groups. Switching between parameters groups and operating modes is realized by means of the " ↔ " button (Fig.5.1.).
In the "parameters setting" mode it is possible to scroll and program the device parameters. After this mode switched on, the number and the name of a parameter are displayed on the top line, the parameter value – on the bottom line. The " ↑ ", " ↓ " buttons serve to scroll the parameters.
FC employs the data access lockout against an accidental change of parameters by unauthorized personnel. It is possible to change the parameters only after entering the proper code into **Parameter 1.1**. ("Lockout"). The method enabling parameters access is shown in Fig 5.4.a
After the system enabled and a parameter selected, the "*" button should be pressed in order to change the parameter value. The parameters setting mode is displayed by the [...] symbol.
The "↑ ", "↓ " buttons serve in this mode for changing the parameter value.
An example of a "Min.frequency" parameter change from 0,5 to 0,6 Hz is shown in Fig.5.5.

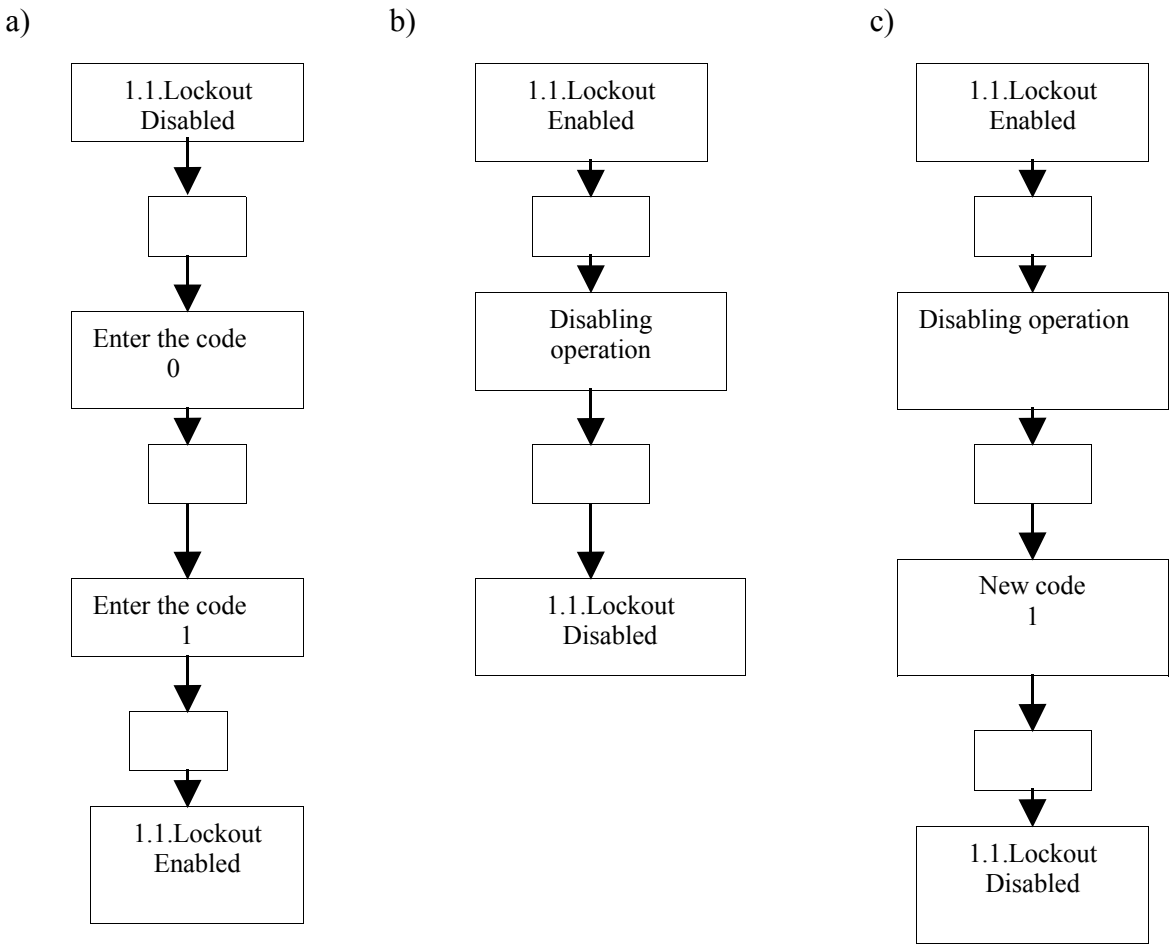
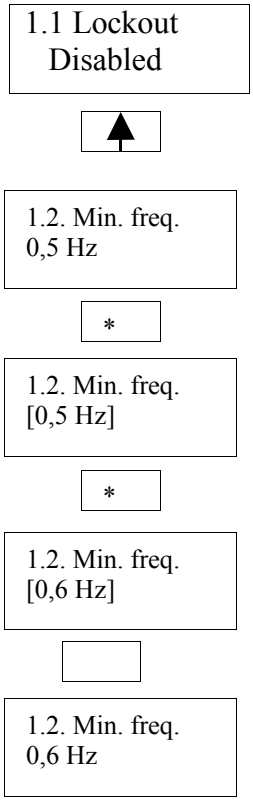


Fig.5.4. Enabling parameters access
a) system enabling
b) system disabling (without an access code change)
c) system disabling (with a new access code)

Fig. 5.5. An example of a parameter setting change



5.4. Emergency signalling

An illuminated red LED and a message on the display inform about a failure.

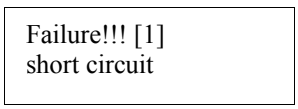


Fig. 5.6. An example of a failure message.

A fault designation is displayed on the screen, (in brackets – a number of failures after automatic reloads)
At the push of the [STOP] button the emergency signal is cleared and FC further operation is possible.

Table 5.1. List of possible failures

No	Display	Description	Probable cause	Trouble-shooting
1	Low U d.c.	Low voltage in the d.c. circuit	Low mains voltage or an open circuit	Check input wires and phase voltage
2	High U d.c.	High voltage in the d.c. circuit	Mains overvoltage, intensive motor deceleration	Check the supply line. Increase deceleration time, par. 1.5 or 1.7.
3	<I*t	Motor thermal overload	Motor overload operation or long operation at heavy load and low speed	Check motor load (motor current). Check parameters of the motor thermal model par. 3.10; 3.11; 3.12.
4	t>75^{0}C [T>75^{0}C]	Heatsink temperature above 75^{0}C	FC air cooling is a problem; system overload; ambient temperature is too high	Check air cooling (ventilators proper functioning and heatsink contamination)
5	Broken circuit	Broken circuit	One circuit is open	Check wires and mains voltage
6	Short circuit	Short circuit at FC output or transistor module failure	Short circuit in the motor or motor power cable	Switch off the motor and check for any fault availability. Check insulation of wires and motor winding
7	High current	Motor current is too high	Motor acceleration is too fast or an abrupt change of motor load	Increase motor acceleration time. Parameter 1.4, 1.6.
8	External error	Active input of an external failure		Check the digital input (InC3 or InC4), selected as an external failure input
9	Program error	Communication error between processor and control panel	Interference or a broken communication wire of the control panel or processor	Check the communication wire of the control panel
10	“In” error	Signal at anolog input InA1 is lower than 2V(2mA)	Parameters specify a number of turns from the analog input InA1	Check voltage (current) level at analog input InA1. Check parameters set in items 2.6; 2.7
11	Program error	Program misoperation	Interference or CPU fault	
12	Communication error	Communication error between CPU and the communication module	Communication module or connections failure	Check connections between CPU and the communication module
13	Time RS	Max. signal wait time RS		Check external connections and parameters setting

