TRIOL

AK06

VARIABLE SPEED DRIVE FOR ESP APPLICATIONS

PROGRAMMING MANUAL

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Dear customer

Thank you for purchasing Triol Variable Speed Drive (VSD), the key to your successful artificial lift strategy.

We are sure that our variable speed drive technologies allow you to improve operations and adjust production.

VSD is complete with the following manuals:

- Design Manual;
- Operation Manual;
- Quickstart Manual;
- Programming Manual;
- Troubleshooting Manual;
- Approvals/Standards.

Download documentation

<u>IMPORTANT</u>: The list may be extended with the additional documents (The Factory Acceptance Testing (FAT) and others) depending on the VSD line.

<u>NOTE</u>: Quickstart manual includes only the necessary basic steps to start VSD with an induction motor at a well site during pre-commissioning: set-up VSD to motor and transformer, no-load test and test a VSD with step-up transformer. During commissioning shell be set-up protections, operation and starting modes in accordance to a field standards or well design. Explanation of VSD controller settings are given in the Programming manual. Procedures of starting/stop, recommendations for settings, connection of external equipment (such as downhole sensors, analog/digital input/outputs sensors are given in the Operation manual. In case of any problems or failures please use Troubleshooting manual. Design manual includes technical specifications, a set of dimensional drawings and electrical diagrams for Variable Speed Drives Triol AK06. The list of all kinds of user manuals is discussed at the placing an order stage. E-documents version for the product is available on the official Triol Corporation website.

https://triolcorp.us/documents/

Programming Manual AT.654252.408 ver. 1.1.

The manual applies to the commercially available Variable Speed Drives Triol AK06 with UMKA07 controller for ESP application.

Contents

Description and operation

All VSD parameters and operation data are displayed by UMKA07 controller via its large 7’ / 800 x 480 dots liquid-crystal touch screen located in the upper part of the controller front panel. All messages about the VSD current state, actuation of protections, values of operating parameters, etc. are offered as texts without any numerical codes or symbols to simplify reading. Liquid-crystal display is backlit for greater viewing experience under insufficient light conditions. The display is designed to operate within a wide range of ambient temperatures.

The controller’s event log memory capacity is 16 Mb. This allows to store over 1 million of records and to ensure the information is saved with 1 sec recording step over the period of 10 days.

Two physical hot keys located on the right and underneath the UMKA07 display screen are for VSD’s immediate START (green) and STOP (red).

NOTE: there are two versions of UMKA07 controller displays available: with or without touch-screen capability. In touch screen version, the following physical keys are disabled: «CANCEL», «ENTER», «STATUS», «LEFT», «RIGHT», «UP», «DOWN».

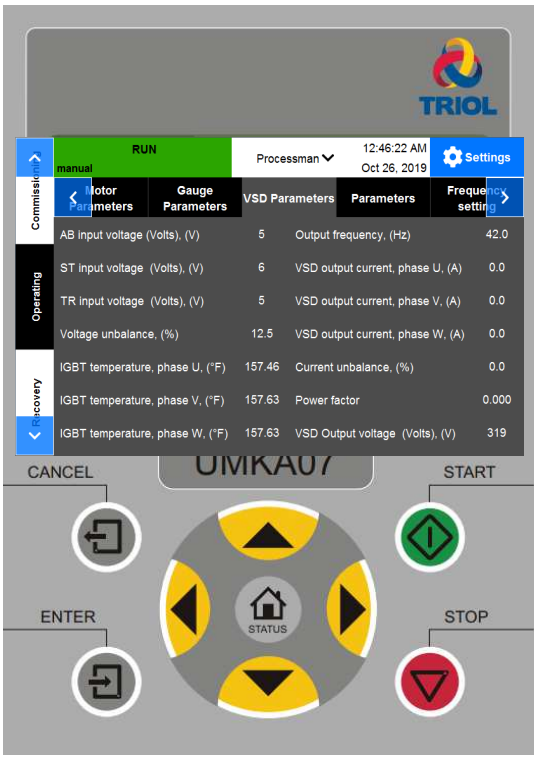


Figure 1 – UMKA07 view

Levels «Processman» and «User» give accesses to different menus:

Menu	Processman	User
Testing	V	X
Commissioning	V	X
Operating	V	V
Recovery	V	V

Access to menu levels is protected by a password. To change the status of a particular access level («V» – permitted, «X» – restricted) tap on the current access level on the display.

Each menu describes VSD lifecycles and gives access to configuration of VSD for each lifecycle. This logic helps quicker commissioning and step-by-step VSD configuration.

General overview of UMKA07 interface is shown on the picture below:

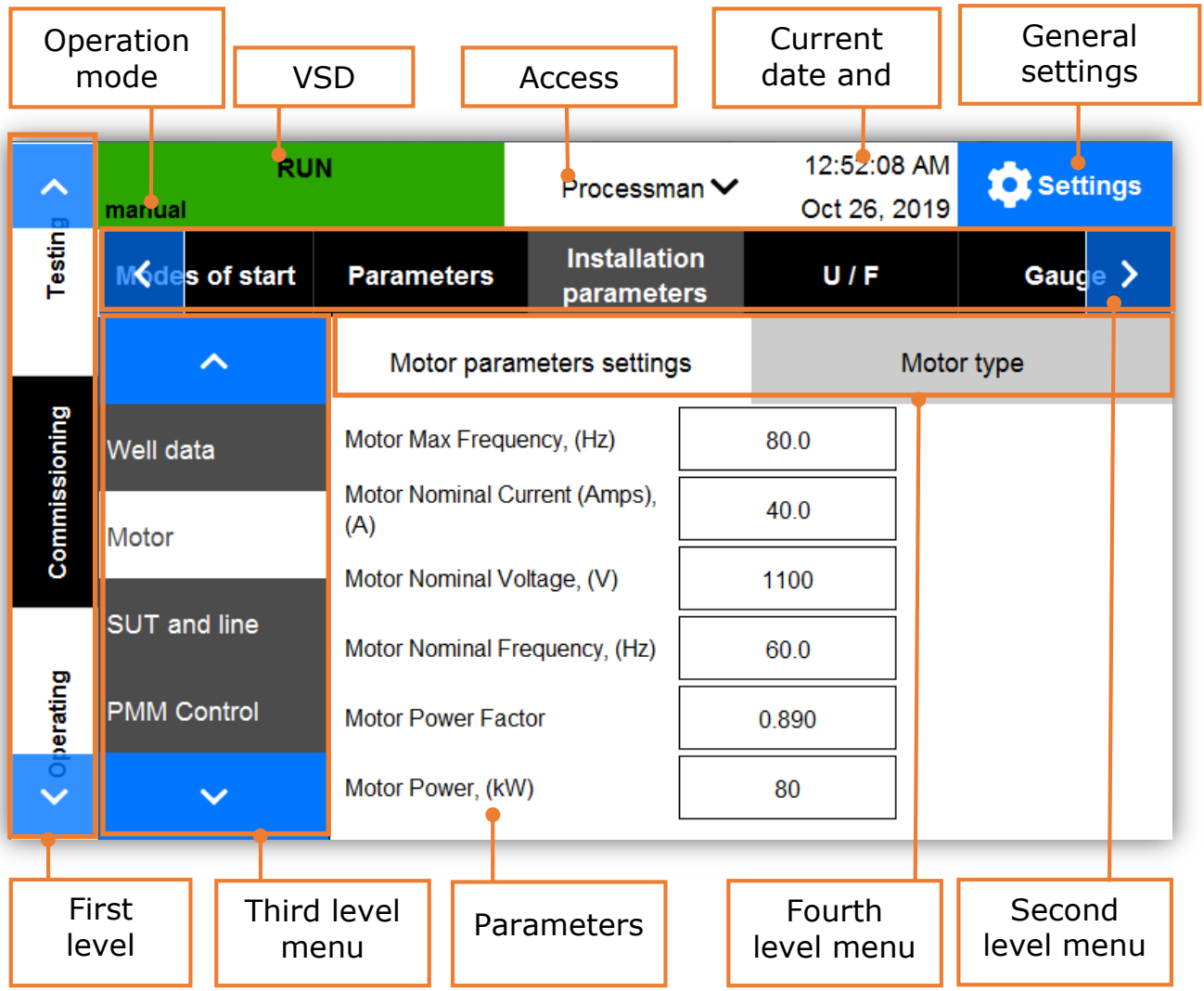
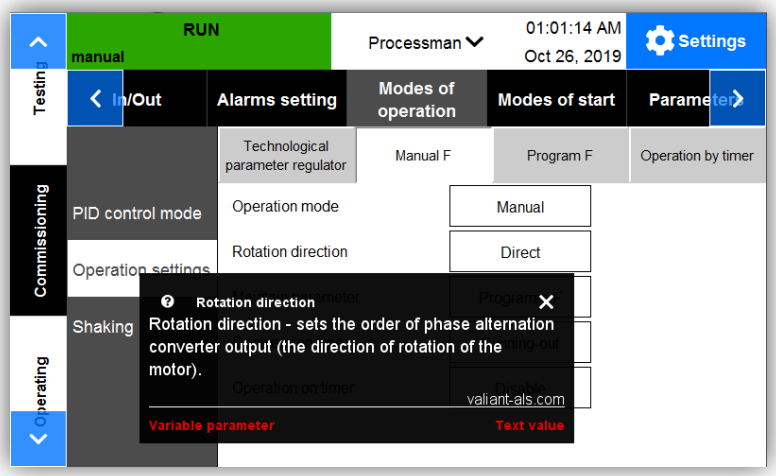
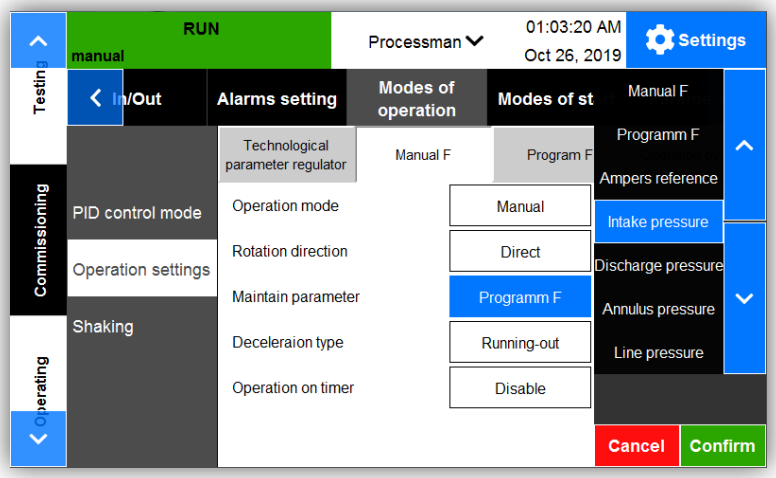


Figure 2 – UMKA07 interface overview

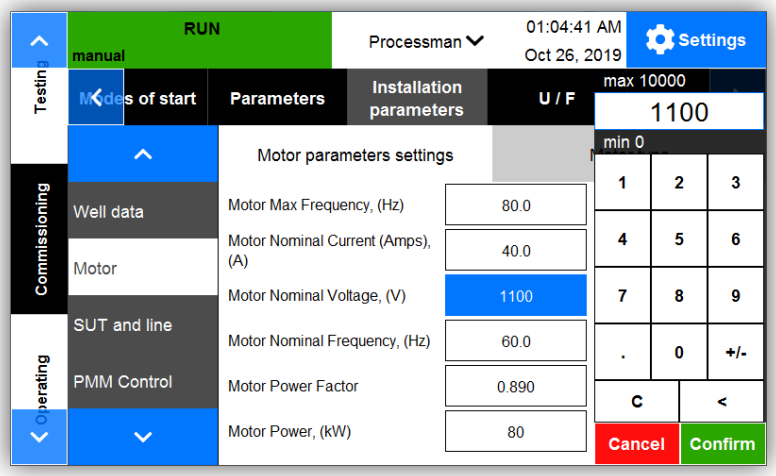
All menu navigation and setpoint adjustment of selected parameter are made by tapping on the corresponding area of touch screen display.



To view reference information about the UMKA07 parameter, just tap on a parameter name: the pop-up window will appear with helpful information about the chosen parameter.



Settings of a parameter that can have a defined value are made by selecting a desired value from the list of possible values. The parameter is highlighted while being edited. Tap on «Confirm» button to store the new value of a parameter.



Numeric parameters are entered via display's pop-up numeric keyboard. To store the new value tap on the «Confirm» button. Numeric keyboard shows possible minimum and maximum values of the editable parameter.

Overview of UMKA07 menu structure

- «**Settings**» - basic HMI settings and VSD information

Display	Language	Date and time	Measurement units	VSDC information	VSD information	USB Operation

- «**Testing**» - pre-commissioning VSD test procedure

Parameters input	Parameters output	Gauge	D.ins/outs	A.outs	A.ins

- «**Commissioning**» - all necessary settings for VSD commissioning

Parameters	Installation parameters	U / F	Gauge	In/Out	Alarms setting	Modes of operation	Modes of start
	Motor	Frequency settings	Gauge select	Didgital inputs	Overload	Operation settings	Soft
	Pump	U / F curve	Intake pressure	Didgital outputs	Underload	Power ON - start	With synchronization
	SUT and line		Discharge pressure	Analog inputs	Current unbalance	Shaking	Swinging
	PMM control		Amb.(Intake) temperature	Analog outputs	Insulation	Gas lock mode	Jogging
	Well data		Discharge temperature		Backspin	PID control mode	Unblocking
			Motor temperature		Input voltage	I-sync	Hard
			Vibration		Frequency	Current optimization	
					DC bus voltage		
					IGBT overheating		
					Overcurrent		
					IGBT fault		
					Door		
					SCADA		
					Phase rotation		
					Contact pressure gauge		

- «**Operating**» - actual parameters of ESP operation and speed adjustment

Parameters	Frequency setting	Motor Parameters	Gauge Parameters	VSD Parameters

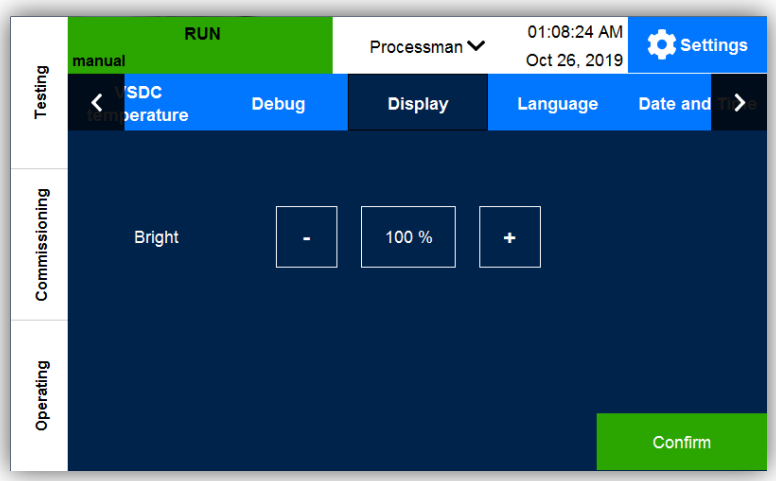
- «**Recovery**»- analysis of ESP operation

Actual crash	Crash log	Event log	Log settings	Start -UP graph	Diagnostic
	List		Set register by time		
	Crash log data		Set register by changes		
	Crash log graph		Custom register set		
			Clear logs		

«Settings» menu

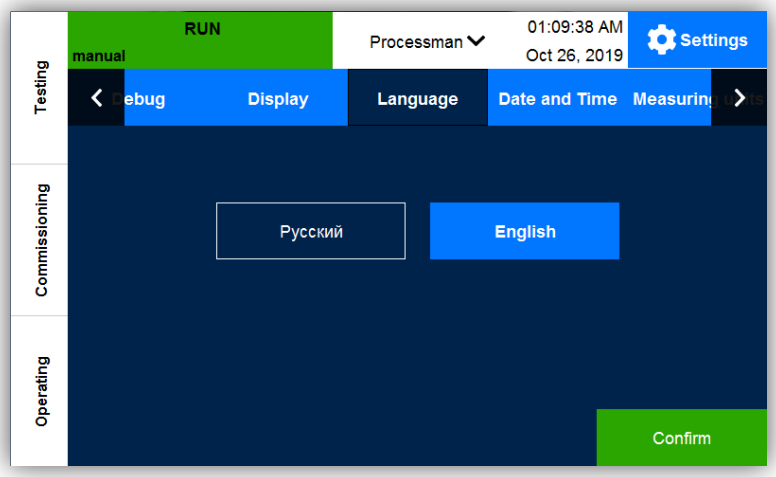
«Settings» menu offers to set and store the following parameters: display brightness, language, date and time, unit of measure. Additionally, this menu contains information about the VSD and UMKA07 controller.

«Display»



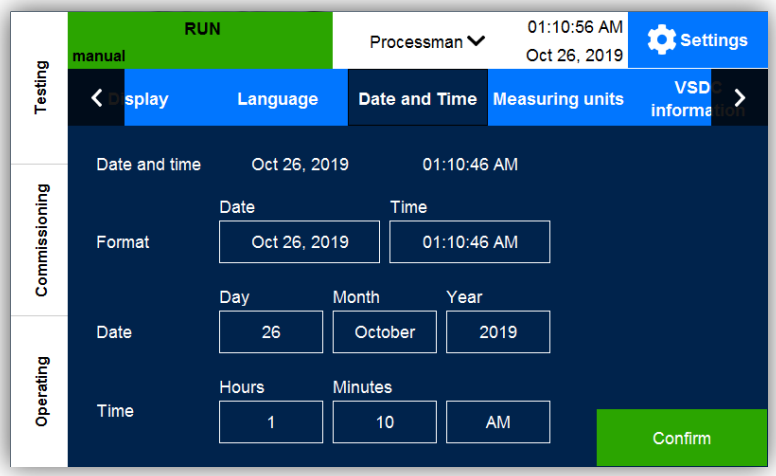
Setting controller's display brightness.

«Language»



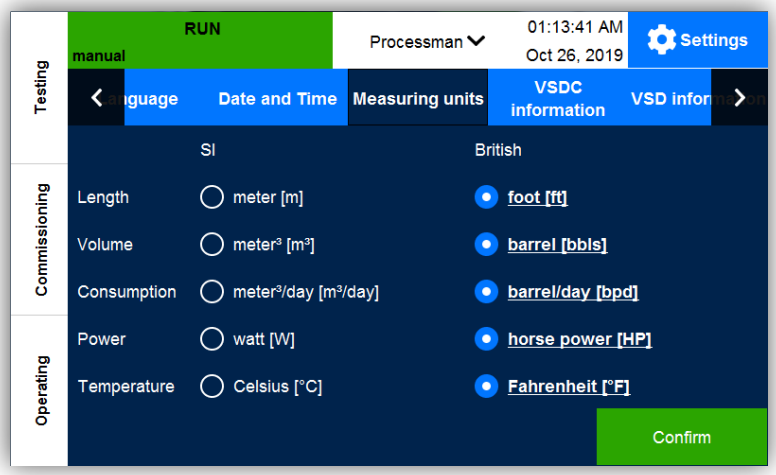
Setting a language of UMKA07 controller interface. As of now, available languages are English and Russian.

«Date and time»



Setting the format of displayed date and time. Setting and storing the current date and time values.

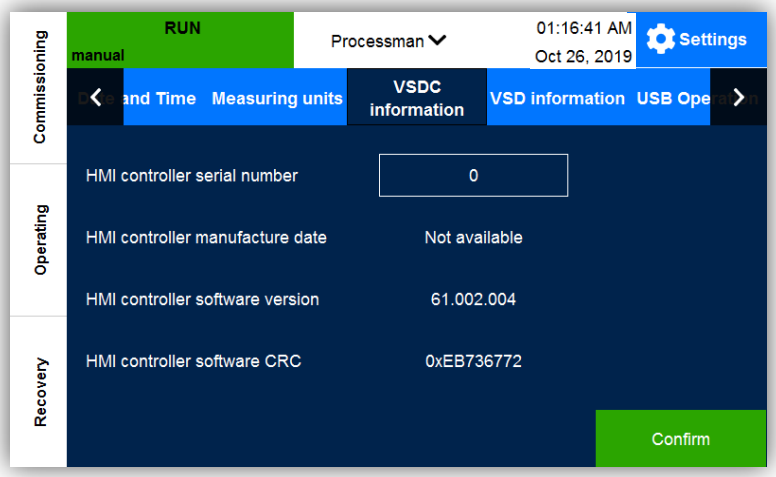
«Measuring units»



Setting measuring units for the following physical parameters:

- length;
- volume;
- consumption;
- power;
- temperature.

«VSDC units»



This menu shows:

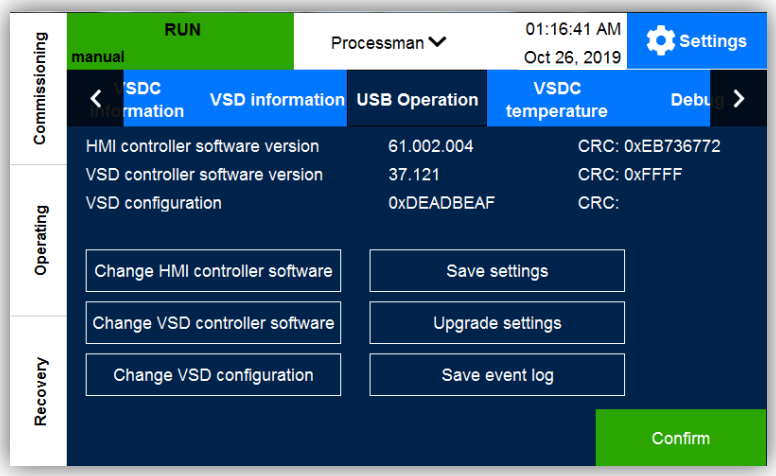
- UMKA07 controller manufacturing date;
- UMKA07 serial number;
- software version;
- software Cyclic Redundancy Check (CRC).

«VSD information»

This menu shows:

- full product name;
- manufacturing date;
- serial number;
- VSD full name;
- nominal power;
- output current;
- supply voltage;
- frequency;
- protection;
- ambient temperature;
- software version;
- software Cyclic Redundancy Check (CRC).

«USB Operation»



UMKA07 is fully compatible with USB Flash (up to 32 Gbyte) and supports FAT32 file system.

This menu offers to store all the current settings of all parameters set by the operator via «Save settings» function.

To store settings onto USB Flash, proceed as follows:

1. connect USB Flash to the USB port;
2. make sure USB Flash is recognized (the corresponding message will pop up on the display);
3. press «Save settings»;
4. wait until the procedure is completed.

«Upgrade settings» function offers to restore settings via connected USB Flash.

To upload saved settings via USB Flash, proceed as follows:

1. go to «Settings» → «USB Operation» and memorize current version of software version (see parameter «HMI controller software version»);
2. connect USB Flash to USB port;
3. choose the file with «Factory settings» from the list of offered files. By default, Factory default settings file contains software version number to be compatible with;
4. press «Save settings»;
5. wait until procedure is completed.

Function «Save event log» offers to download the Event Log file onto USB Flash. Additionally, Event Log file is automatically downloaded onto USB Flash every time it is connected to the USB port.

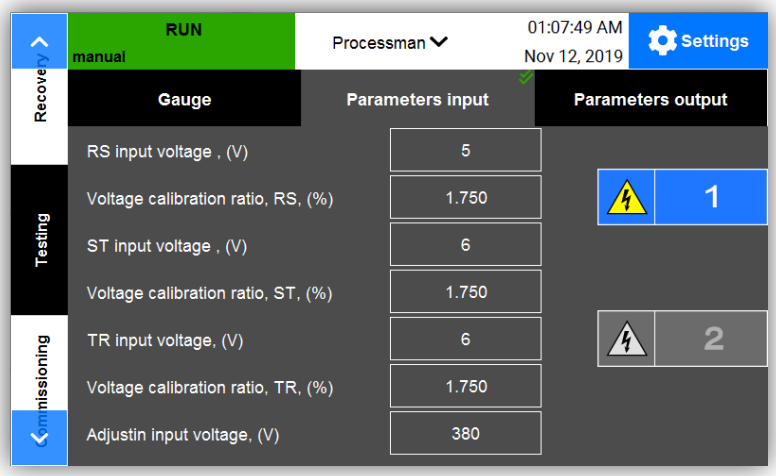
ATTENTION! It is strictly prohibited to disconnect VSD from power source or unplug USB flash from USB port until any USB flash procedure is still in progress.

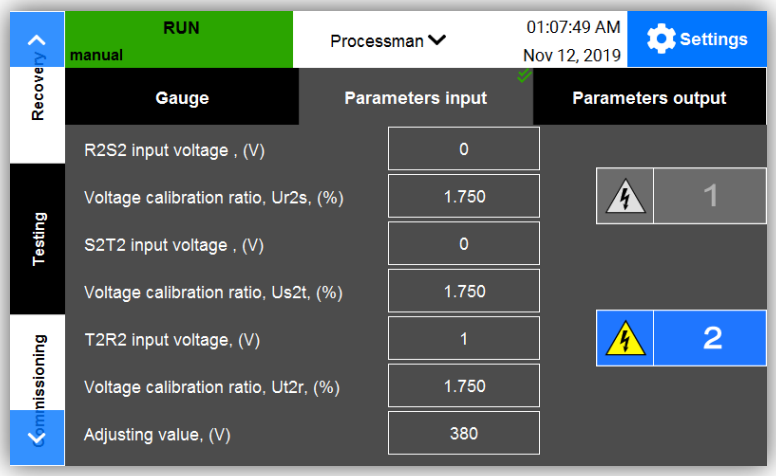
«Testing» menu

«Testing» menu is intended for the first test after unpacking VSD, calibrating input voltages (if its needed), configuring and testing digital/analog inputs/outputs, downhole sensor etc.

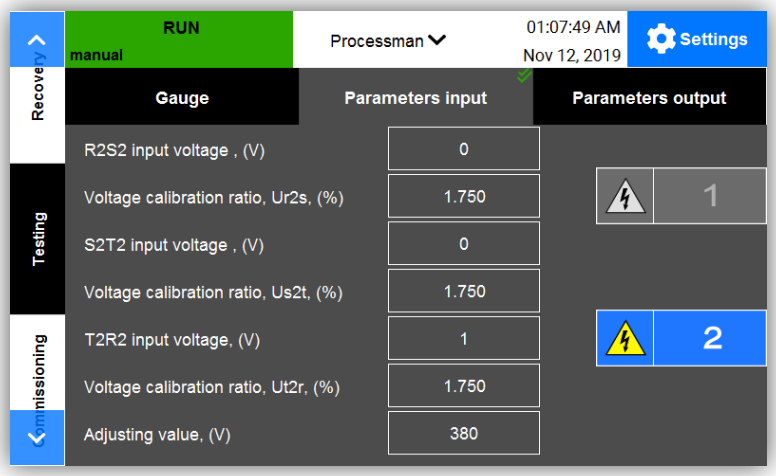
«Parameters inputs»

This second-level menu represents actual values of phase-to-phase voltages and enables the user to calibrate measuring channel. Calibration is performed at the input voltage applied by entering a value measured by multimeter APRA 91 (measuring inaccuracy ± (1.3% + 4 units) or by a similar instrument.

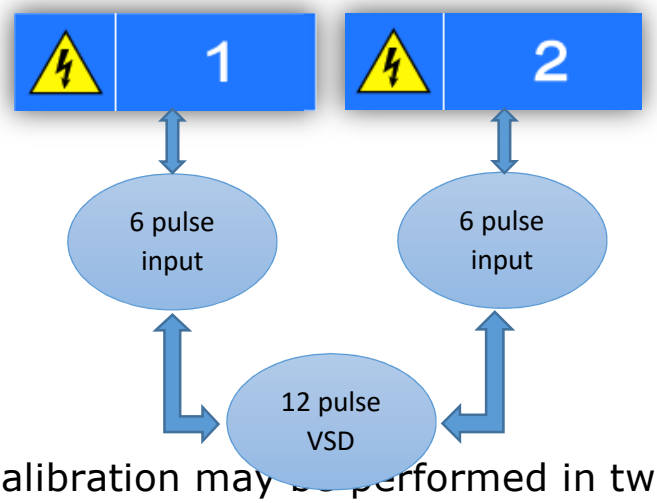




- «RS input voltage» parameter — indication of input voltage between R and S phases;
- «Voltage calibration ratio, RS» parameter — RS phase-to-phase voltage compensation factor;
- «ST input voltage» parameter — indication of input voltage between S and T phases;
- «Voltage calibration ratio, ST» parameter — ST phase-to-phase voltage compensation factor;
- «TR input voltage» parameter — indication of input voltage between T and R phases;



- «Voltage calibration ratio, TR» parameter — TR phase-to-phase voltage compensation factor.



An active status of the button «1» indicates the first net voltage, the active status of the button «2» indicates the second net voltage.

Calibration may be performed in two ways:

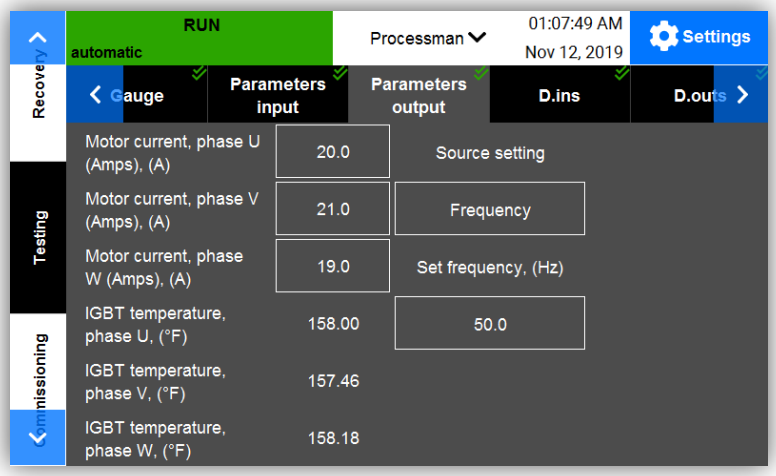
1. by entering measured values for parameters «RS input voltage», «ST input voltage», «TR input voltage» (more convenient method);
2. by entering compensation factors in percentage terms for parameters «Voltage calibration ratio, RS», «Voltage calibration ratio, ST», «Voltage calibration ratio, TR».

The Adjustment range is 50—200 % of the actual measured value when using any method of calibration. The adjustment range must be within 100±10% range. If the adjustment range have much more deviation it can be a reason of failure in the measurement circuit in VSD (look diagnostic in troubleshooting manual).

When calibration is completed press «Confirm» to save data.

«Parameters output»

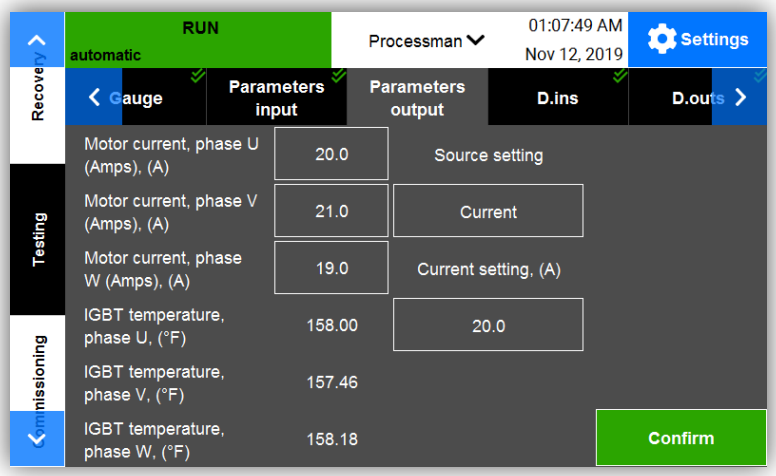
The menu intended for a test motor start and offers the following functions:



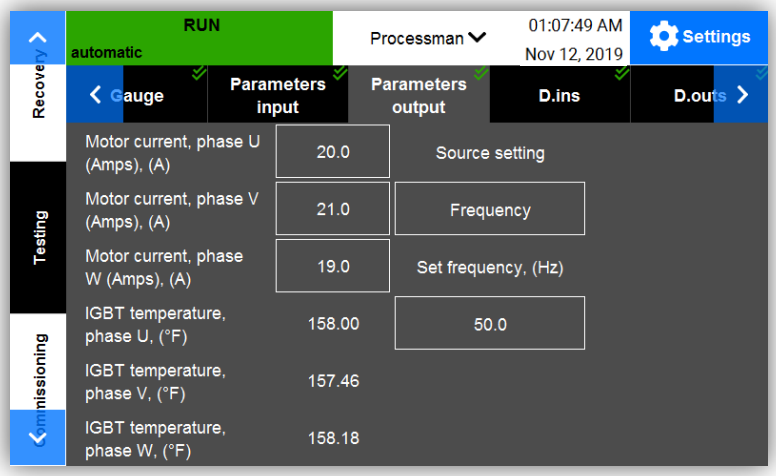
- «Motor current, (phase U/phase V/phase W) » –this parameter shows the value of motor current for each U/V/W phase. With the help of these parameters, it's possible to calibrate the parameters on the controller screen with the measured ones.

Calibration is carried out in the following way:

1. connect the drive to the load of at least 50% of the VSD rated current;
2. press the «start» button ;
3. wait until the VSD reaches its operating frequency;
4. measure the motor current in phase U, enter the parameters in the parameter «Motor current, phase U»;
5. repeat the steps for phases V and W.



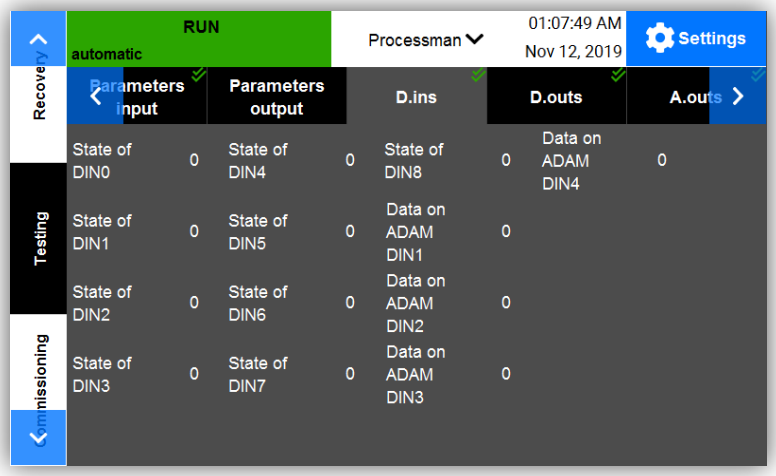
- «IGBT temperature, (phase U/phase V/phase W) » – these parameters show the temperature of IGBT inverter power switches;

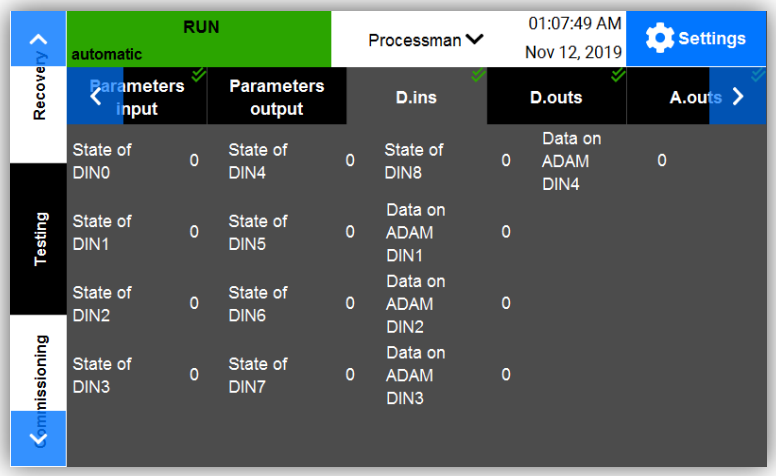


- «Source setting» offers setting the parameter for the exact moment. Selecting «Frequency» - the VSD maintains the set value of the output frequency. Selecting «Current» – the VSD maintains the set output current;
- «Current frequency» and «Set frequency» – allow setting the value of the supported parameter according to «Source setting».

«Digital inputs»

This menu is intended for displaying of the VSD digital inputs current. This menu allows you to compare the values of the UMKA07 digital input with the real time value.

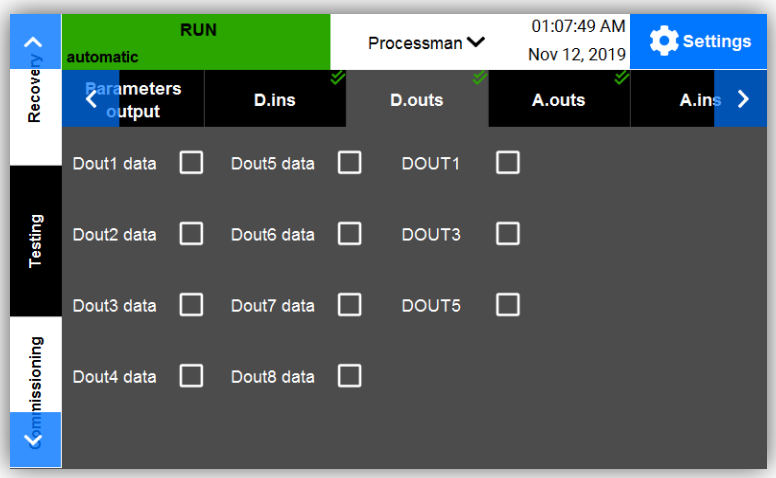




- UKMA07 DIN1 signal is located on external terminal;
- digital inputs DIN0, DIN2-DIN8 are not intended for connection of user equipment;
- «0» or«1» - shows the current status of the digital input. «0» corresponds to 0 V at the digital input; «1» corresponds to +24V at the digital input;
- «Data on ADAM DIN0 – DIN3» – digital inputs values.

«Digital outputs»

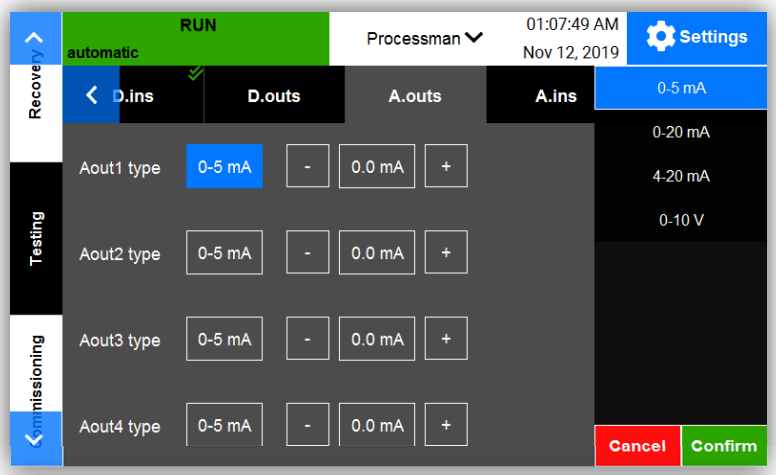
This menu allows you to check the hardware of the digital outputs.

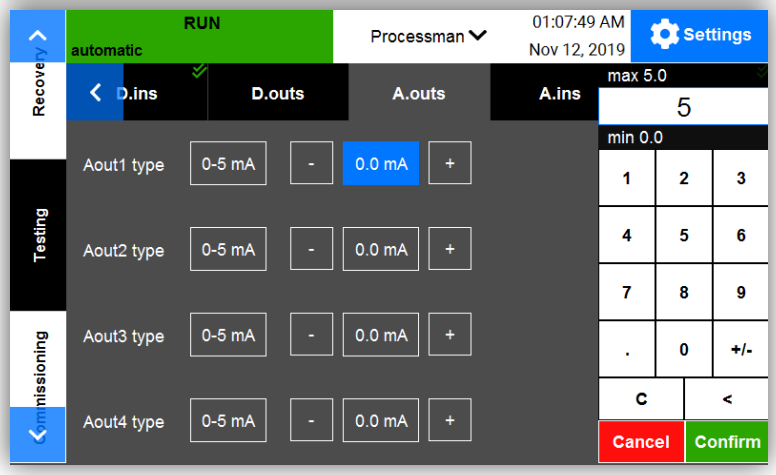


- sign ☐ with the name of digital input indicates that there is no voltage supplied from the digital input;
- sign ☑ with the name of the digital input indicates that there is voltage supplied from the digital input.

«Analog outputs»

This menu is intended for the check of analog outputs availability.