6. CONTROL

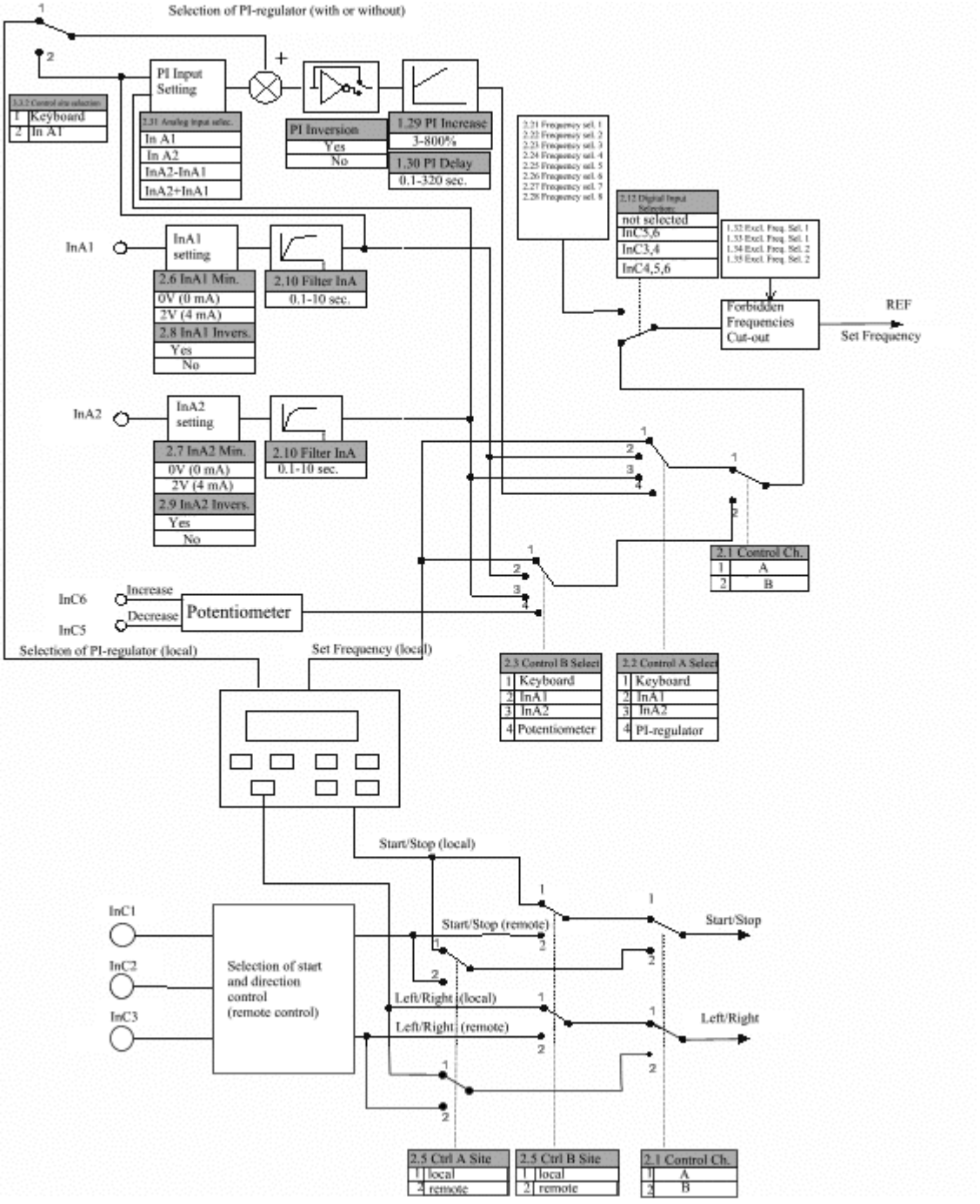


Fig. 6.1. Structure of the FC internal control logic.

Program settings are set by means of the proper parameter or a digital input.
FC can be controlled from the keyboard or from external digital inputs. A combination of these 2 types of control is possible, namely, START from the keyboard, frequency setting by means of external contacts (inputs) and vice versa. The possibility exists of programming two control channels A and B. It is convenient for a quick change of these channels (parameter 2.1 or the corresponding digital input).

7. PARAMETERS

7.1. Parameters list

Table 7.1.

Par No	Parameter	Description	Range	Factory setting	Change during operation
First group (common parameters)					
1.1.	Lockout	Access code for parameters change	1-255	1	yes
1.2.	Min. frequency	Min. output frequency	0,5-50Hz	0,5Hz	yes
1.3.	Max. frequency	Max. output frequency	25-200Hz	50Hz	yes
1.4.	Acceleration time 1	Time for FC to change output frequency from 50Hz to 0 Hz	0,1-250s	5s	yes
1.5.	Deceleration time 1	Time for FC to change output frequency from 50 to 0 Hz	0,1-250s	5s	yes
1.6.	Acceleration time 2	Time for FC to change output frequency from 0 to 50 Hz for the selected dynamics 2	0,1-250s	20s	yes
1.7.	Deceleration time 2	Time for FC to change output frequency from 50 to 0 Hz for the selected dynamics 2	0,1-250s	20s	yes
1.8.	U/F characteristic	U/F characteristic selection	linear square law	linear	no
1.9.	U for F=0Hz	Torque increase for low motor speed (voltage for F=0 Hz)	0-40% U_{nom}	10%	yes
1.11.	F for U max	Frequency at which output voltage is max	25-200Hz	50Hz	yes
1.12	I limit	Motor current limiting value	25-150% I_{nom}	150% I_{nom}	yes
1.13	F carrier	Power transistors control frequency	2,5 kHz 5 kHz	5 kHz	no
1.14	Lower frequency 1	Lower frequency of the first cut-out band	0,5-par. 1.15	0,5Hz	yes
1.15	Upper frequency 1	Upper frequency of the first cut-out band	par.1.14-200 Hz	0,5 Hz	yes
1.16	Lower frequency 2	Lower frequency of the second cut-out band	0,5-par.1.17	0,5Hz	yes

1.17	Upper frequency 2	Upper frequencyof the second cut-out band	par.1.16-200Hz	0,5Hz	yes
1.19	Direction	Selection of a motor rotation direction or permission for reverse-direction operation	left right l/r	l/r	no
1.20	Stop	Stop by means of a motor, “ramp” – frequency decrease to zero, then FC switch- off	ramp run-out		
1.21	DC braking time	Direct current braking time	0-250s	0s	yes
1.22	DC braking voltage	Fixed voltage applied to the motor during braking	0-22% U_{nom}	0%	yes
1.23	Motor current	Motor rated current	25-100%	100%	no
1.24	Motor cosφ	Motor cosφ	0,4-0,99	0,8	no
1.25	Number of poles	Number of motor poles	2, 4, 6	4	no
1.26	Slip	Motor rated slip	0-10%	3%	no
1.27	Slip compensation	Motor slip compensation	yes no	no	no
1.28	Display of revolutions	Motor revolutions display	yes no	no	no
1.29	PI-increase	Increase of a proportional value of the PI-regulator	0-800%	100%	yes
1.30	PI-delay	Delay of an integral value of the PI-regulator	0,1-320s	10s	yes
1.31	PI-inversion	Inversion of a PI-regulator value	yes no	no	yes
Second group (control parameters)					
2.1	Control channel	Selection of the control channel A or B	A, B	A	yes
2.2	Selection of control A	Selection of a control device for channel A	InA1 InA2 keyboard	keyboard	no
2.3	Selection of control B	Selection of a control device for channel B	InA1 InA2 keyboard potentiometer	InA1	no
2.4	Control A site	Selection of FC shut- down control and motor rotation direction control	remote local	local	no
2.5	Control B site	Selection of FC shut- down control and motor rotation direction control	remote local	remote	no
2.6	Min InA1	Minimal InA1 input level	0V (0mA) or 2V (4mA)	0V (0mA)	no
2.7	Min InA2	Minimal InA2 input level	0V (0mA) or 2V (4mA)	0V (0mA)	no
2.8	Inversion InA1	Inversion of input InA1	yes no	no	no