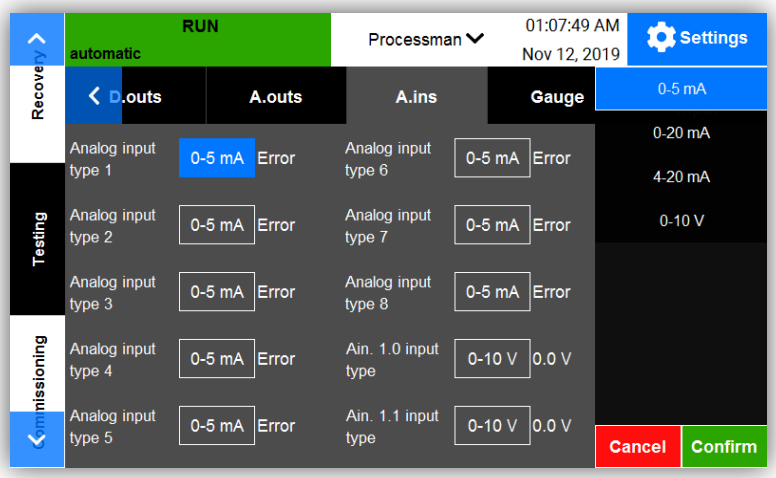


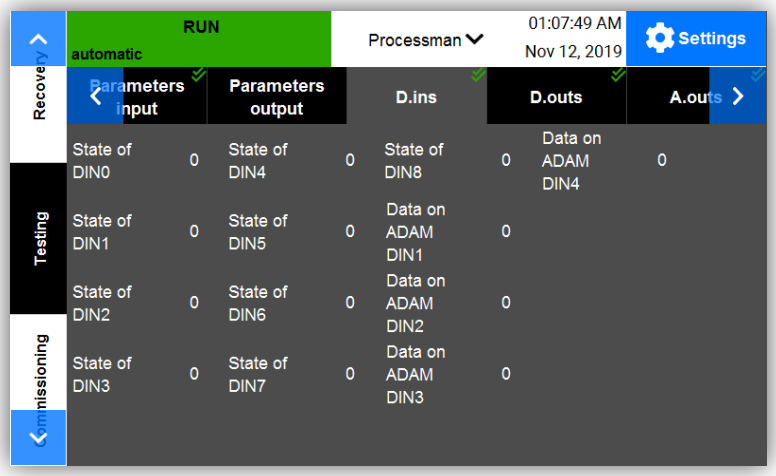
- the menu allows configuring each analog output to work with a wide range of interfaces:
  1) 0-5 mA;
  2) 0-20 mA;
  3) 4-20 mA;
  4) 0-10 V.

- as soon as the user sets the test value (for example, 5 mA, as shown on fig. on the left), and press «Confirm», then the set command is sent to the analog output.

«Analog inputs»

This menu is intended for displaying the current status of all VSD analog inputs. This menu allows you to compare the values of the UMKA07 analog input with the real time value.

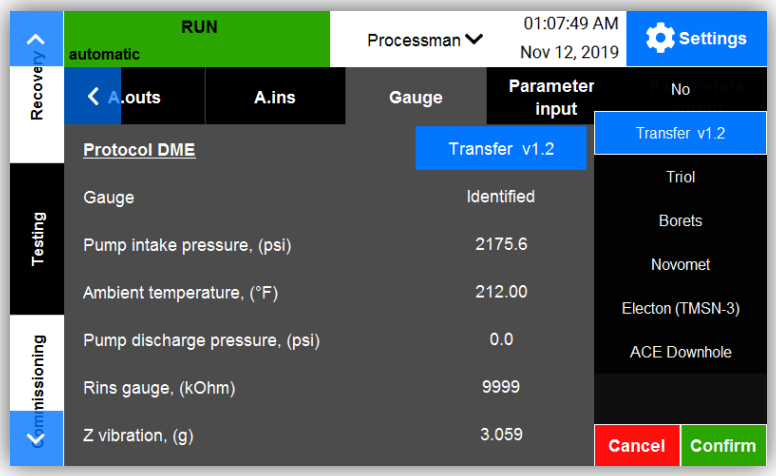




- UKMA07 AIN1.0, AIN1.1 signal is located on external terminal;
- the following interfaces are available for the analog signal:
  1. 0-5 mA;
  2. 0-20 mA;
  3. 4-20 mA;
  4. 0-10 V.
- sensor disconnect and short circuit alarms are provided for 4-20 mA interface;
- there is a sensor disconnect provided for interface 0-5 mA, 0-20 mA.

«Gauge»

The second level menu offers serves to check VSD and downhole equipment communication. The menu shows data received from downhole unit. Types and number of displayed parameters may differ depending on the downhole equipment model.



- «Gauge file setting» — parameter representation and assignment according to a type of downhole equipment unit connected;
- «Gauge» parameter — connected downhole equipment unit status display.

«Commissioning» menu

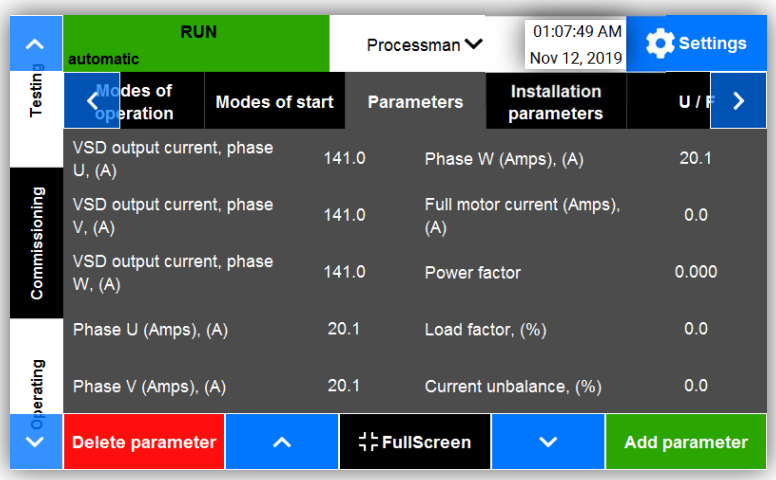
First level menu «Commissioning» is intended for VSD configuration prior to its installation at well. VSD is ready for installation at well when all «Commissioning» parameters are set.

«Commissioning» menu contains:

- «Parameters» menu – adjusting the list of parameters which will be shown on display when operating;
- «Installation parameters» – is intended to set motor, pump, step-up transformer and well parameters;
- «U/F» – allows to set voltage to frequency curve, maximum and minimum working frequencies;
- «Gauge» – allows to set connection AK06 with downhole sensor, configure downhole parameters;
- «In/Out» – allows to set analog/digital inputs and outputs configuration;
- «Alarms setting» – all VSD alarms settings are located in this menu;
- «Modes of operation» menu is intended to adjust technological process at every well;
- «Modes of start» menu contains different algorithms for starting ESM under different conditions.

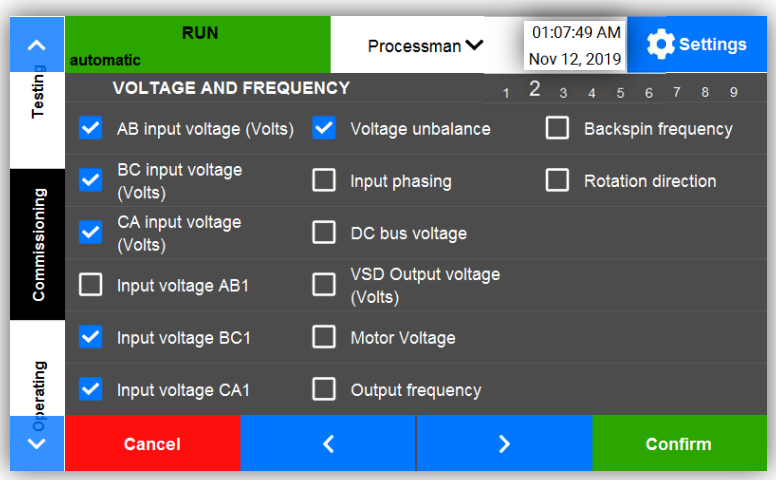
«Parameters» menu

This menu displays current values/parameters of VSD, Motor, and Well.



10 of different parameters can be displayed simultaneously. To scroll through the list of parameters use ^ or v.

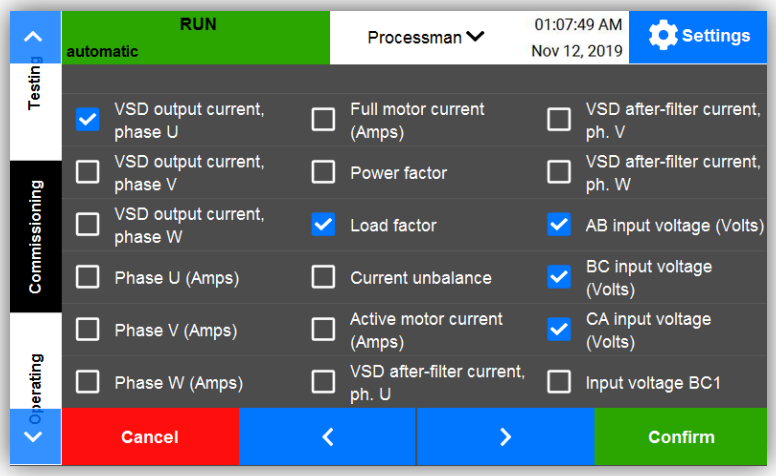
«Full screen» mode offers to maximize the display area for showing more additional parameters on screen.



The operator can independently set number of parameters displayed by UMKA07 HMI controller.

«ADD parameter» function offers to add other parameters to be displayed on the screen. All available parameters are divided into 9 logical groups:

- 1st group – Current's;
- 2nd group – Voltage and frequency;
- 3rd group – Insulation, Motor electric power, IGBT inverter temperature;
- 4th group – Process Parameters;
- 5th group – Sensors and SCADA (the state of communication between telemetry and Automated Control System, and its data);
- 6th group – Discrete outputs;
- 7th group – Analog outputs;
- 8th group – Analog inputs;
- 9th group – Discrete inputs.



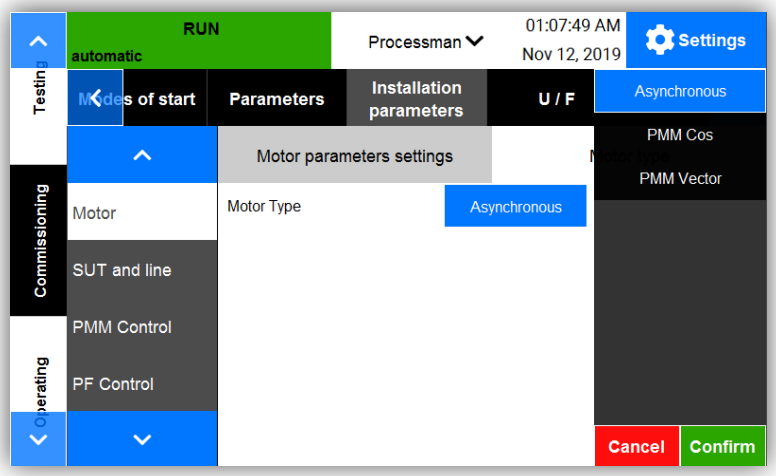
Chosen parameters are added to the screen in the same sequence as they are selected.

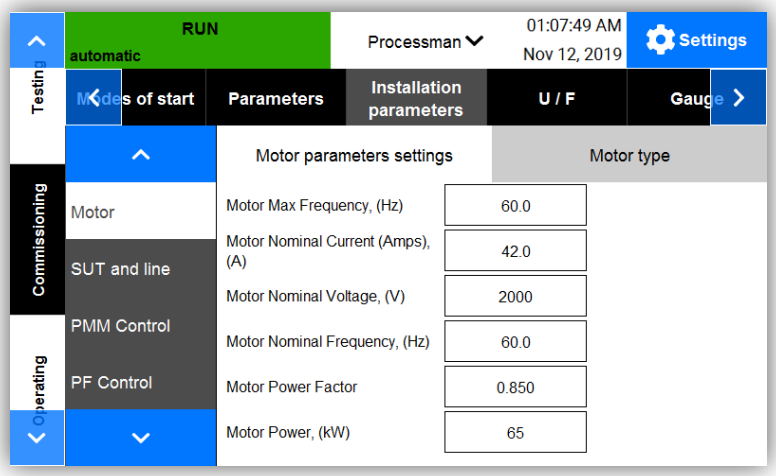
«Delete parameters» menu allows you to remove parameters from the list of displayed on the screen.

«Installation parameters» second level menu.

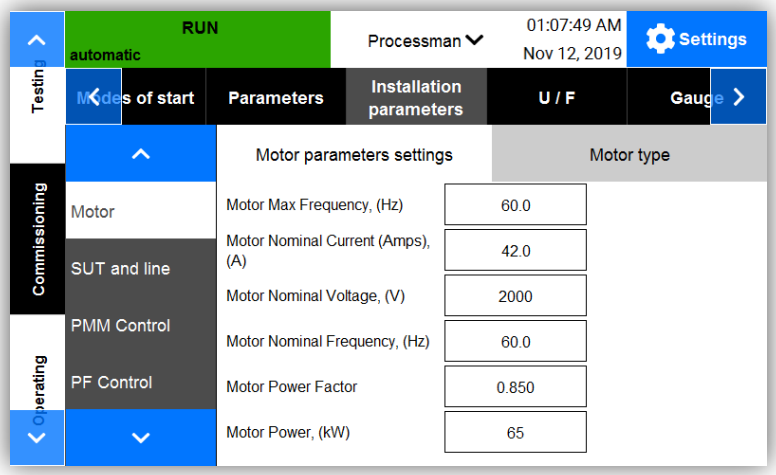
Third – level menu «Motor»

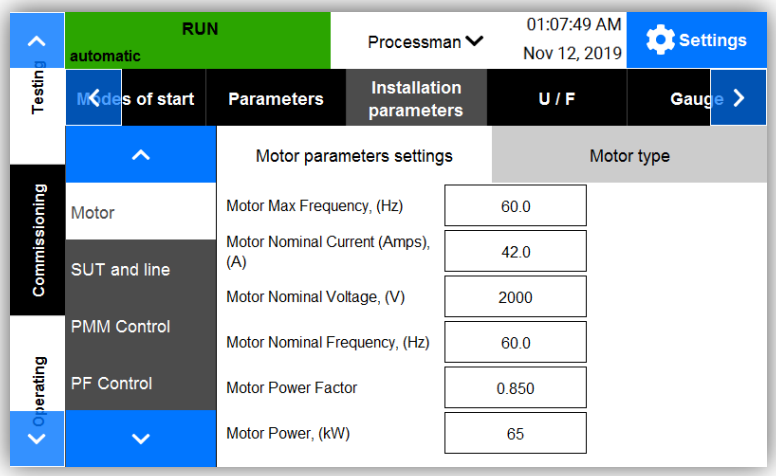
Third-level menu «Motor» offers to set motor parameters and motor type.



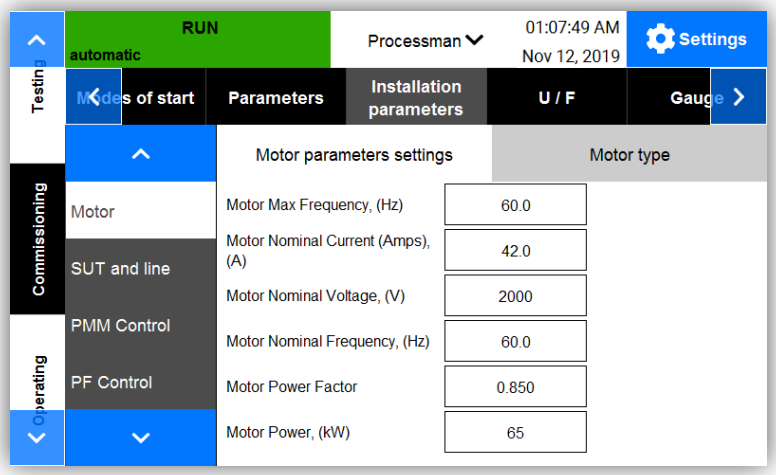


- «Motor type» function offers selecting a type of a motor to match a particular motor type operated at the well. Motor types available: asynchronous or permanent magnet;
- «Motor max frequency» parameter — maximum frequency at which motor will be operate. This parameter is used for calculating step-up transformer recommended tap;





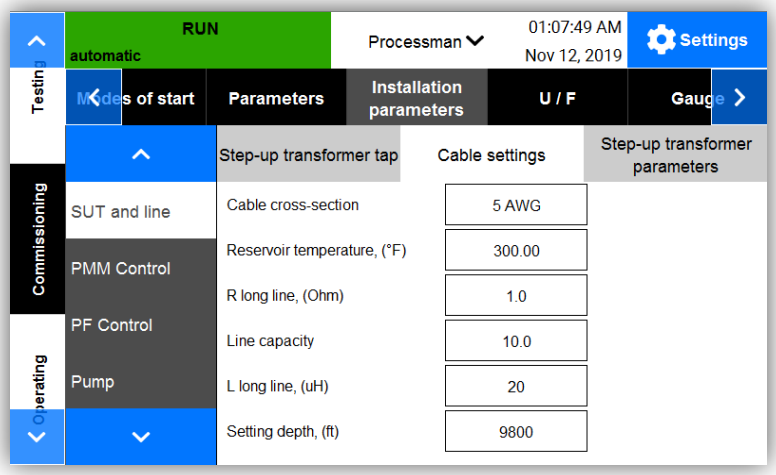
- «Motor nominal current» parameter — motor rated current. This parameter is used for protecting the submersible motor against overloads, for calculating the ESM load factor and for tripping on underload. It is set according to the motor specification;
- «Motor nominal voltage» - value of motor nominal voltage. It is set according to the motor specification;
- «Motor nominal frequency» parameter — rated motor frequency. This parameter is used for calculating step-up transformer recommended tap;
- «Motor Power Factor» parameter — rated motor power factor. It is set according to the motor specification;



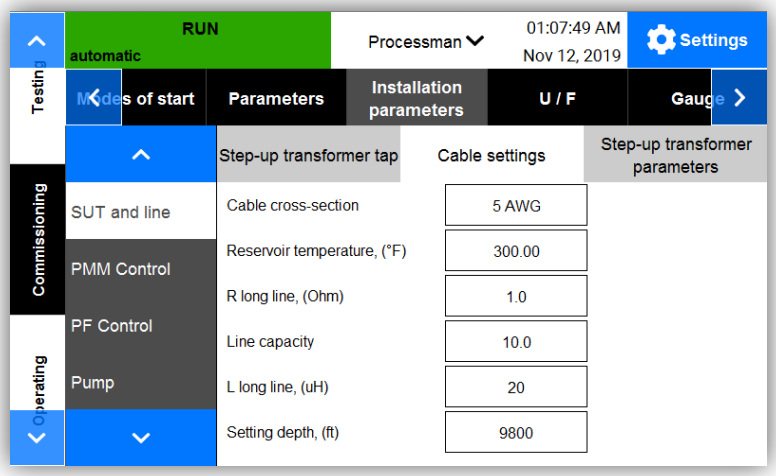
- «Motor Power» parameter — motor installed rated power. It is set according to the motor specification.

Third – level menu «SUT and line»

Designed to set Step-Up Transformer values and line parameters from step-up transformer to motor.