2.9	Inversion InA1	Inversion of input InA2	yes no	no	no
2.10	Filter InA	The time constant of a control signal filter (both analog inputs lag)	0,00-9,99s	0,1s	
2.11	START/ STOP	Selection of a FC stop and start control method when remote control is used	ST/STOP L/R ST_L ST_R ST-Im STOP ST-Im L/R	ST/STOP L/R	no
2.12	Selection of a digital input	Setting digital inputs for selection of constant (fixed) output frequencies	off InC5,6 InC3,4 InC4,5,6	InC5,6	no
2.13	InC3 configuration	Defining InC3 input function	-off -emergency stop -oper.permit -A/B control -emergency clear -dynam. ½ -external failure	external failure	no
2.14	InC4 configuration	Defining InC4 input function	see par. 2.13	off	no
2.16	K1 configuration	Defining K1 relay function	-off -ready -error -t>65^{0}C -operation -F>Fcontr -I>I limit -F=Fset	operation	yes
2.17	K2 configuration	Defining K2 relay function	see par.2.16	ready	yes
2.19	InC4 configuration	Defining InC4 digital input function	see par. 2.16	F>Fcontr	yes
2.24	F contr.	Frequency, when exceeded, switches a selected relay	0,5- 200Hz	0,5Hz	yes
2.25	Fixed frequency 1		0,5- 200Hz	10Hz	yes

2.26	Fixed frequency 2	Programmed frequencies, selected via digital input	0,5- 200Hz	20Hz	yes
			0,5- 200Hz	30Hz	yes
2.27	Fixed frequency 3		0,5- 200Hz	10Hz	yes
			0,5- 200Hz	20Hz	yes
2.28	Fixed frequency 4		0,5- 200Hz	30Hz	yes
			0,5- 200Hz	30Hz	yes
2.29	Fixed frequency 5				
2.30	Fixed frequency 6				
2.31	Fixed frequency 7				
2.32	Selection of PI-control	Selection of a signal source for PI-regulator	keyboard InA1	keyboard	no
2.33	Selection of PI-input	Selection of a controlled value for PI-regulator	InA1 InA2 InA1-InA2 (InA1+InA2)/ 2	InA1	no
2.34	RS enabled	Initiation of the communication module	yes no	no	yes
2.35	RS rate	Communication rate	1200, 2400, 4800, 9600	9600	no
2.36	FC No	FC number	1-255	1	no
2.37	Time out	MODBUS not used	-	-	-
2.38	RS time	Allowable time between two signals of a remotely controlled RS-485 communication module	0-120s	0	no
Third group (failures and protection)					
3.1	Failures	Register of 4 last failures	where: 1 is the last failure		yes
3.2	Number of restarts	Number of automatic reloads of FC after a failure within the time, set in par.3.3.	0-3	0	no
3.3	Reloads time (t)	Time within which reloads are possible (time for reloading)	10-250s	10	yes
3.4	Restart<Udc	Permission to reload at low voltage Udc	yes no	no	no
3.5	Restart<Udc	Permission to reload at high voltage Udc	yes no	no	no
3.6	Restart>1	Reload at overcurrent	yes	no	no
3.7	Restart>T	Reload at elevated heatsink temperature	yes no	no	no
3.8	Restart<InA	Reload at input signal lower 2V(4mA)	yes no	no	no
3.9	Protection I^2t	Initiation/lockout of motor protection	yes no	yes	no

3.10	I therm.limit	Current; when exceeded, load is added actively	25-150%Ir	100%	yes
3.11	Itherm F=0	Permissible current for motor shut-down when thermal protection is activated	0-150%	50%	yes
3.12	Fixed t_{motor}	The time constant of motor heating	1-200min	18 min	yes
3.13	Factory settings (defaulf parameters)	Initiation of this parameter loads factory settings	yes no	no	
3.14	No signal at input	No signal at analog input	failure, F const. 7	f const.	yes

7.2. Parameters description : first group (common parameters)

7.2.1. Minimal and maximal frequency

Parameter 1.2 makes it possible to set a minimal operating frequency. When started, the motor begins to operate at a frequency not lower than F min.
Parameter 1.3 is an upper limit of the output frequency

7.2.2. Parameters specifying the system dynamics

Parameter 1.4 (acceleration time 1) and **parameter 1.6** (acceleration time 2) specify the rate of frequency increase during an increase of speed.
Parameter 1.5 (deceleration time 1) and **parameter 1.7** (deceleration time 2) specify a frequency decrease. These parameters specify the time (sec) of frequency variation for 50 Hz.
It is possible to change the dynamics of FC acceleration and shut-down using InC3 or InC4. To do this it is necessary to set **parameter 2.13** or **parameter 2.14** to “Dynamics ½”. If a signal is applied to the selected digital input, FC will operate with the dynamics, specified in parameters 1.6 and 1.7.

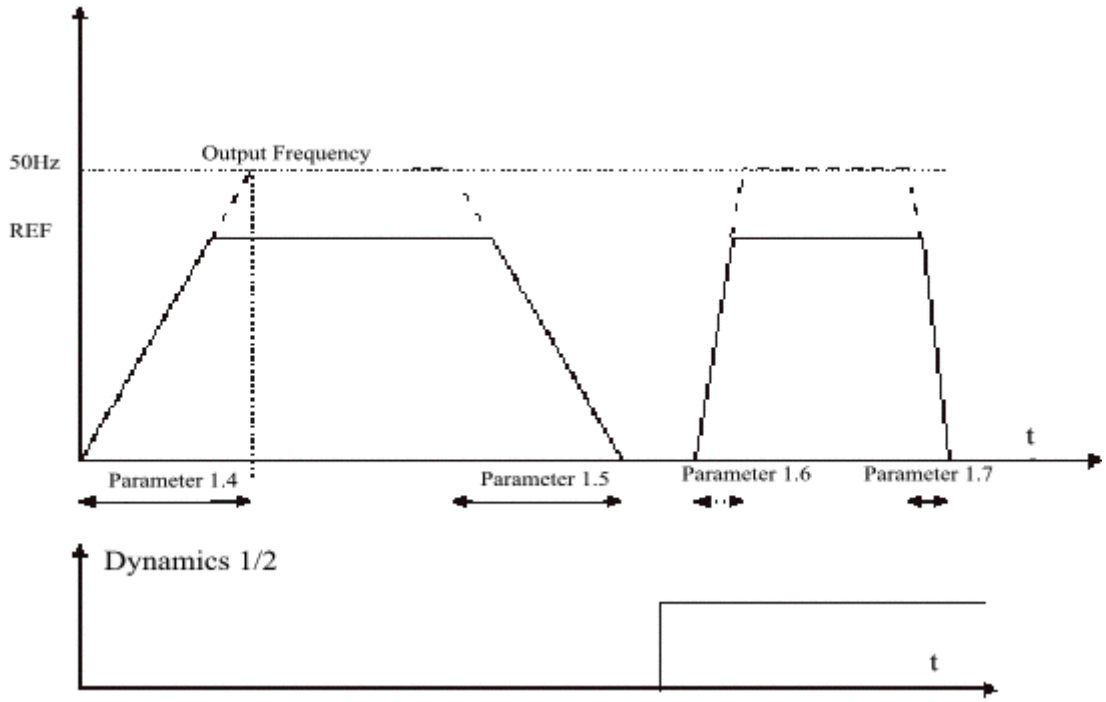


Fig.7.1. Acceleration and shut-down time

7.2.3. Parameters specifying U/F characteristic

Parameter 1.8 allows to select the type of U/F characteristic. A linear characteristic is used when there is a constant load moment depending on speed.
When the moment increases in proportion to the speed squared it is advisable to use a square-law characteristic to reduce the noise and losses in the motor.
Parameter 1.9 is the so-called increase of voltage at low frequencies. This parameter allows to compensate a voltage drop across a winding resistance and to correspondingly increase the moment for low speed.

- With small motors the compensation voltage can be higher than with big motors, because small motors have a higher winding resistance. If the load moment is high, the compensation voltage must be set so high as to start the motor. Compensation voltage must be set as lower as possible, because being too high, the compensation voltage may result in motor overload or motor overheat.

Parameter 1.11. is a field reduction point. This is mainly the motor rated frequency.
With frequencies higher than those shown in parameter 1.11 the motor operates with a reduced moment. The motor operates only with constant power.

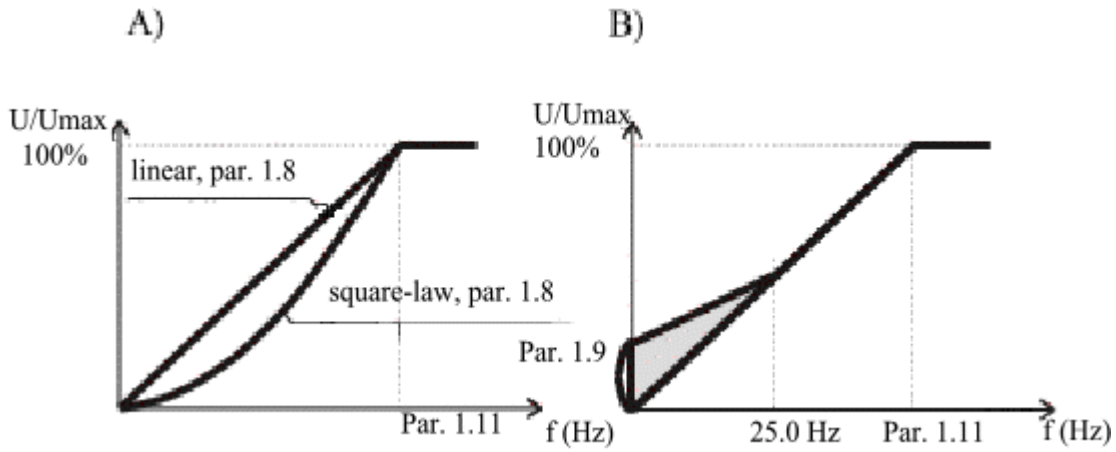


Fig.7.2. U/F characteristic
a) linear and square-law characteristic
b) compensation voltage variation

7.2.4. Current limiting

Parameter 1.12 sets current limiting. The parameter value is expressed in percent of the FC rated current. The factory setting (default value) is set to 150% of the system rated current.

Attention!
1. The FC rated current is not the rated current of the motor. In case a lower – powered motor is used, one should decrease the current limiting setting.
2. The current limiting time is not controlled and during prolonged overloads FC may be switched off because of a heatsink overtemperature.

If a motor load is so high that the motor current reaches the parameter 1.12 setting, the system output frequency decreases.
A current regulator operation increases the FC start-up time.

7.2.5. Carrier frequency

Parameter 1.13 allows to change the power transistors frequency control. Two carrier frequencies can be set: 2,5 KHz and 5KHz. At 5KHz the motor noise is lower, but FC losses increase. In case of a failure because of the heatsink overtemperature one should decrease the carrier frequency.

7.2.6. Frequencies to be excluded

With some systems there may be a need to avoid FC operation at some output frequencies because of the resonance in the electric motor drive.
FC provides the possibility of excluding 2 frequency bands. For this it is necessary to set the upper and lower frequency values (limits) for each band. For the preset frequencies, the output frequency between the lower and the upper limits is the lower limit when the operating frequency increases, and the upper limit when the operating frequency decreases. (Fig 7.3.).

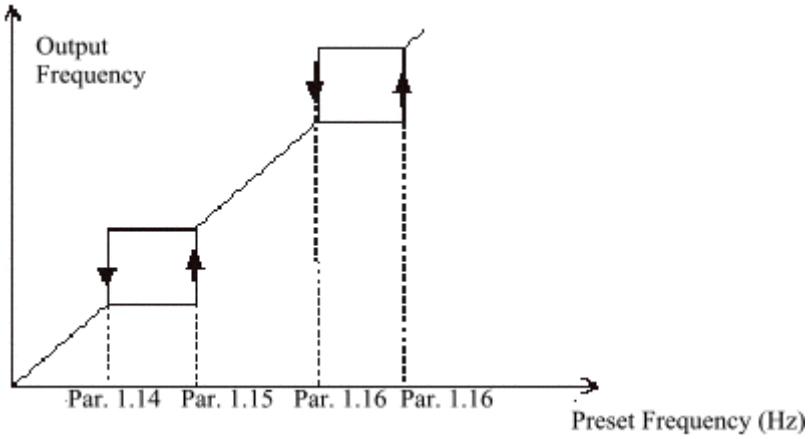


Fig 7.3. Frequency band cut-out (Excluded frequencies)

7.2.7. Reverse operation mode lockout

Parameter 1.19 allows to lockout the reverse operation mode. For this purpose the parameter must be set to “left” or “right” depending on the necessity. In this case FC will operate only in a specified direction, independently of control. For FC to operate in 2 directions, the parameter must be set to “l/r”. The FC direction will be set remotely or by a selected button on the control panel (local operating mode).

7.2.8. Shut-down method

Parameter 1.20 defines FC shut-down method.
“Run-out” method: after the STOP command FC will be deenergized (will switch off power) and the motor will stop by means of a run-out.
“Ramp” method: after the STOP command FC will start reducing the frequency up to 0,1 Hz according to the parameters that set the deceleration time and then will switch off power. For the purpose of reducing the deceleration time it is possible to preset the deceleration parameter using direct current.
For this purpose parameters 1.21 and 1.22 should be set to other values than zero.
Parameter 1.21 sets the time for constant voltage being applied, parameter 1.22 sets the constant voltage applied to the motor winding. The higher this value, the more effective the braking, but the current passing through the motor increases resulting in the motor overheat. When parameter 1.20 is set to “run-out”, after the “STOP” command a constant voltage is applied to the motor. For braking by way of decreasing a frequency; constant voltage is applied only when frequency is equal to 0,5Hz.