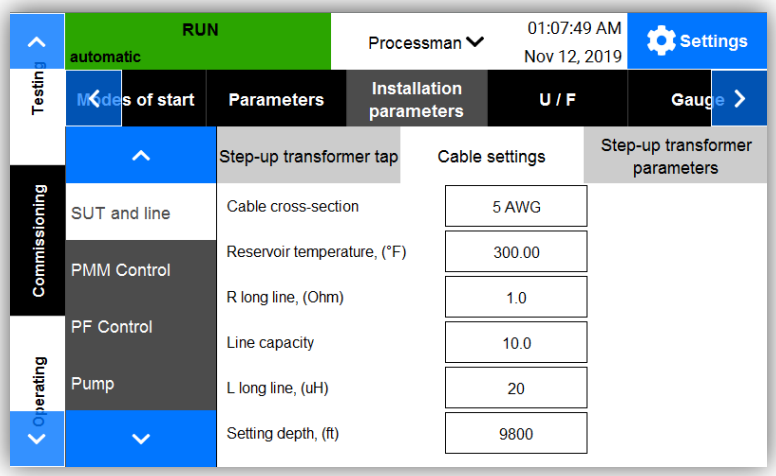


- «Cable cross-section» parameter — allows to set cable cross section from step-up transformer to motor. It is used for calculating the step-up transformer's tap voltage automatically;
- «Reservoir temperature» parameter — allows to set temperature in well. It is used for calculating the step-up transformer's tap voltage automatically;

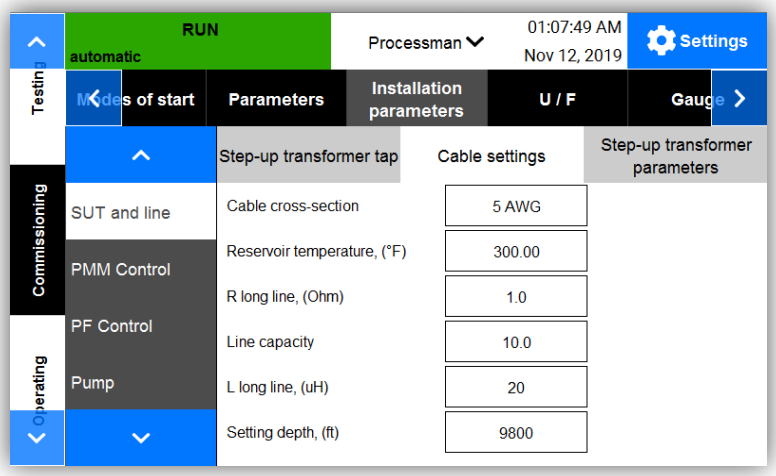


Cable cross-section: 5 AWG
Reservoir temperature, (°F): 300.00
R long line, (Ohm): 1.0
Line capacity: 10.0
L long line, (uH): 20
Setting depth, (ft): 9800

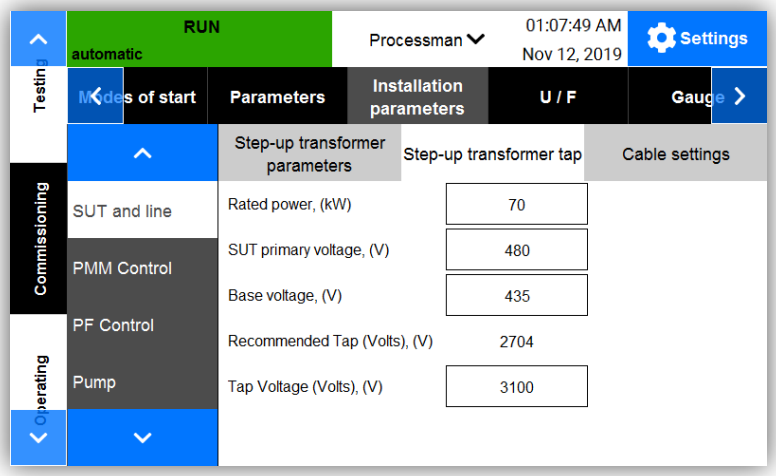
- «R long line» – allows to set cable resistance. It is necessary to enter the resistance value of the long line based on the cable datasheet and line length. This parameter is used for setting PMM Vector mode.

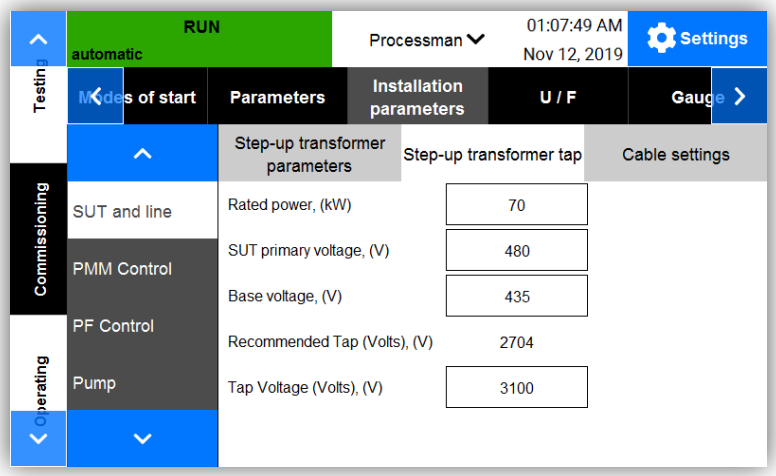

Cable cross-section: 5 AWG
Reservoir temperature, (°F): 300.00
R long line, (Ohm): 1.0
Line capacity: 10.0
L long line, (uH): 20
Setting depth, (ft): 9800

- «Line capacity» – allows to set cable capacity. It is necessary to enter the value of long line capacity based on the long line datasheet and line length. This parameter is used for setting PMM Vector mode;

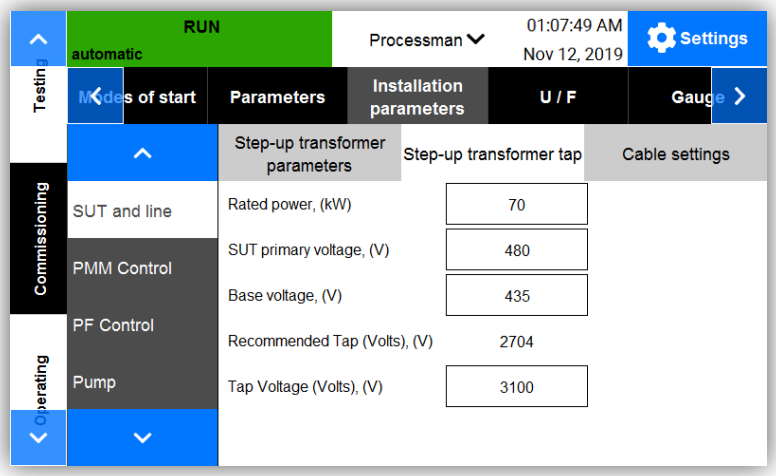

Cable cross-section: 5 AWG
Reservoir temperature, (°F): 300.00
R long line, (Ohm): 1.0
Line capacity: 10.0
L long line, (uH): 20
Setting depth, (ft): 9800

- «L long line» – allows to set cable inductance. It is necessary to enter the value of long line capacity based on the long line datasheet and line length. This parameter is used for setting PMM Vector mode;





- «Setting depth» – setting well depth. This parameter is used for calculating step-up transformer recommended tap;
- «Rated power» parameter — power of step-up transformer. It is set according to the transformer specification;
- «Step-up transformer primary volts» parameter — parameter is intended for setting tap voltage of the step-up transformer primary winding. This parameter is used for calculating U/F curve;
- «Base voltage» parameter is intended to set real VSD output voltage including voltage drops at sinewave filter. This parameter should be set 10% less than input voltage. It is used for calculating the step-up transformer's tap voltage automatically;



- «Tap voltage» – allows to save the value of the installed tap on the step-up transformer. The parameter is used for calculating motor parameters.

«Recommended Tap» parameter — calculated recommended tap voltage. «Recommended Tap» calculates as follows:

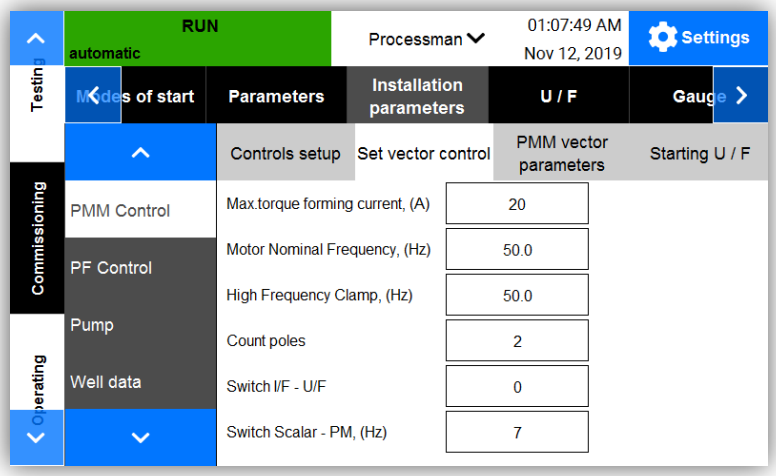
$$«\text{Recommended Tap}» = \left(\frac{«\text{Motor nominal voltage}» * «\text{Motor max frequency}»}{«\text{Motor nominal voltage}»} + \Delta U\right) * \frac{«\text{Step-up transformer primary volts}»}{«\text{Base voltage}»},$$

Where, ΔU– voltage losses which are depends from cable length, reservoir temperature.

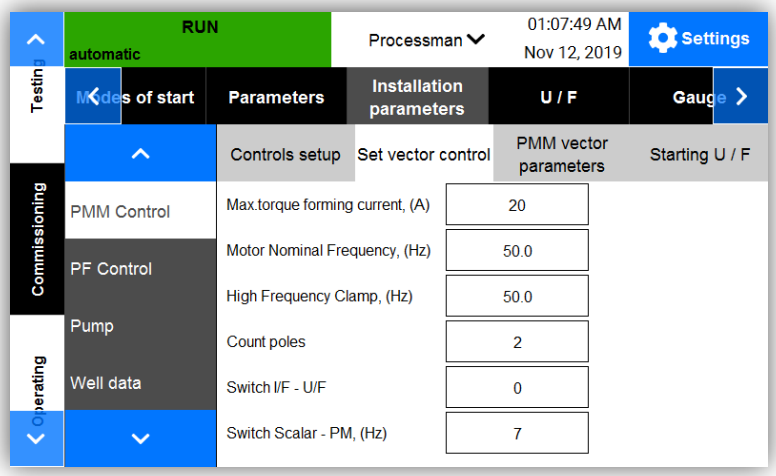
$$«\Delta U» = \frac{\text{Voltage losses from table} * «\text{Setting depth}»}{1000}$$

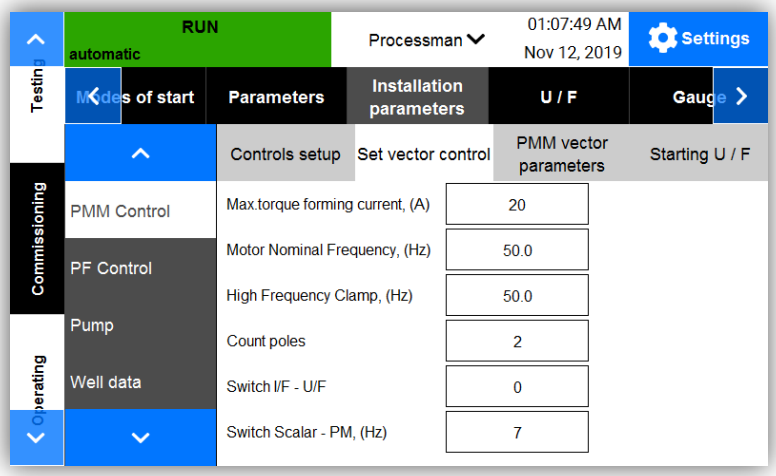
Third – level menu «PMM Control»

This menu is designed to set Vector Control parameters for PM motor the main menu has three 4th-level sub menus:



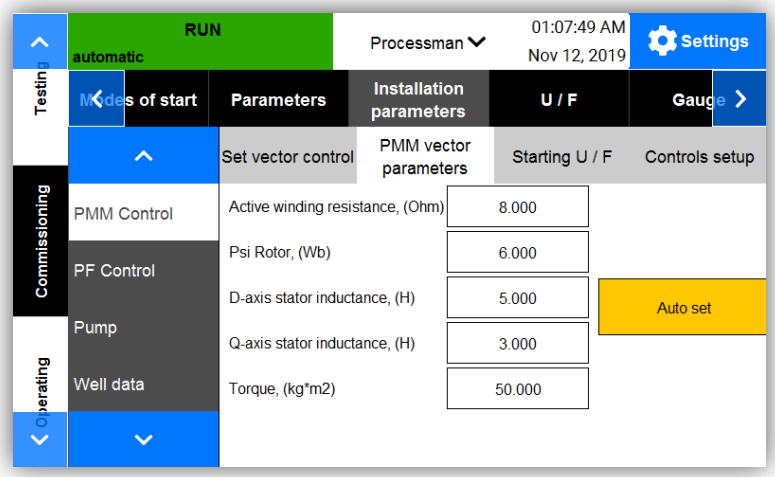
- «Set vector control»;
- «PMM vector parameters»;
- «Starting U/F»;
- «Controls setup».





In «Set vector control» menu the following parameters must be entered:

- «Max. torque forming current (A)» – this parameter is entered according to the motor documentation. It is designed to limit an active current level in Vector mode;
- «Motor Nominal Frequency, (Hz)» – nominal motor frequency;
- «Low Frequency Clamp, (Hz)» – limit of the maximum motor frequency in Vector mode;
- «Count poles» – number of motor poles. It is set according to technical parameters of the motor;
- «Switch I/F -U/F» have to set 0.
- «Switch Scalar – PM» set 7-10 Hz For 60 Hz motor and 15-20 Hz for 200 Hz motor;



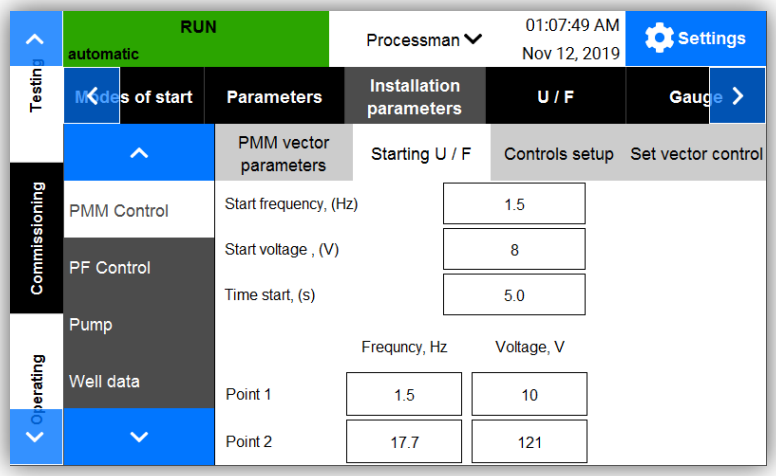
In «PMM vector parameters» menu the following parameters must be entered to enable PM motor operating in Vector mode:

- «Active winding resistance, (Ohm)» – active motor winding resistance;
- «Psi Rotor, (Wb)» – motor flux linkage. This parameter must be set according to the motor technical documentation;
- «D-axis stator inductance, (H)» – motor stator inductance along the D-axis;
- «Q-axis stator inductance, (H)» – motor stator inductance along the Q-axis;
- «Torque, (kg*m^2)» – moment of inertia.

«Auto set»:

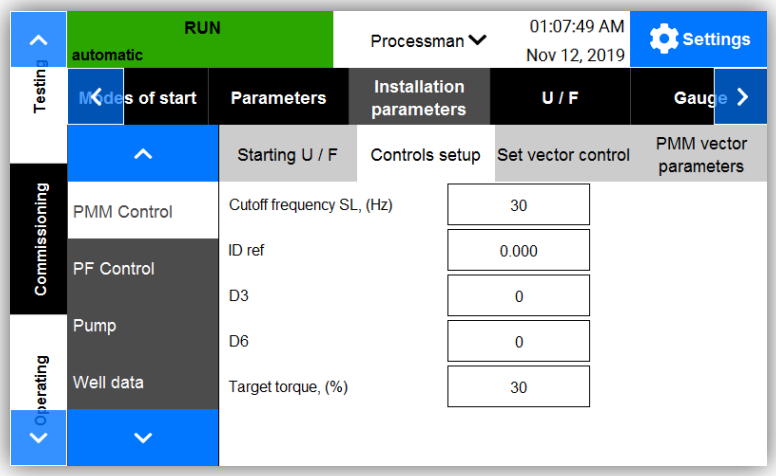
If the parameters «D-axis stator inductance, (H)», «Q-axis stator inductance, (H)», «Torque, (kg*m^2)» are unknown, they can be determined using the «Auto set» function.

Step by step instruction of «Auto set» mode is described in «Quickstart manual», in paragraph «Start up with permanent magnet motor» page 14.



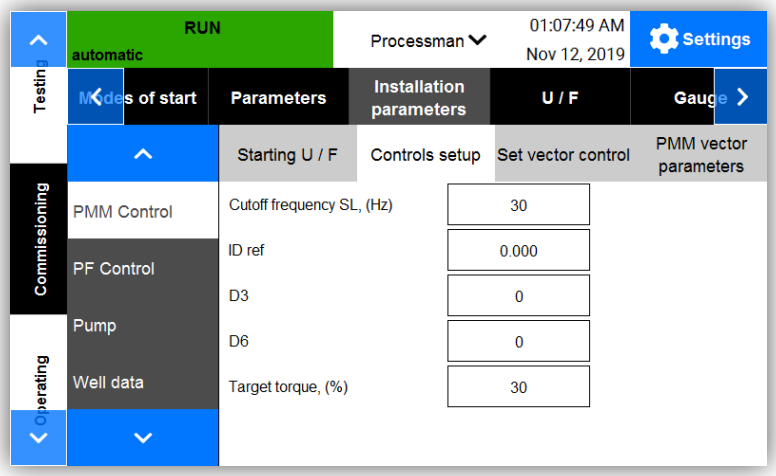
Starting «U/F» menu is designed for setting up U/F characteristics at initial stages of acceleration.

- Start frequency, (Hz) –initial frequency of Vector algorithm;
- Start voltage, (V) – initial voltage of VSD at «Start frequency»;
- Time start, (s) – starting time during which the VSD will maintain the initial frequency. Once Time start is over, the motor will accelerate further;
- Point 1 – the next point (after initial one) at which the motor will start accelerating further;
- Point 2 – the next point after «Point 1»;



«Control setup» menu is designed for vector's regulators adjusting.

- Cutoff frequency SL set to 30.
- Id ref set to 0;
- «D3», «D6» in depended with

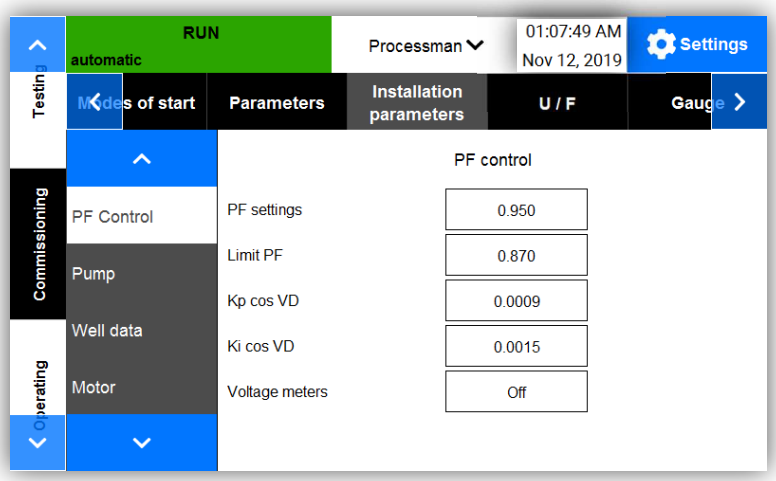


rated motor frequency: «D3» = 1000, «D6» = 200 for 60 Hz motor; «D3» = 400, «D6» = 10 for 200 Hz motor;

- «Target torque» = 15%.

Third – level menu «PF Control»

In case «Motor Type» set «PMM Cos» there is a 3rd menu which gives access to PMM cos algorithm configuration.



There are parameters in this menu:

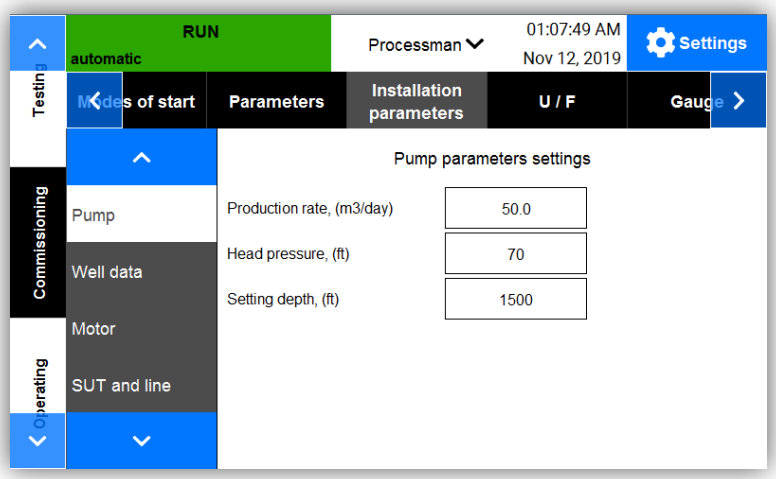
«PF settings» – is intended to set power factor setpoint which VSD will be maintain.

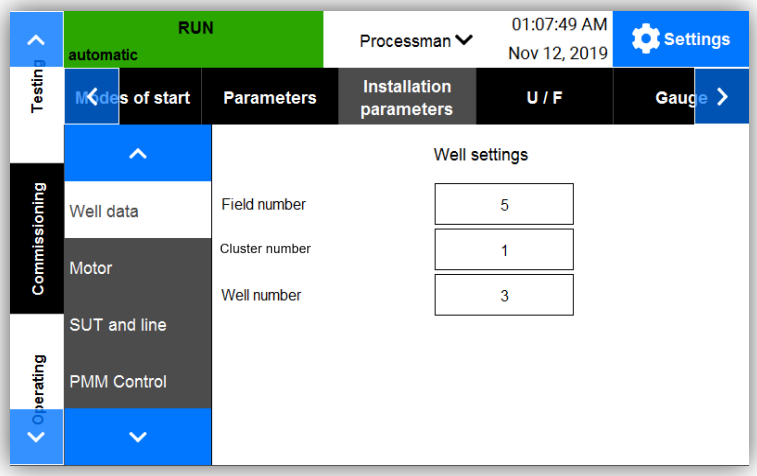
«Limit PF» – upper power factor limit.

«Kp cos VD» – proportional gain in PMM cos algorithm.

«Ki cos VD» – integral gain in PMM cos algorithm.

Third – level menu «Pump» and «Well data»





These menus offer to enter parameters of the pump and well.

Pump information:

- «Production rate» parameter — reference parameter to be set as per value specified in documentation supplied together with ESPU. This parameter is used for calculating step-up transformer recommended tap;
- «Head pressure» parameter — reference parameter to be set as per value specified in documentation supplied together with ESPU. This parameter is used for calculating step-up transformer recommended tap.

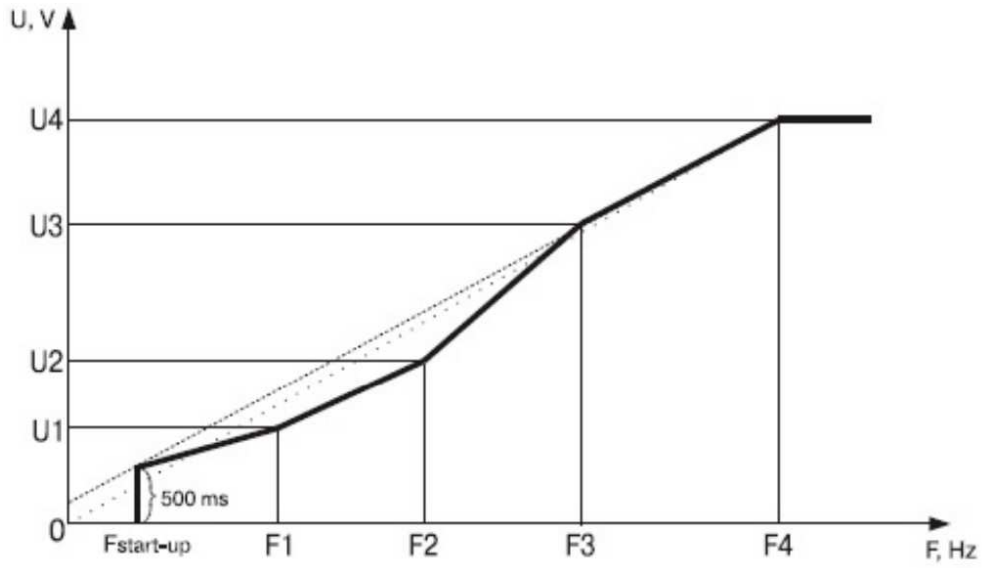
Well information:

- «Field number»;
- «Cluster number»;
- «Well number».

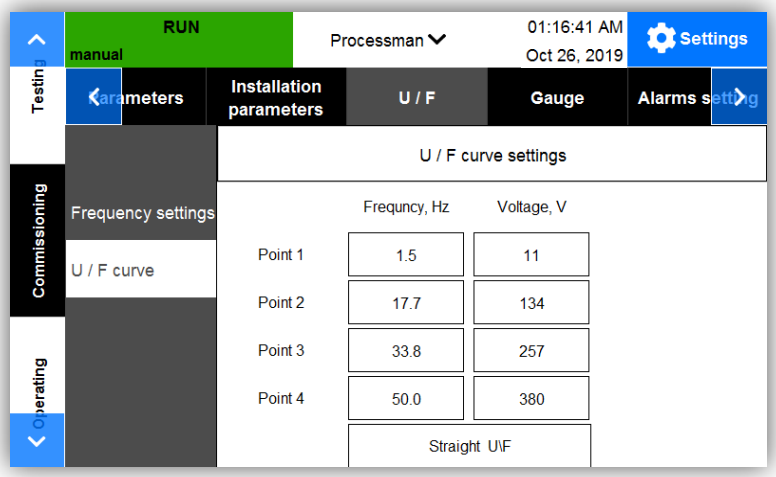
«U/F»

This second-level menu allows to defining ratio between VSD frequency and voltage if frequency is adjustable (U/F characteristic).

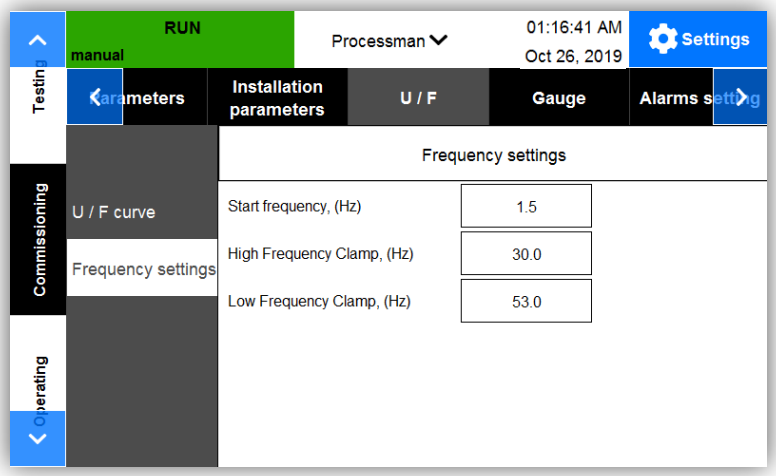
A graph depicting the shape of U/F characteristic



Second-level menu «U/F» comprises the following parameters:

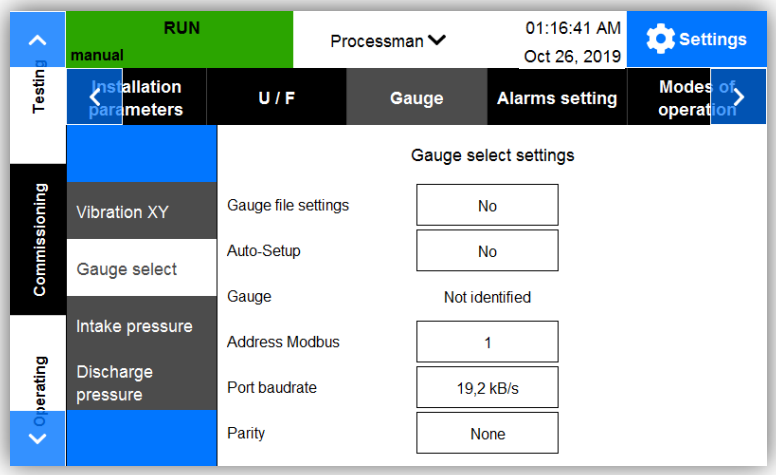


- «Start frequency» parameter — minimum output frequency generated by VSD;
- «Point X» parameter — defines value of frequency and voltage in corresponded points U/F characteristic;
- to the fourth breakpoint of U/F characteristic;
- «Low frequency clamp» parameter set minimal VSD output frequency.



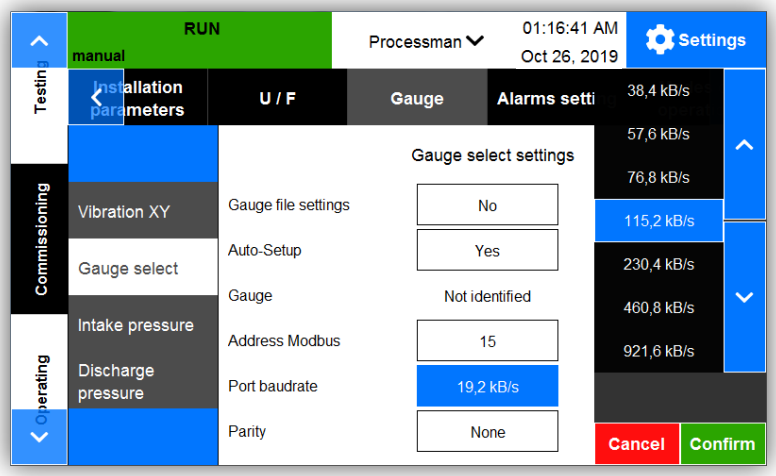
- «High frequency clamp » parameter set maximum VSD output frequency;
- «Straight U/F» parameter — rectify U/F. Only qualified personnel may be authorized to change U/F characteristic.

Gauge



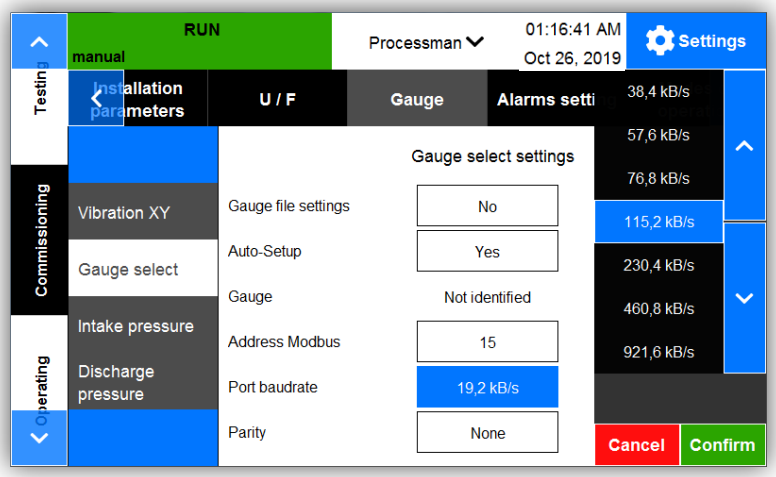
«Gauge» parameter indicates status of the data exchange between UMKA07 controller and telemetry unit through the digital data-exchange channel.

- «Identified» option indicates that the communication is established and information may be acquired from the telemetry sensor;
- Otherwise this parameter will be set to «Not identified».



Remember that the telemetry unit identification process may take up to 2 minutes.

«Address Modbus» parameter — representation and assignment of address for terrestrial telemetering unit connected. It is set according to the telemetry specification.



«Port baud rate» parameter defines the rate of data exchange between VSDC and downhole sensor. It is set according to the telemetry specification.

«Parity» parameter allows set parity bit according to downhole sensor specification.

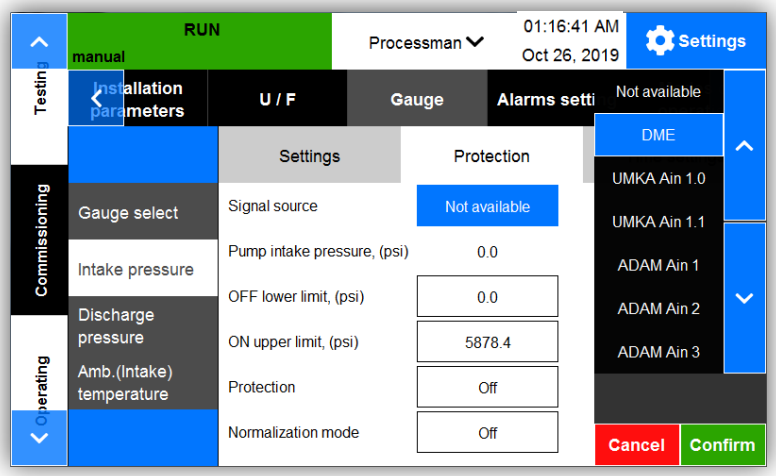
There are 9 telemetry parameters in UMKA07:

- «Intake pressure»;
- «Discharge pressure»;
- «Amp. (intake) temperature»;
- «Discharge temperature»;
- «Motor temperature»;
- «X Vibration»;
- «Y Vibration»;
- «Z Vibration»;
- «XY Vibration».

These parameters have similar settings below. The difference between settings is in the special physical sense of measuring the value. For example, switching off sets on the lower limit for intake pressure («OFF lower limit») and on the upper limit for motor temperature («OFF upper limit»).

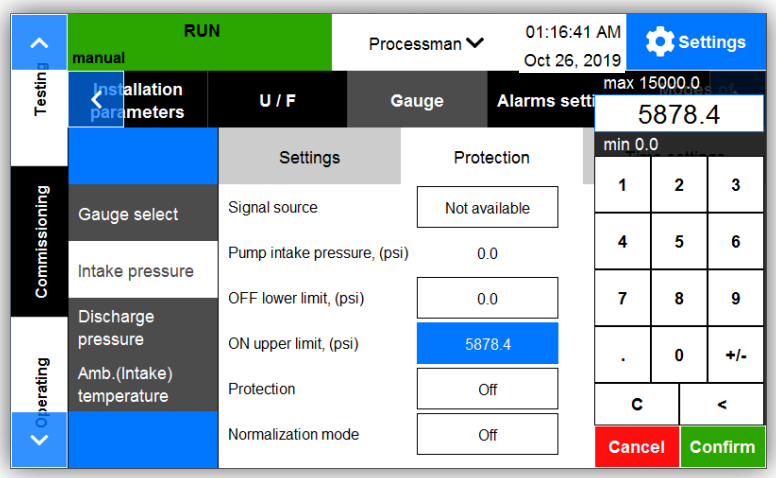
«Insulation, Pump intake pressure, pump discharge pressure, ambient (intake) temperature, discharge temperature, motor temperature, XY vibration, Z vibration» – displays current value telemetry's parameters in menu «protection» window.

In four-level menu «Protection» there are:

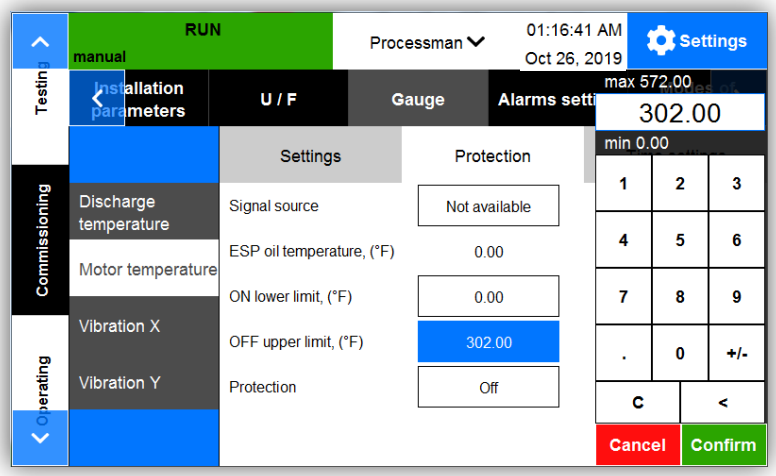


«Signal source» parameter – allows to set data source. UMKA07 can receive data from downhole measurement equipment (DME) or from analog inputs.

«ON (OFF) lower (upper) limit» – parameter is the limit of switching-on/off by the protection. VSD will be switched if the actual value of the parameter will be higher/lower than the value of this parameter



«OFF lower limit» parameter – lower limit VSD tripping. VSD will be tripped if actual value of the parameter is lower than the «OFF lower limit» parameter.

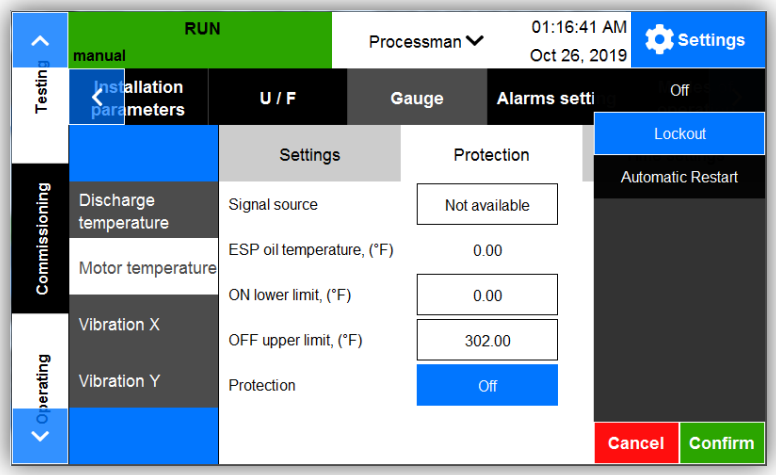


«ON upper limit» parameter – upper limit of Automatic restart triggering after protection has functioned. Thus, Automatic restart would not take place until current parameter value is lower than the «ON upper limit» parameter.

Manual start may be enabled only if the current value exceeds the «ON upper limit» parameter.

«OFF upper limit» – parameter is the upper limit of switching-off. VSD will be switched off if the actual value of the parameter will be higher than the value of this parameter.

«Protection» – parameter may be set to:

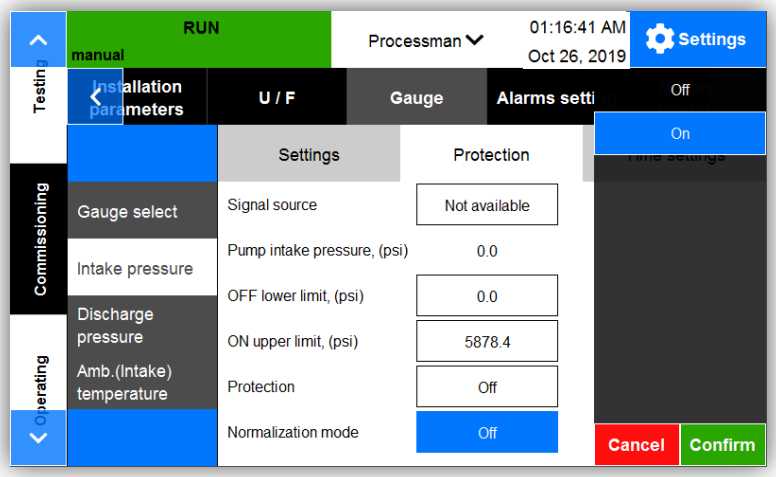


«Automatic restart» — parameter checkout is enabled. Automatic restart is possible;

«Off» — parameter checkout is disabled. Emergency values are ignored;

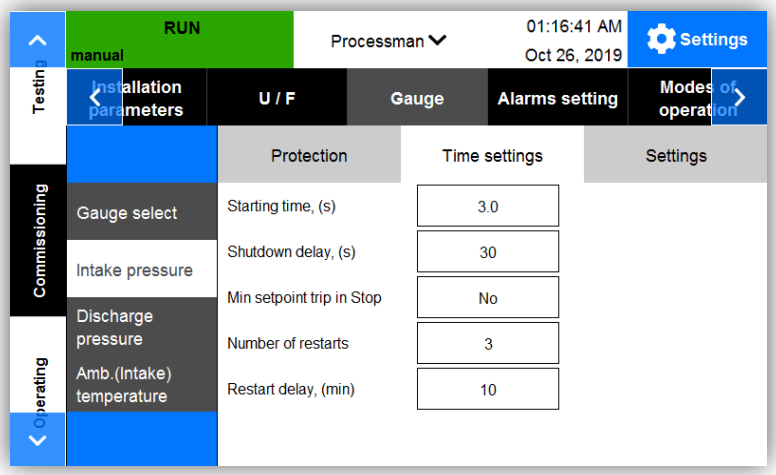
«Lockout» — parameter checkout is

enabled. Automatic restart is not possible.



«Normalization mode» – parameter enables startup depending on the pump suction pressure. If this parameter set to «ON» VSD will automatically restart if actual intake pressure value will be higher than «ON upper limit» parameter.

In four-level menu «Time settings» there are:



«Starting time» – protection operation delay at VSD starting.

«Shutdown delay» – delay time for VSD tripping caused by protection when actual value of the parameter goes beyond the «ON/OFF lower/upper limit».

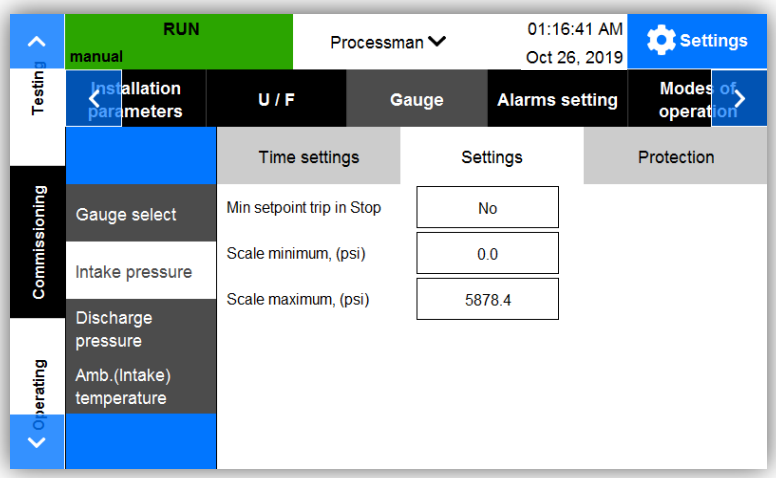
«Min setpoint trip in Stop» – parameter defines the protection tripping in STOP.

«Number of restarts» – number of automatic restarts after VSD is tripped by this protection.