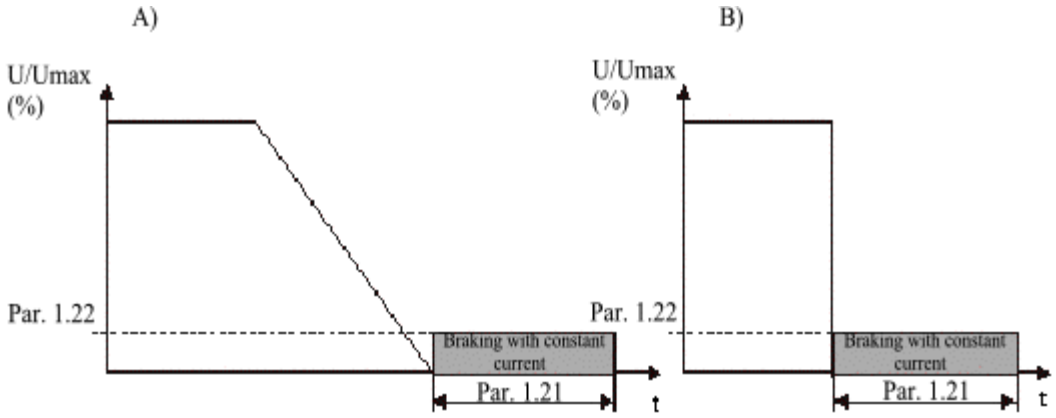


Fig 7.4. Braking by means of constant current.

a) "ramp" stop (shut-down)
b) "run-out" stop (shut-down)

7.2.9. Motor rated data

On the basis of the motor nameplate data, one should specify the rated current, $\cos\varphi_n$ and on the basis of the rated speed one should specify a number of motor pole pairs.
Parameter 1.23- a motor rated current in percent of a FC rated current.
Parameter 1.24- a motor rated power factor, $\cos\varphi_n$.
In **parameter 1.25** a number of motor poles must be set. Table 7.2 shows a number of poles depending on a synchronous speed.
-Synchronous speed can be set, assuming the value closest to the rated speed to be the synchronous speed.

Table 7.2

Synchronous speed	number of poles
3000	2
1500	4
1000	6
750	8

Parameter 1.25 is a motor nominal slip, it is calculated by the formula:

$$Sn= (n_s-n_n) *100\% / n_s$$

7.2.10. Slip compensation

If parameter 1.27 is set to”yes”, the device operates with a slim compensation. An output frequency must be encreased so that to keep a constant motor speed at load variations.

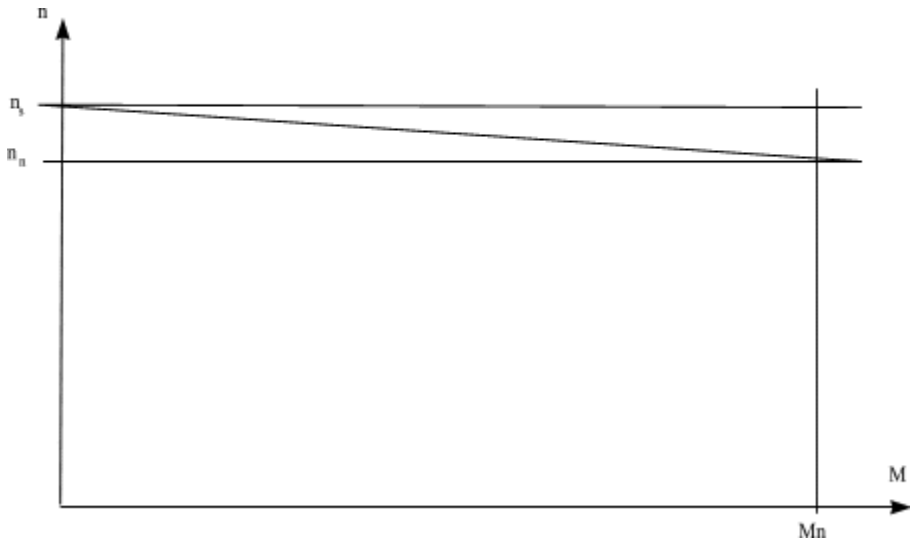


Fig.7.5 Motor speed-load moment relation

a) a system without a slim compensation
b) a system with a slim compensation

7.2.11 Output speed display

FC provides displaying of speed in RPM. For this purpose parameter 1.28 must be set to “yes”. In that case the operating mode screen will display the speed in RPM instead of an output frequency.
Attention!
This speed is defined by the output frequency conversion, motor load variations are not taken into account.

7.2.12. Setting PI-regulator parameters

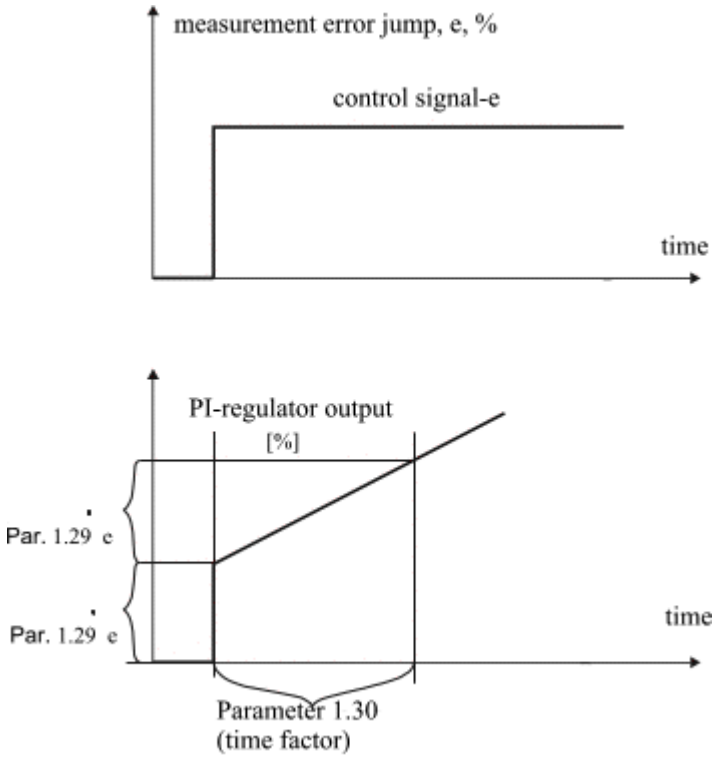


Fig.7.6 PI-regulator output at a jump of the measurement error

Parameter 1.29 sets an increase of the term of a proportion of the PI-regulator and parameter 1.30 defines the PI-regulator factor.
Fig.7.6 depicts a response of the PI-regulator to the measurement error jump (the measurement error is a difference between the set value and the control value).
Using parameter 1.31, it is possible to change the measurement error sign. When this parameter is set to "yes', an increase of the set value influences an increase of the PI-regulator output.
!00% of the PI-regulator output corresponds to the max. frequency set in parameter 1.3 and 0% of the PI-regulator output corresponds to the frequency set by parameter 1.2.

7.3. Parameters description: second group (control parameters)

7.3.1. Selection of a control site and a control device.
Parameter 2.1 defines variants of control via A or B channels.
It is possible to set 2 independent variants of control individually for A channel and B channel, as well as a quick change of the channel by parameter 2.1 or by any of the digital inputs InC3 or InC4 programmed to "A/B control" by changing the status on the corresponding digital input.
Parameter 2.2. allows to specify frequency control for channel A.
It is possible to select one of the following **control devices:**

- one of two analog inputs InA1 and InA2
- keyboard (" ↑ "," ↓ " buttons)
- potentiometer

- speed setting via digital inputs InC5, InC6 according to the following table:

Table 7.3

InC5	InC6	set frequency
0	0	without changes
1	0	increase
0	1	decrease
1	1	without changes

Parameter 2.3 is similar to par.2.2 for channel B.
Parameter 2.4 specifies the start and motor direction control sites for channel B.