«Restart delay» – automatic restart delay time after the

parameter has been restored.

In four-level menu «Settings» there are:



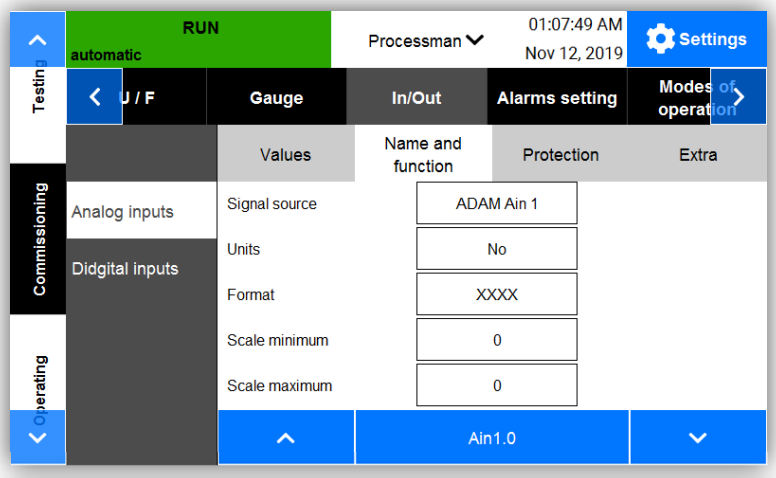
«Scale minimum» parameter — allow to set sensor minimum scale. This parameter is used for calibrating analog input, and it may take any value when digital input is used.

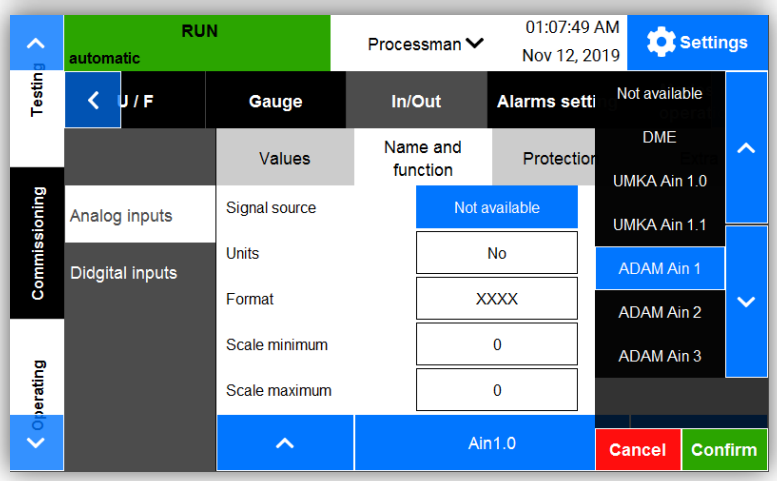
«Scale maximum» parameter — allow to set sensor maximum scale. This parameter is used for calibrating analog input, and it may take any value when digital input is used.

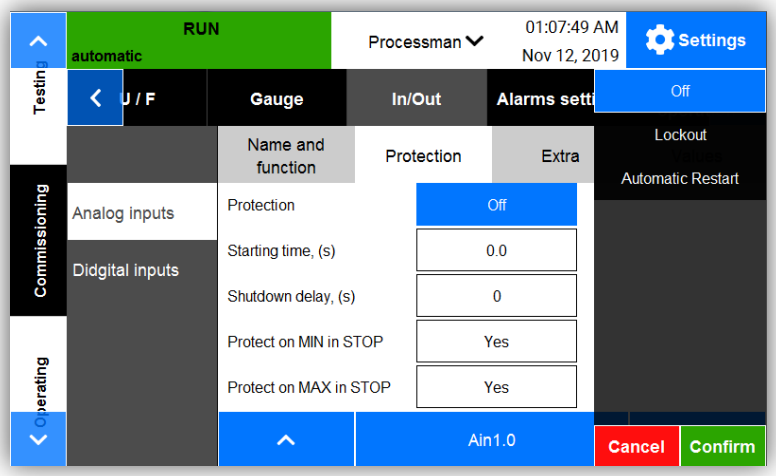
In/Out

This second level menu is intended for setting of digital and analog inputs and outputs of the VSD.

Analog inputs







Switching between the analog inputs is carried out by the buttons at the bottom of the screen.  .

«Signal source» – allows to choose the source of the selected analog input.

«Units» – allow to set the physical value of the measured parameter.

«Format» – allows to set the accuracy of the displayed data.

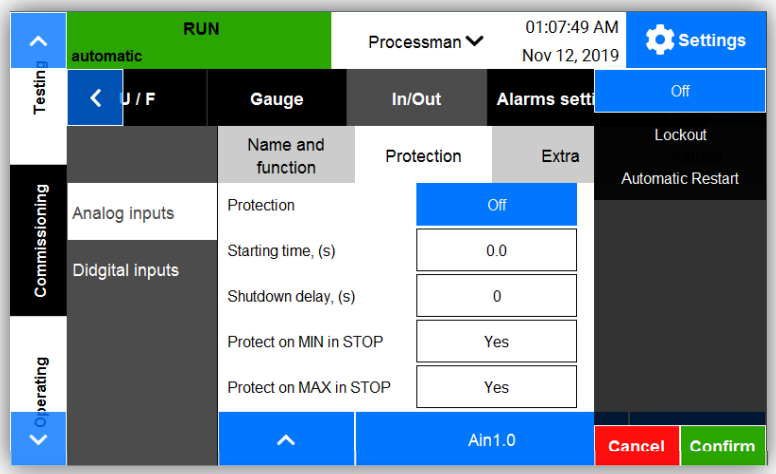
«Scale minimum» – is intended for setting the minimum sensor sensitivity.

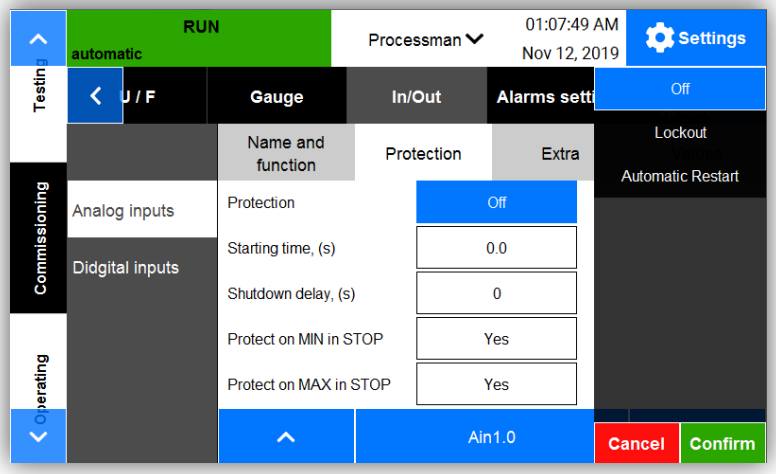
«Scale maximum» – is intended for setting the maximum sensor sensitivity.

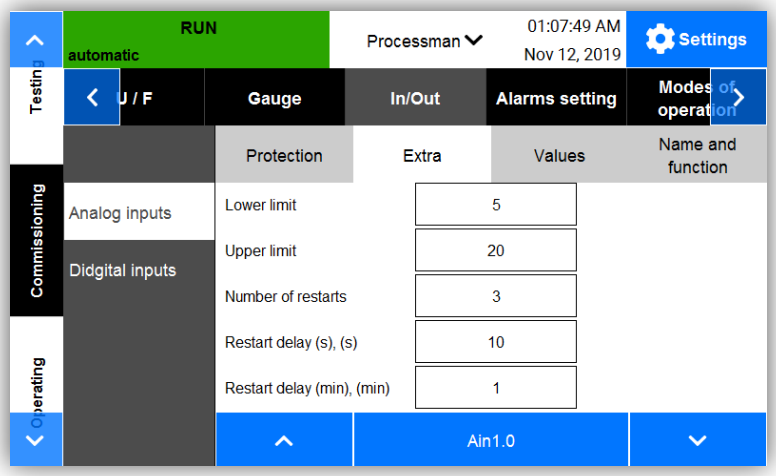
«Protection» – parameter may be set to:

«Automatic restart» — parameter checkout is enabled. Automatic restart is possible;

«Off» — parameter checkout is disabled.







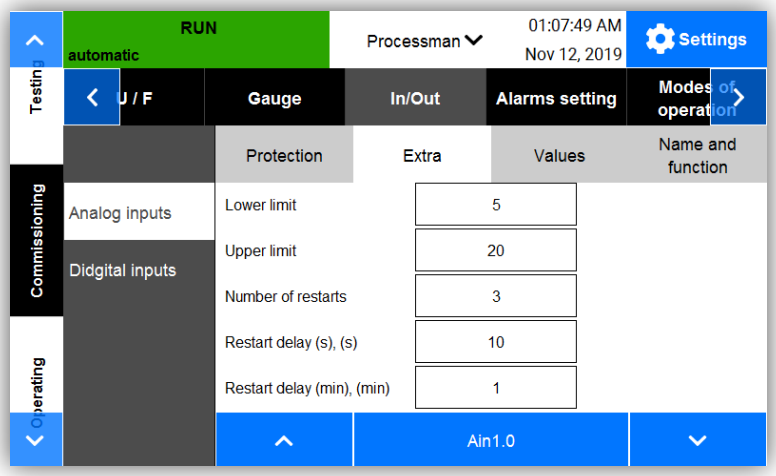
Emergency values are ignored;

«Lockout» — parameter checkout is enabled. Automatic restart is not possible.

«Starting time» – protection operation delay at VSD starting.«Shutdown delay» – delay time for VSD tripping caused by protection when actual value of the parameter goes beyond the «ON/OFF lower/upper limit».

«Protect on MIN in STOP» – if this parameter set to «Yes» VSD will be tripped in case «Current value of user Ain» less then «Lower limit».

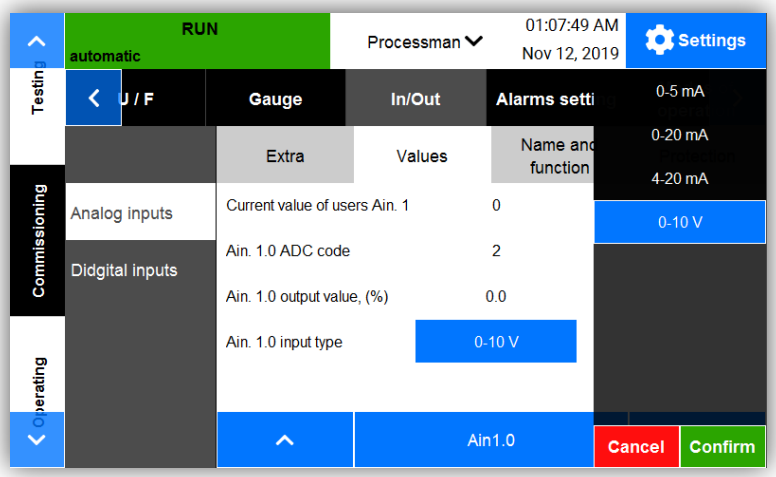
«Protect on MAX in STOP» if this parameter set to «Yes» VSD will be tripped in case «Current value of user Ain» more then «Upper limit».



«ON (OFF) lower (upper) limit» – parameter is the limit of switching-on/off by the protection. VSD will be switched if the actual value of the parameter will be higher/lower than the value of this parameter.

«Number of restarts» parameter — number of Automatic restarts after motor tripping by analog input protection.

«Restart delay» (min) – automatic restart delay time after the parameter has been restored in minutes.

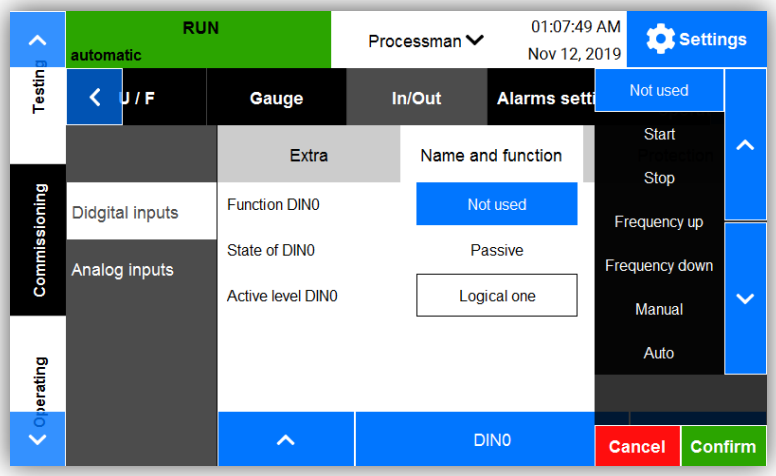


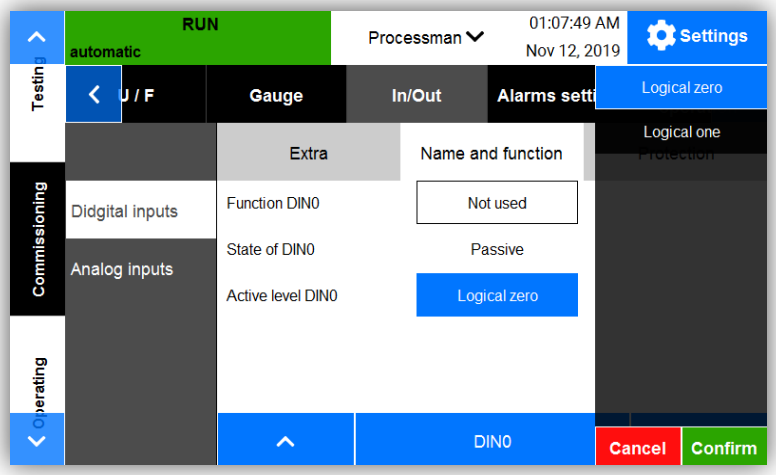
«Current value of users Ain. 1.0» – display actual Analog input 1.0 value.

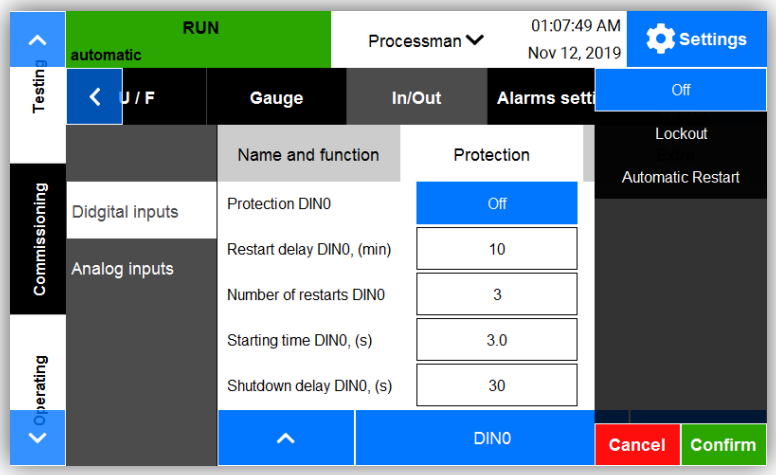
«Ain. 1.0 output value», (%) – displays actual Analog input 1.0 in percent's.

«Ain. 1.0 input type» – is intended to set Ain. 1.0 input type.

Digital inputs







«Function DIN» - allows to choose the VSD action that is performed if there's a signal the digital input.

«State of DIN» – display actual state of DIN:

- «passive» – at DIN applied 0...1 V;
- «active» – at DIN applied +10…+30 V DC.

«Active level DIN» – is intended to set DIN threshold:

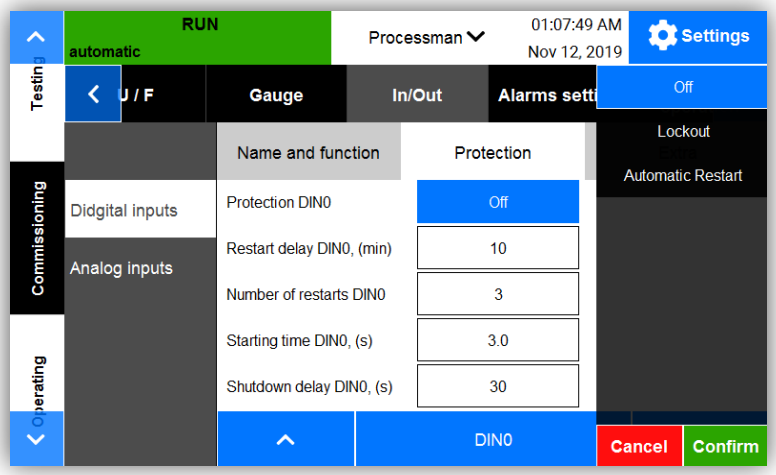
- «Logical zero» – at DIN applied 0...1 V;
- «Logical one» – at DIN applied+10...30 V DC.

«Protection» – parameter may be set to:

«Automatic restart» — parameter checkout is enabled. Automatic restart is possible;

«Off» — parameter checkout is disabled. Emergency values are ignored;

«Lockout» — parameter checkout is



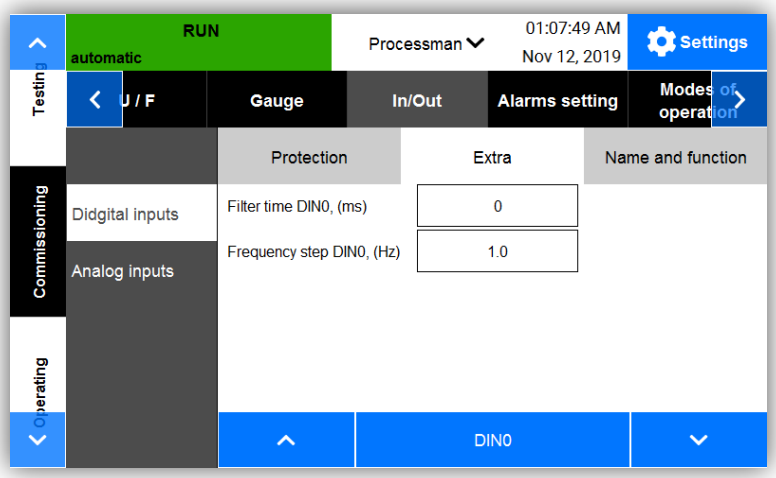
enabled. Automatic restart is not possible.

«Restart delay DIN» – automatic restart delay time after the parameter has been restored.

«Number of restarts» parameter — number of Automatic restarts after motor tripping by analog input protection.

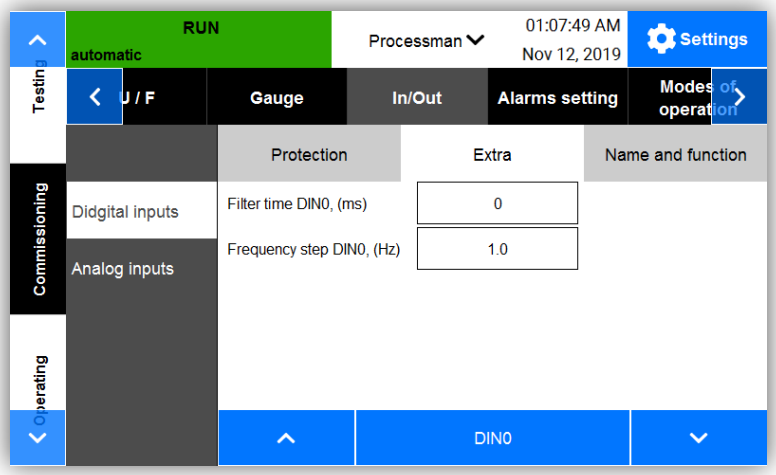
«Starting time» – protection operation delay at VSD starting.

«Shutdown delay» – delay time for VSD tripping caused by protection when actual value of the parameter goes beyond threshold value.



«Filter time DIN» - the delay, during which the signal does not change its value, then the VSD performs an action set in «Function DIN» parameter.

If the signal changes its value faster than the specified time runs out, then the signal is detected as a disturbance and VSD operation continues without changes.



«Frequency step DIN» – determines the step of increasing / decreasing the frequency when a signal is received at the digital input. This parameter is available only if «Frequency up» or «Frequency down» is selected in the «Function DIN» parameter.

Alarms setting

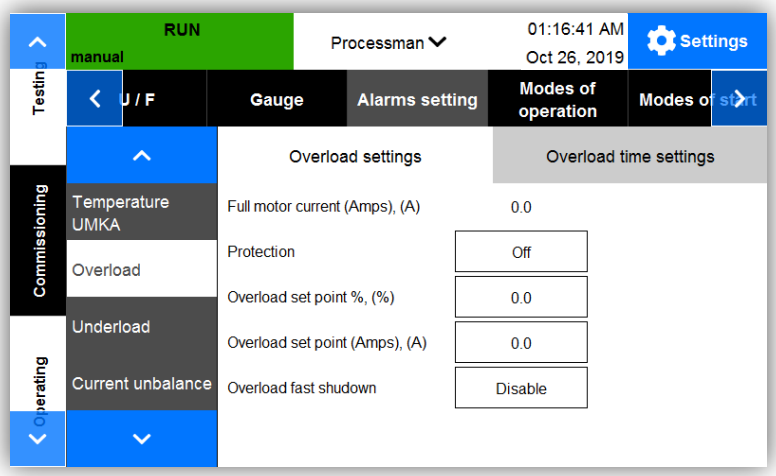
This first-level menu contains parameters defining operation algorithms of protections against inadmissible deviations of electric submersible motor & variable speed drive performance characteristics. Settings make it possible to debug automatic restart when VSD operates in automatic mode.

UMKA07 alarm list:

- overload;
- underload;
- current unbalance;
- insulation;
- frequency backspin;
- mains voltage;
- low frequency;
- voltage at DC bus;
- power switches overheating;
- overcurrent;
- power switches;
- doors;
- phase rotation;
- contact pressure gauge;
- communications;
- alarm STOP;
- temperature UMKA.

«Overload» protection

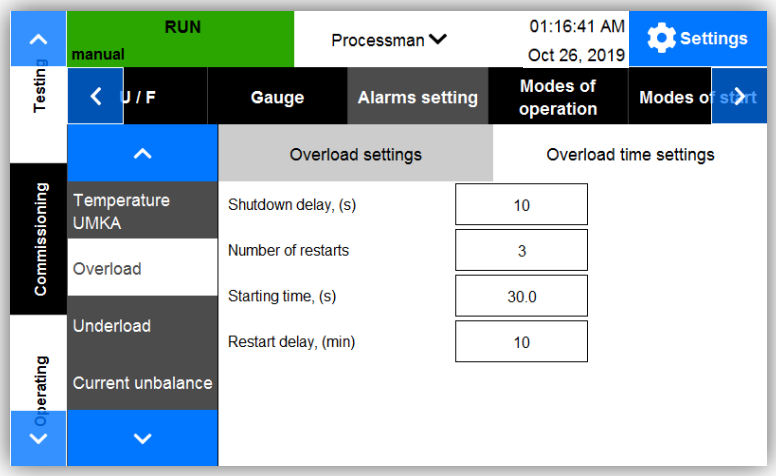
The protection is intended for tripping the electric motor. That's why values of «Motor nominal current» and «Tap Voltage (Volts)» («Commissioning» menu → «Installation parameters» menu → «Tap Voltage (Volts)» parameter) parameters shall be set in line with the submersible motor rated current to ensure proper functioning of the overload protection.



«Full motor current» parameter — indication of the motor current.

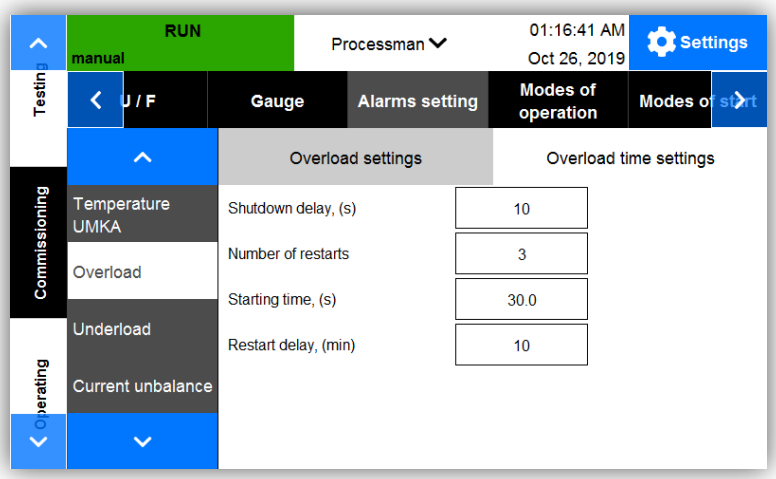
«Protection» parameter assigns one of three possible options of the protection operation:

- «Off» — protection disabled;
- «Lockout» — after the motor has been tripped by a protection it cannot be switched on again until it is started by operator or through VSD;
- «Automatic restart» — after the motor has been tripped by a protection it can be switched on again in a time set by «Restart delay» parameter.



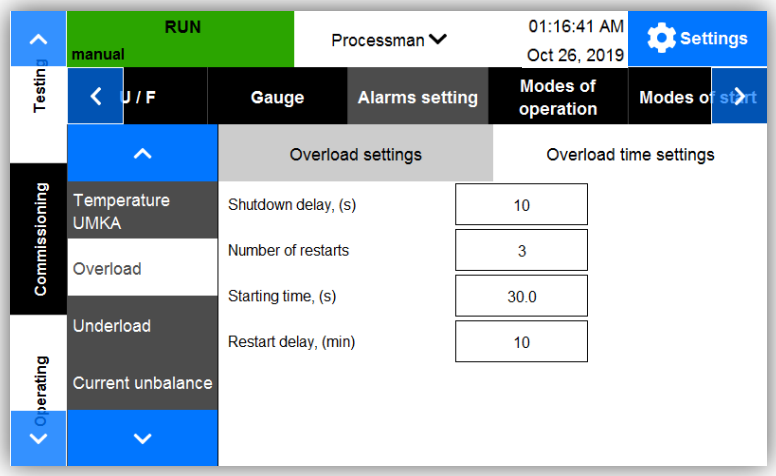
«Overload set value %» and «Overload setpoint (Amps)» parameter — set value of overload current as a percentage or the rated motor current parameter («Commissioning» menu → «Installation parameters» menu → «Motor nominal current» parameter) upon reaching or exceeding of which overload protection operates.

«Overload fast shutdown» parameter enables the mode of fast overload tripping.



Sequence of operations for enabling the mode of fast overload tripping:

- «Overload fast shutdown» parameter shall be set to «Permit»;
- Insulation resistance level control is on: «Protection» parameter shall be set to «Off».



«Shutdown delay» parameter — delay time of motor tripping caused by overload protection when the VSD output current exceeds the value set by «Motor nominal current» parameter. Tripping time depends on the rate of current rise: the higher is the VSD output current as compared with that set by «Motor nominal current» parameter, the faster tripping will take place.

$$T_{shutdown\ delay} = Shutdown\ delay * \frac{I^2_{motor\ nominal\ current}}{I^2_{motor\ current}}$$

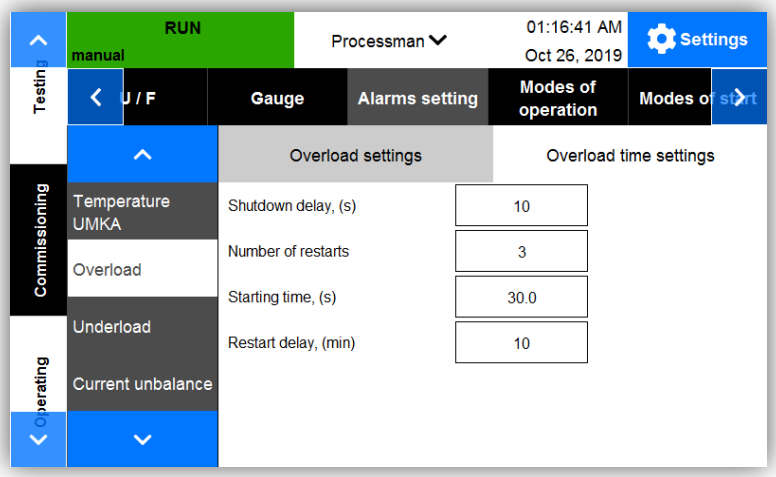
where:

$T_{shutdown\ delay}$ – the time after which the VSD will stop operating due to «Overload» instance;

$Shutdown\ delay$ – «shutdown delay» parameter in second level «Overload» menu;

$I^2_{motor\ nominal\ current}$ – «Motor nominal current» parameter in second level menu «Installation parameters»;

$I^2_{motor\ current}$ – actual motor current value. Also, this parameter displays in UMKA07 as «Full motor current (Amps)» parameter in menu «Parameters».



«Number of restarts» parameter — number of Automatic restarts after motor tripping occurs by overload protection.

«Starting time» - this parameter sets a time bracket for protection being temporary disabled from the

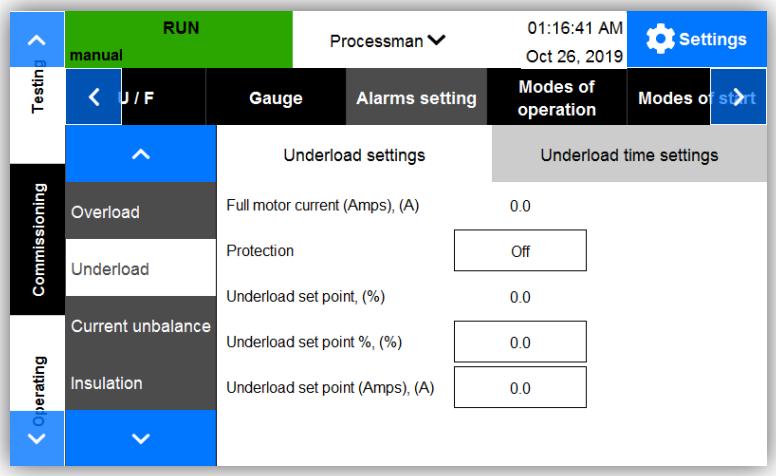
moment the motor starts running.

«Restart delay» parameter — delay time to Automatic restart after motor tripping by overload protection.

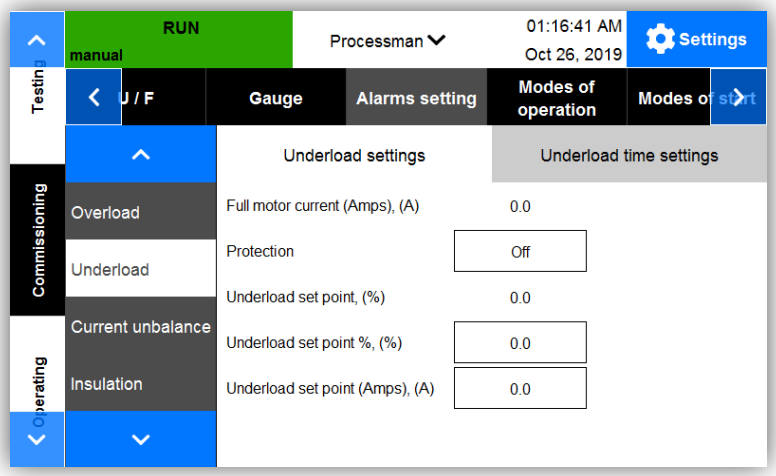
If this protection is active the appropriate message is displayed («Overload»).

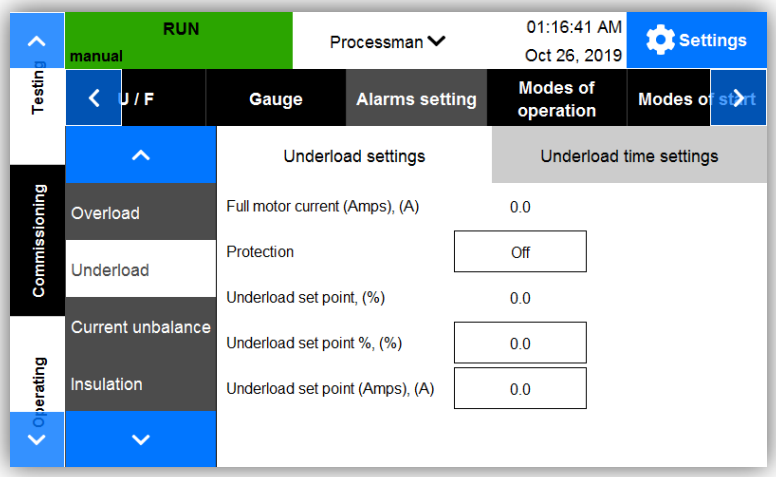
«Underload» protection

This protection allows stopping the VSD at motor underload.

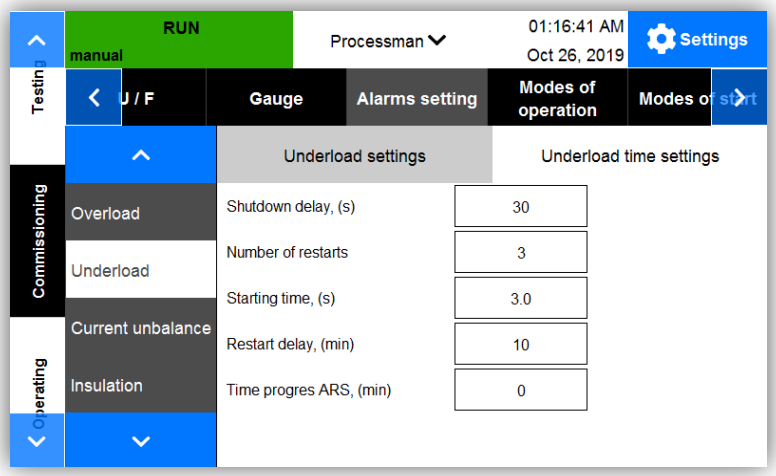


- «Full motor current» parameter — indication of the motor current.
- «Protection» parameter assigns one of three possible options of the protection operation:
- «Off» — protection disabled;





- «Lockout» — after the motor has been tripped by a protection it cannot be switched on again until it is started by operator or through the VSD;
- «Automatic restart» — after the motor has been tripped by a protection it can be switched on again within a time set by «Restart delay» parameter;
- «Underload set value %» and «Underload setpoint (Amps)» parameter — set value of underload current as a percentage or the rated motor current parameter («Commissioning» menu → «Installation parameters» menu → «Motor nominal current» parameter) upon reaching or lowering of which underload protection operates.

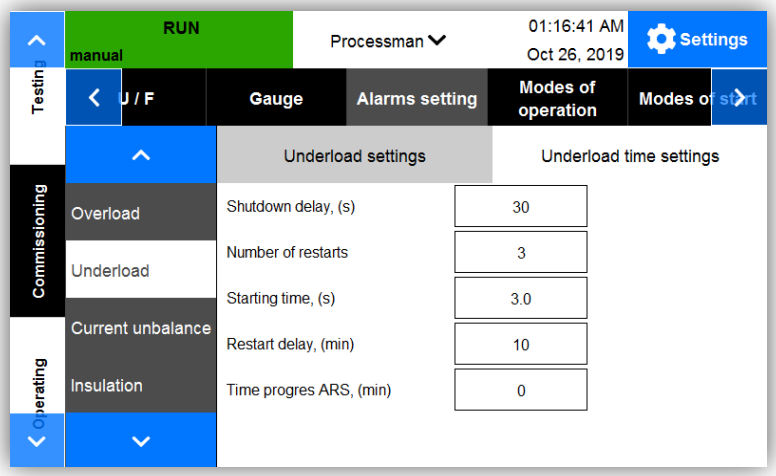


If programmed frequency change mode «Program F» («Commissioning» menu → Modes of operation» menu → «Program F» menu) enabled there is «Underload set point» parameter in this menu by which Underload protections operates in «Program F» mode.

«Shutdown delay» parameter — delay time of motor tripping caused by underload protection.

«Number of restarts» parameter — number of Automatic restarts after motor tripping by underload protection.

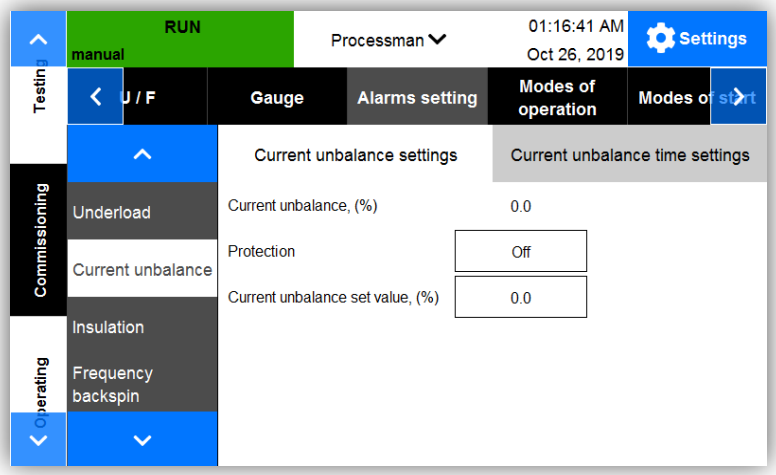
«Starting time» - this parameter sets a time bracket for protection being temporary disabled from the moment the motor starts running.



«Restart delay» parameter — delay time to Automatic restart after motor tripping by overload protection.

«Time Progress ARS» parameter represents time delta of the Automatic restart progressive delay. This time delta sum up each motor trip to «Restart delay».

«Current unbalance» protection



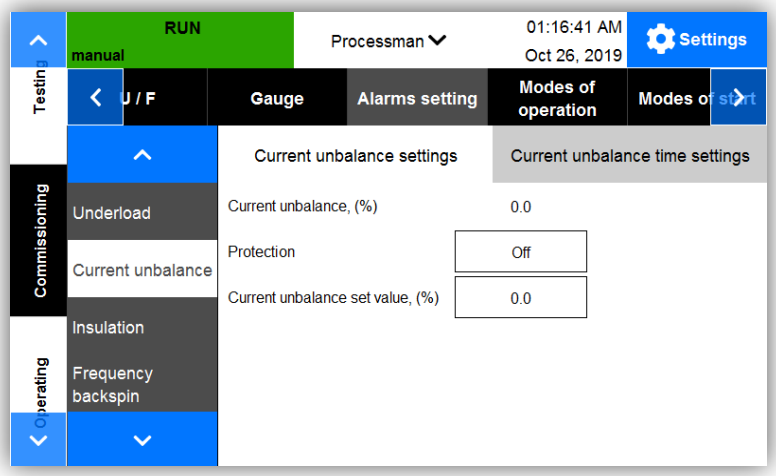
«Current unbalance» parameter — indication of the VSD actual current unbalance.

$$Current\ unbalance\ = \frac{(I_{VSD\ max}\ -\ I_{VSD\ min})}{I_{VSD\ average}} * 100\%$$

where:

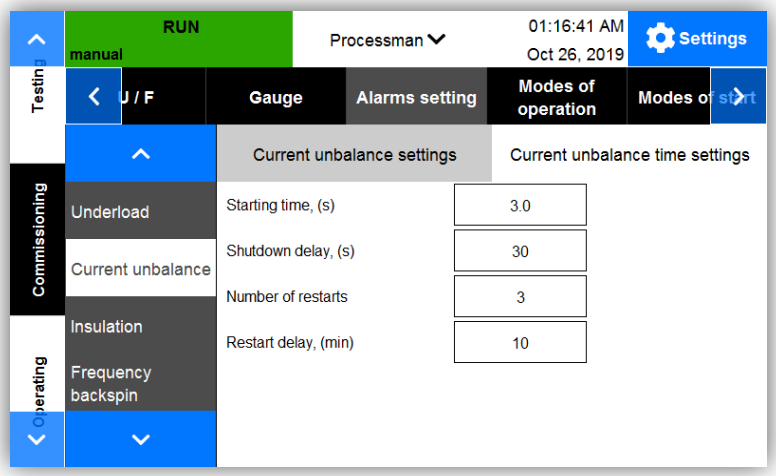
$I_{VSD\ max}$ and $I_{VSD\ min}$ – actual VSD maximum and minimum output currents;

$I_{VSD\ average}$ – average value between VSD output currents at phase U, phase V, phase W.



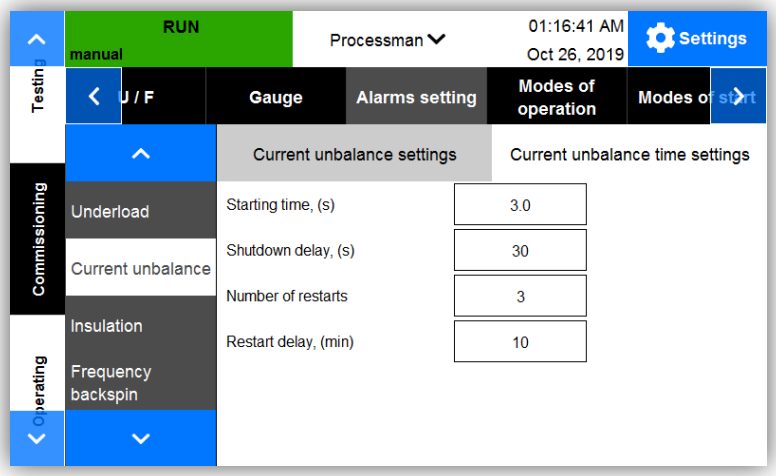
«Protection» parameter assigns one of three possible options of the protection operation:

- «Off» — protection disabled;
- «Lockout» — after the motor has been tripped by a protection it cannot be switched on again until it is started by operator or through VSD;
- «Automatic restart» — after the motor has been tripped by a protection it can be switched on again in a time set by «Restart delay» parameter.