Types of control
-"Remote" (digital inputs) (start,stop and direction via digital inputs)
-"Local" (control panel)

Parameter 2.5 is similar to par. 2.4 for channel B.

7.3.2. Selection of FC control via inputs.

Parameter 2.6 specifies the minimal level of a control signal 0V (0 mA) or 2V (4mA) at the analog input InA1, whereby the frequency is equal to the minimal frequency (par.1.2) , if **parameter 2.8** is set to "no", or to the maximal frequency (par.1.3), if **parameter 2.8** is set to "yes'.

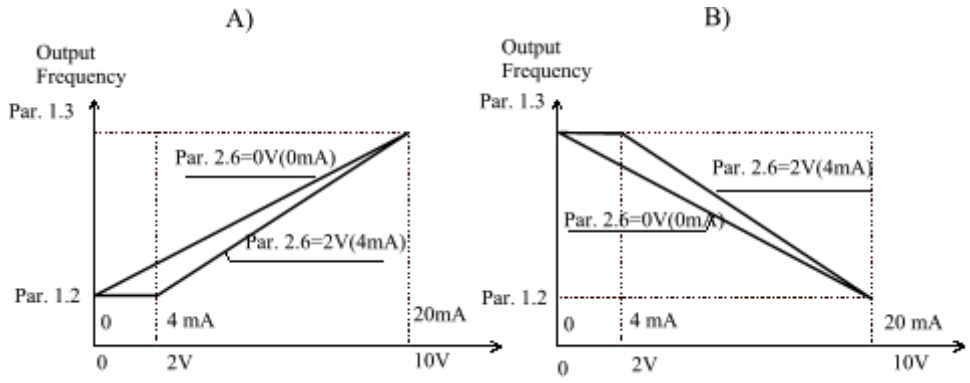


Fig 7.7. Control characteristic

a) InA1, par.2.8: "no"
b) InA1, par. 2.8: "yes"

Parameters 2.7 and 2.9 are similar to **par.2.6 and 2.8**, only for the input InA2.
Parameter 2.10 serves to set the time constant of the analog input filter with a consequent filtering of the input signal noise.
- This parameter covers both analog inputs InA1 and InA2.

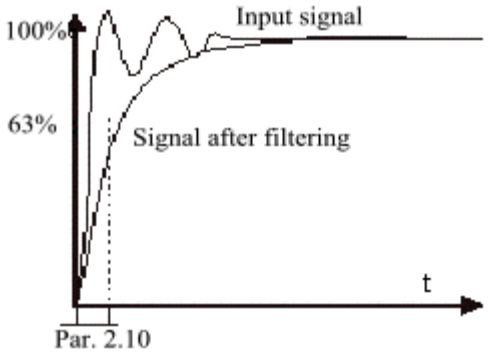


Fig. 7.8. Filtering of signals from analog inputs.

7.3.3. Selection of FC control for a remote operating mode.

Parameter 2.11 allows to set digital inputs functions to realize the motor start and direction.
Possible settings:
-"ST/STOP LR" InC1 serves to issue the "START/STOP" command, InC2 - to change the direction (Fig.7.9a)
-"ST_L ST-R" InC1 –start to the left, InC2- start to the right (Fig.7.9b)
-"ST-IM STOP" InC1- impulse triggering/ InC2- stop (Fig.7.9c)
-"ST-IM L/R" InC1- impulse start/ InC2- stop, InC3- selection of a direction (Fig.7.9d)

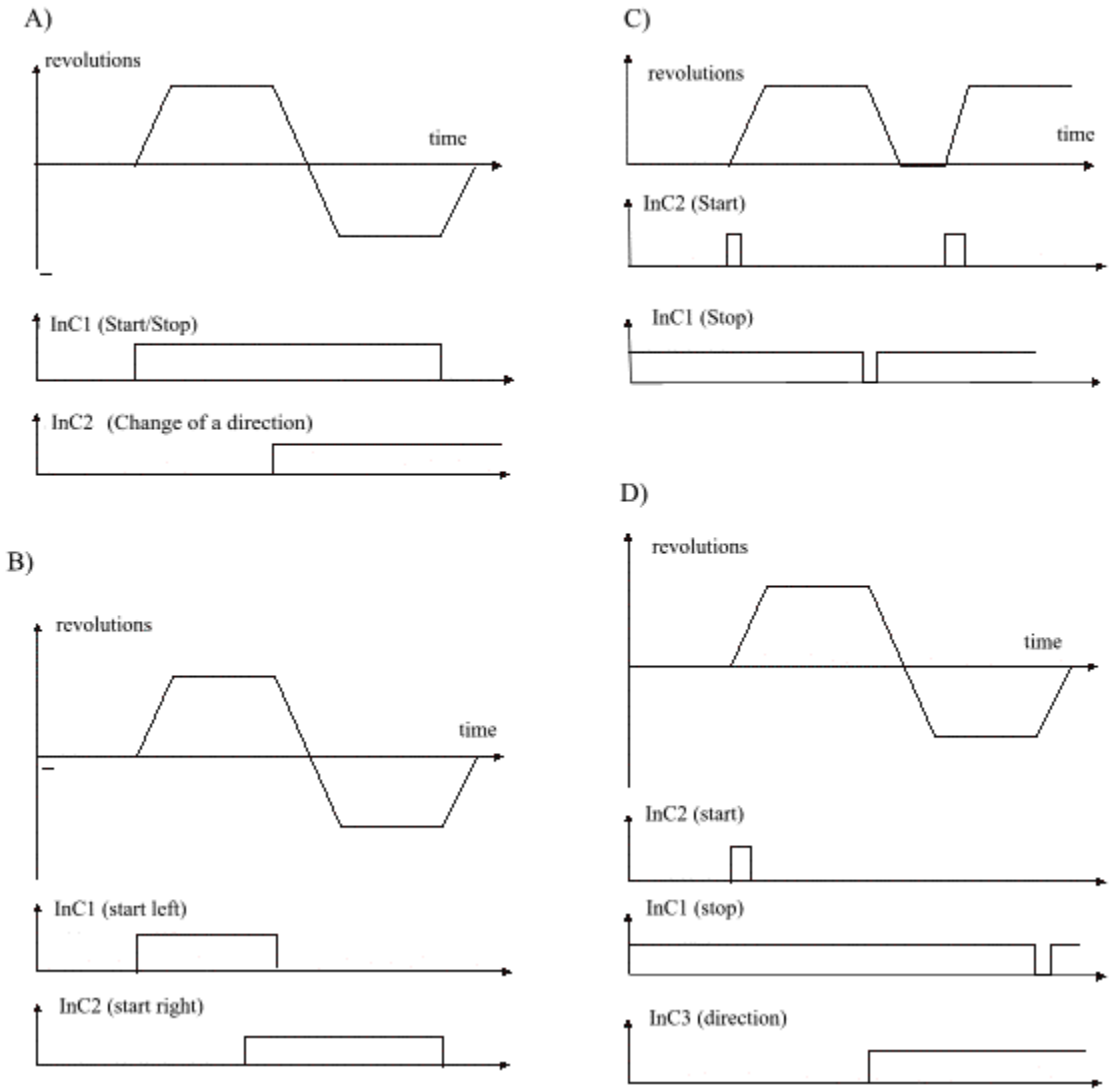


Fig.7.9. Control using digital inputs

a) Parameter 2.11 "ST/STOP LR"
b) Parameter 2.11 "ST_ L ST_R"
c) Parameter 2.11 "ST-Im STOP"
d) Parameter 2.11 "ST-Im L/R"

7.3.4. Selecting constant frequencies

FC provides selecting 3 or 7 programmed output frequencies for combining digital inputs.

Table 7.4

Parameter 2.25	Constant frequency 1
Parameter 2.26	Constant frequency 2
Parameter 2.26	Constant frequency 2
Parameter 2.27	Constant frequency 3
Parameter 2.28	Constant frequency 4
Parameter 2.29	Constant frequency 5
Parameter 2.30	Constant frequency 6
Parameter 2.31	Constant frequency 7

Parameter 2.12 makes it posible to select digital inputs in order to select constant output frequencies.

Possible variants:
-“off”-constant frequencies are not set
-“InC5,6”- the possibility of selecting three constant frequencies via the InC5 and InC6 inputs
-“InC3,4”- the possibility of selecting 3 constant frequencies via the InC3 and InC4 inputs.

Table 7.5

InC4, InC6	InC5, InC3	Frequency
0	0	not selected
0	1	Constant frequency 1
1	0	Constant frequency 2
1	1	Constant frequency 3

-“InC4.5.6”- the possibility of selecting 7 constant frequencies via the InC4, InC5 and InC6 inputs.

Table 7.6

InC4	InC5	InC6	Frequency
0	0	0	not selected
0	0	1	constant frequency 1
0	1	0	constant frequency 2
0	1	1	constant frequency 3
1	0	0	constant frequency 4
1	0	1	constant frequency 5
1	1	0	constant frequency 6
1	1	1	constant frequency 7

7.3.5. Setting parameters for programmed inputs InC3 and InC4

If InC3 and InC4 were not used to select constant frequencies and InC3 was not used to control the operating mode direction, additional functions can be programmed for these inputs.
Parameter 2.13 specifies a function for the InC3 input.

Table 7.7

Parameter 2.13 meaning	Description
off	Digital input inactive
emergency stop	1-FC shut-down (run-out)
oper.permit	Permission for operation 0- operation not possible
contr. A/B	Change of control channel (0-A; 1-B)
emerg.clear	Emergency clearing (change from 0 to 1 clears a failure message and allows to resume the FC operation)
dynam. ½	Change of dynamics 0- selection of acceleration time 1 and deceleration time 1 1- selection of acceleration time 2 and deceleration time 2

0- means low voltage at a digital input (not connected)
1- means high voltage at the digital input InC3 (connected to 24V)
Parameter 2.14 is similar to par. 2.13 for InC4 input.

7.3.6. Setting parameters for relay outputs and OutC1 digital output

Parameter 2.16 specifies K1 relay function.

Table 7.8

Parameter 2.16 meaning	Description
off	relay is not used
ready	when on, indicates FC availability for operation
fault	when on, indicates a failure
operation	when on, indicates voltage applied to the motor
t> 65^0C	when on, indicates heatsink overtemperature
I > I limit	when on, indicates current limiting operating mode
F=F_{set}	when on, indicates that the set frequency is reached
F> F_{contr}	when on, indicates that the control frequency set in par. 2.24 is reached (symmetrical hysteresis +- 0,5 Hz)

Parameter 2.17 is similar to par.2.16 for K2 relay

Parameter 2.20 specifies a function of the digital output OutC1 (output with an open collector).

7.3.7. PI-regulator configuration

Parameter 2.32 specifies a signal source (device) for the PI-regulator. Setting a specified value is possible from the keyboard or from the analog input InA1.The specifying value may vary within 0-100%. The purpose of the PI-generator is to keep an input value at the level of the specifying value. The input value is configured by parameter 2.3.
Input values may be:
-InA1- a signal is applied to the analog input InA1; parameters specifying the InA1 input are taken into account (par. 2.6, par. 2.8, par.2.10).
-InA2- a signal is applied to the analog input InA2; prameters specifying the InA2 input are taken into account (par.2.7, par. 2.9, par.2.10).
-InA1-InA2- a controlled value is a difference between two inputs.
-InA1+InA2- a controlled value is an average value of 2 inputs.

7.3.8. Communication parameters configuration

Parameter 2.34 activates the FC control through serial communication. This parameter can be changed during motor operation. If parameter 2.34 is set to “no”, all control signals from RS will be ignored.
Bit rate is set using **parameter 2.35.** Posible values are 1200, 2400, 4800 and 9600 bit.
Parameter 2.36 corresponds to the FC number. Only one device with this number may operate in the network.
Parameter 2.38 specifies a setting of the allowable time between serial communication signals. If FC does not get the right impulse within the period of time specified in this parameter, it will switch off the motor and display the emergency message “ Time RS”. This is possible only in the activated operating mode with RS.

7.4 Parameters description: the third group (failures and protection)

7.4.1. Failures register

Four last failures are automatically registered in **parameter 3.1.** Index 1 means the last fault, 2- the one next to the last etc.

7.4.2. Automatic reloading

If FC stops because of a failure, there is a possibility of an automatic restart of operation after the cause of the failure has been cleared**. Parameter 3.2** specifies a permissible number of starts (number of reloads) within the time set by **parameter 3.3.**

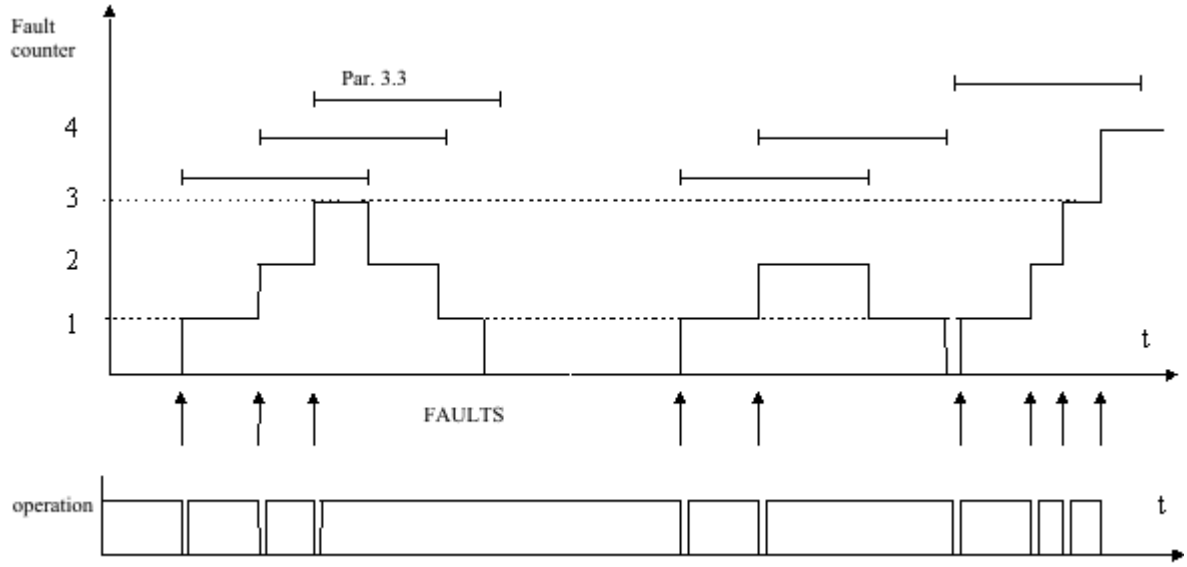


Fig.7.10. Automatic restart of an operating mode when there are 3 reloads

If within the time set by parameter 3.3 the number of faults exceeds the set number of reloads, FC will not automatically resume the operating mode. To resume operation. it is necessary to press the "STOP" button on the control panel or to apply a signal to the digital input programmed for faults clearing or switch FC off and on.
Parameter 3.4- a permission to reload FC after the failure "low voltage in the d.c. circuit".
Parameter 3.5- a permission to reload FC after the failure "high voltage in the d.c. circuit"
Parameter 3.6- a permission for the FC reloading after the failure "high output current"
Parameter 3.7- a permission to reload FC after the failure "heatsink overtemperature".
Parameter 3.8- a permission to reload FC after the failure "signal level at the InA input is lower than 2V (4mA)".

7.4.3. Motor thermal protection

A built-in mathematical model of the motor allows to calculate its temperature theoretically.
The model design takes account of the following assumptions:
-an exponential increase of a winding temperature
-max. temperature for continuous operation at motor rated current
-temperature gain (increase) in proportion to the ratio $(I/I_{nom})^2$
-the cooling constant for a shut-down motor is four times as much as that during operation.

Parameter 3.10 specifies a motor constant (steady-state) current (f>25 Hz). For low frequencies a permissible constant motor current is lower, because a standard motor is cooled by a ventilator mounted on the motor shaft.
A motor load can be specified on the basis of the characteristic shown in Fig. 7.11. During motor cooling without optional ventilation **parameter 3.11** must be set to 35% of the motor current. When using a motor with optional ventilation this parameter can be increased, for example, up to 75% of the motor current. **Parameter 3.12,** which sets the motor heating constant, is very important. This parameter defines a period of time within which a motor temperature gain reaches 63 % of the final temperature gain.
In practice this time is taken to be
par.3.12= 2*tσ [min] (tσ [c.] is specified in the motor technical data).

It is possible to set the parameters shown in Table 7.9

Table 7.9

Motor power. kW	Number of poles		
	2	4	6
	The motor heating constant, min		
2.2	11	17	24
3.0	12	18	26
4.0	13	19	29
5.5	15	21	29
7.5	16	23	31
11	19	26	34
15	20	29	39

Parameters 3.10, 3.11 are set in percent of the FC rated current. If a motor rated current differs from a FC current, it is necessary to correct the set parameters values.

Example
A 15 kW frequency converter powers a motor with the rated current of 27.5 A. The FC rated current is 30A. Parameter 3.10 must be set to 27.5A (27.5/30*100%), i.e. 92% of the FC rated current.

a) for a motor without an optional ventilator, parameter 3.11 must be set to 35% of the motor current.

parameter 3.11= 35%/100* par.3.10
parameter 3.11= 35%/100* 92%=32%
parameter 3.11= 32% I_{nom}

b) for a motor with an optional ventilator, the expected current for a shut-down motor is 70 % of the motor current.

parameter 3.11= 0,7*par. 3.10
parameter 3.11= 0.7* 92%
parameter 3.11= 64%

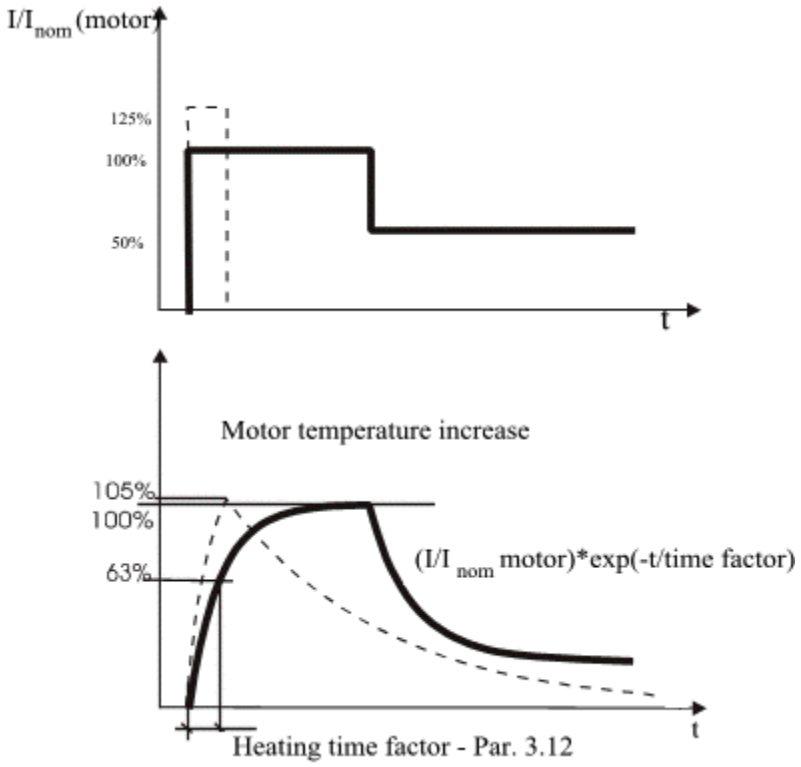


Fig 7.11 Motor heating (model used in FC),
a dash line- FC off at the current more than I=1.25 I_{nom} (motor)

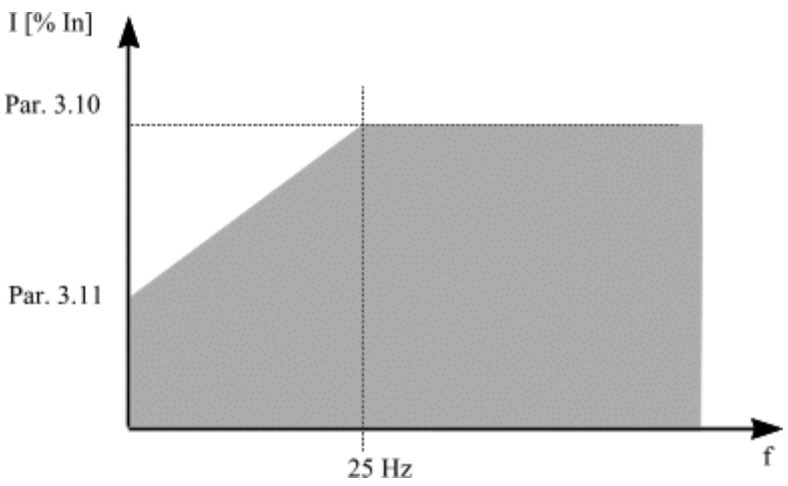


Fig. 7.12 Motor load characteristic

For operation with an external ventilator parameter 3.11 must be set to 70 % I_{nom}, without a ventilator- to 35% I_{nom}.

7.4.4. Setting factory parameters

After setting **parameter 3.13** to "yes" FC default values will be loaded.

7.4.5. FC operation when an input signal at the InA1 and InA2 inputs is missing

To operate FC using analog signals for control and in a floating zero operating mode, parameter 3.14 must specify a response to an input signal fade (loss) (from 2 to 10 V or 4-20 mA). It is possible to select a stop (shut-down) and a failure message or continuation of the operation with the constant speed of f7, specified in parameter 2.31.