«Cur. unbal. set value» parameter defines the VSD maximum allowable current imbalance in percentage terms. If such an imbalance exceeds the preset value the VSD will be tripped.

«Starting time» - this parameter sets a time bracket for protection being temporary disabled from the moment the motor starts running.



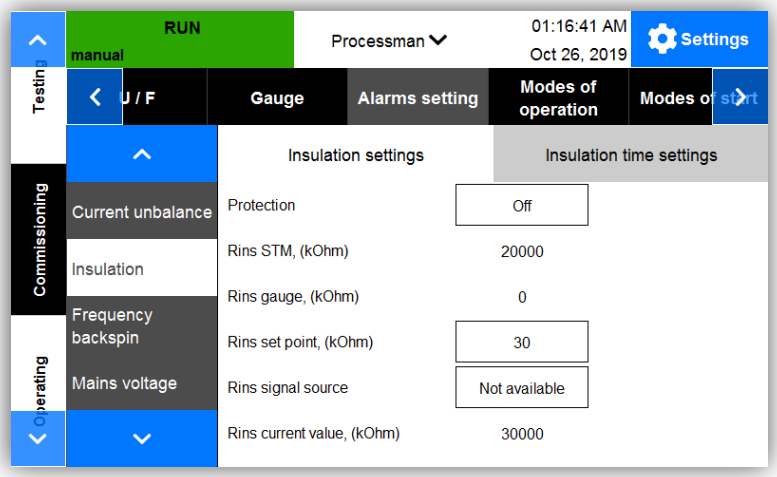
«Shutdown delay» parameter — delay time of motor tripping caused by current unbalance.

«Number of restarts» parameter — number of Automatic restarts after motor tripping by current unbalance protection.

«Restart delay» parameter — delay time to Automatic restart after motor tripping by current unbalance protection.

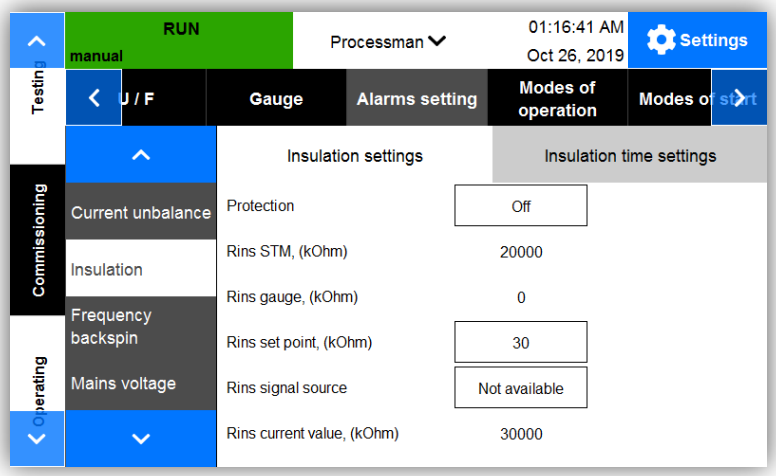
«Insulation» protection

This menu is designed to configure the operation of the VSD when detecting a decrease in the insulation resistance of a submersible motor during its operation.



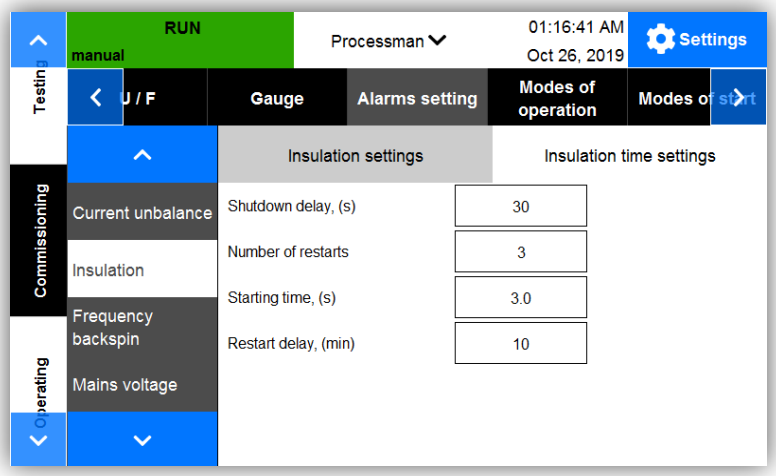
«Protection» parameter assigns one of three possible options of the protection operation:

- «Off» — protection disabled;
- «Lockout» — after the motor has been tripped by a protection it cannot be switched on again until it is started by operator or through VSD;



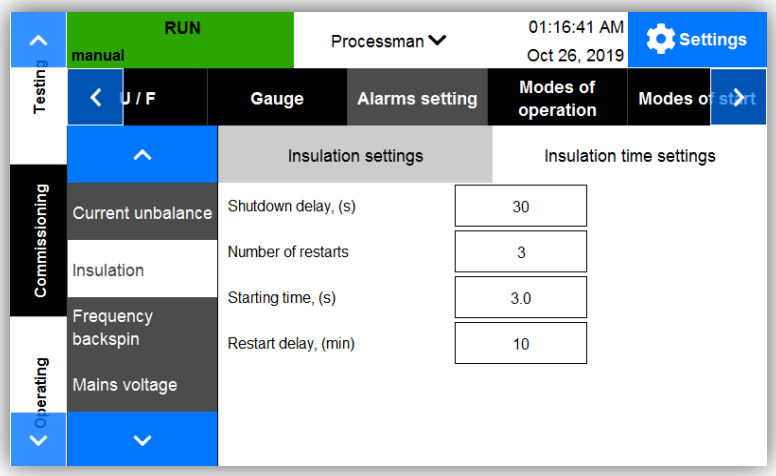
- «Automatic restart» — after the motor has been tripped by a protection it can be switched on again in a time set by «Restart delay» parameter.

«Rins set point» parameter — sets value of the insulation resistance. Motor will be shut down if resistance value is lower than «Rins set point» value (Automatic restart is possible if «Protection» parameter set to «Automatic restart»).



«Rins signal source» – is intended to choose insulation resistance measurement channel:

- «Controller» insulation resistance is measured by UMKA07 if downhole equipment is not connected;
- «DME» Insulation resistance by downhole measurement equipment.



«Rins current value» – displays insulation resistance current value.

«Shutdown delay».

«OFF time» parameter — delay of shut down after «Insulation resistance» protection activation.

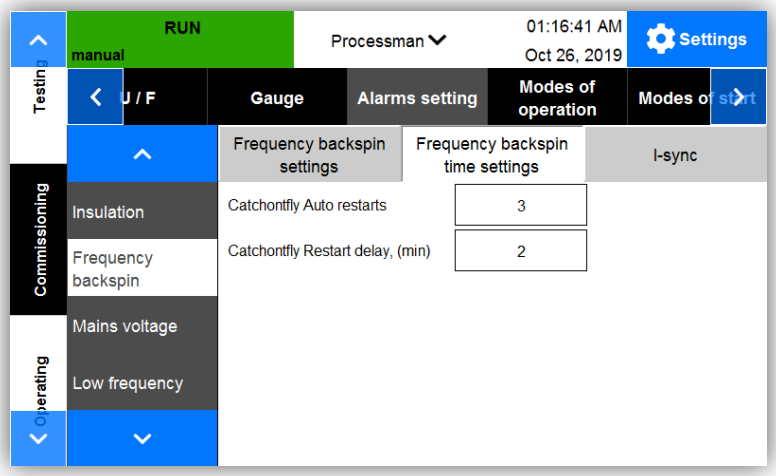
«Number of restarts» parameter — number of automatic restarts after «Insulation resistance» protection activation.

«Starting time» parameter — delay of insulation resistance control after the start of VSD.

«Restart delay» parameter — delay of automatic restart after «Insulation resistance» protection activation.

«Frequency backspin» protection

Third-level menu «Frequency backspin settings» allows to setting the motor start-up at backspin rotation, backspin rotation protection and catch-on-the-fly mode. Backspin rotation is identified when the motor is on. Backspin rotation appears during the motor reverse rotation under the impact of liquid flowing through the pump.



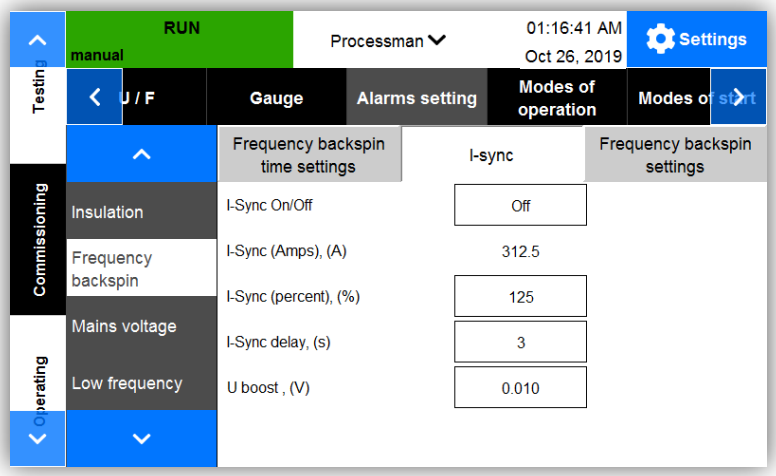
Three modes of operation are available in case of turbine rotation:

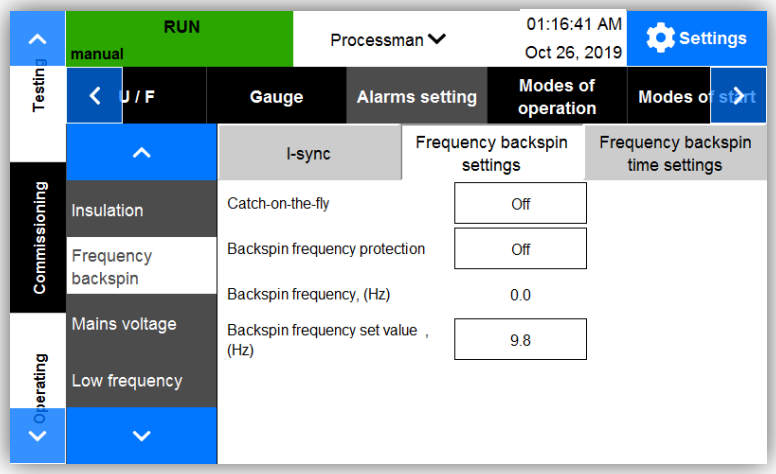
1. Motor protection against starting in case of backspin rotation (defined by «Backspin frequency protection» parameter). VSD doesn't starts-up if frequency backspin higher than user set point («Backspin frequency set value» parameter).
2. Motor «catch-on-the-fly» in case of backspin rotation. «Catch-on-the-fly» algorithm is based on the principle of current control (starting current limitation) by changing the Variable Speed Drive output frequency. Motor start-up in the «catch-on-the-fly» mode is performed if « Catch-on-the-fly » parameter is set to «On» and the motor startup mode — to «Soft». «Catch-on-the-fly» mode is assumed to be completed successfully if the Variable Speed Drive has reached the reference frequency (its value is defined by «Frequency setting»).
3. I-sync in this operation mode VSD starting with output current limit. When current grow up upper the limit setpoint VSD reduce the output frequency.

- «I-sync» – allows enabling or disabling the current limiting mode in the VSD.
- «I-sync, Amps» – motor current limit setting in amperes.

- «I-sync, setpoint» – motor current limit setting as a percentage of the rated motor current set by the «Motor nominal Current (Amps)» parameter in the «Installation parameters» menu.
- «I-sync delay» – this parameter allows setting the operating time current limit at start.
  - «U boost, V» parameter – sets the coefficient value of the controller current limitation at start-up.

Third-level menu «Frequency backspin settings» comprises the following parameters:

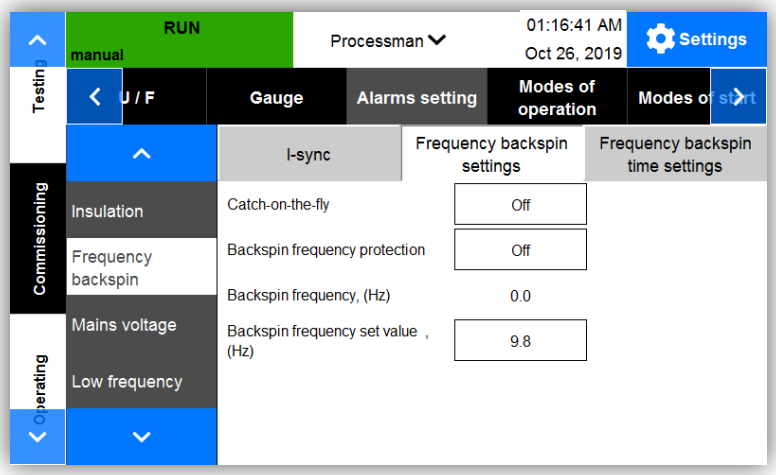




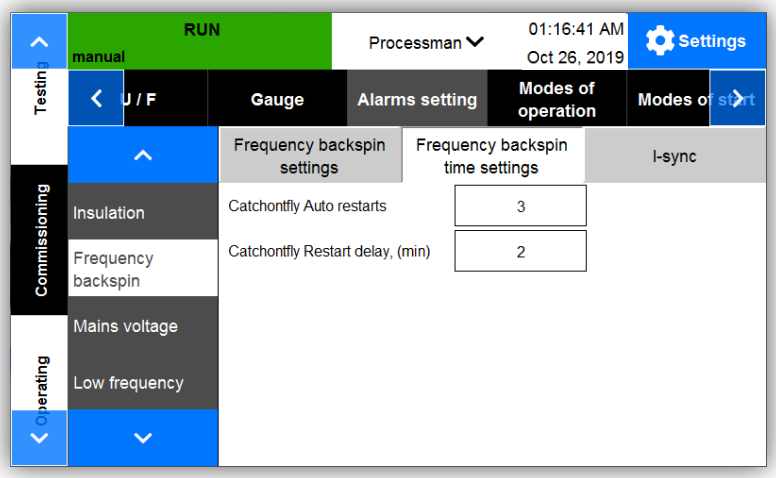
«Catch-on-the fly» – allows permitting or disabling this mode. If «Catch-on-the fly» mode enables, «Backspin frequency protection» is OFF.

«Backspin frequency protection» – allows permitting or disabling this mode. If «Backspin frequency protection» mode enables, «Catch-on-the fly» is OFF.

«Backspin frequency» parameter indicates the motor backspin rotation frequency.



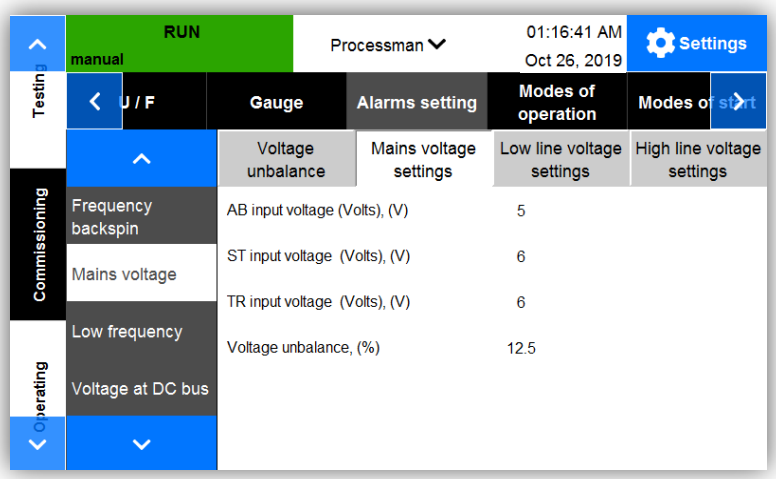
«Backspin frequency set value» parameter defines a value of the backspin rotation frequency exceedance which results in impossibility of the Variable Speed Drive start-up if a backspin rotation takes place. Too high value of this setting may cause the VSD/motor overcurrent/overload.



«Catch-on-the fly Auto restarts» parameter – number of automatic restarts after VSD has been tripped by backspin rotation protection.

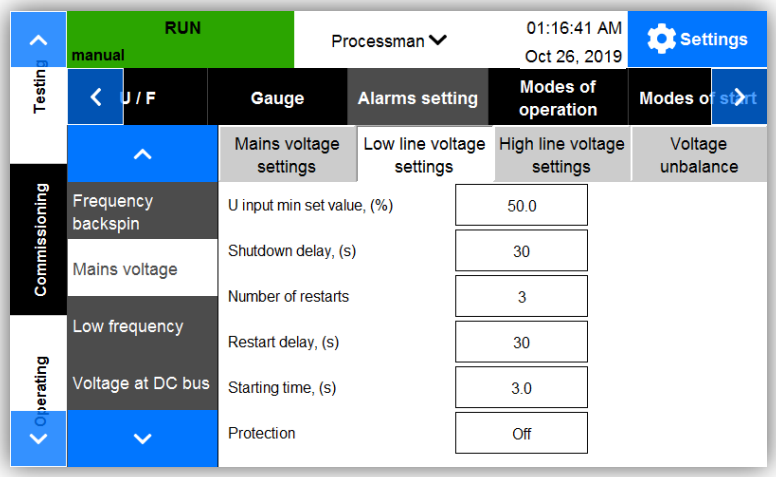
«Catch-on-the fly Restart delay» parameter — automatic restarts delay after an attempt to perform «catch on- the-fly» start. If this protection operates, an appropriate message («Backspin») shall appear on the controller display.

Mains voltage



Mains voltage menu consists of below sub menus:

- «Mains voltage setting» – displays current line voltages and voltage unbalance;
- «Low line voltage settings» – allows to set low line threshold setpoint and protections time;
- «High line voltage settings» – allows to set high line threshold setpoint and protections time;



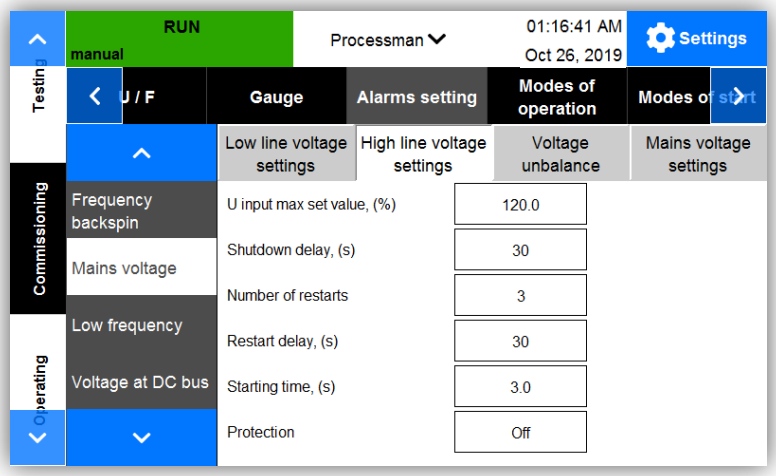
- «Voltage unbalance» –sets input voltage unbalance and protections time.

«ST input voltage» parameter — actual value of line voltage between phases R and S (A and B).

«TR input voltage» parameter — actual value of line voltage between phases S and T (B and C).

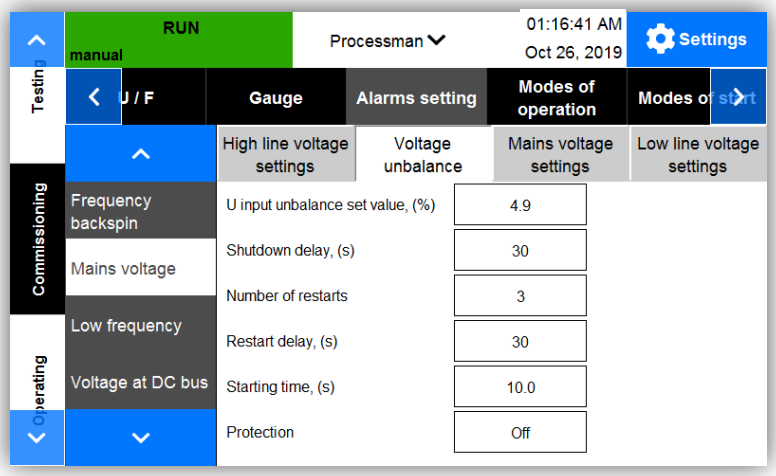
«RS input voltage» parameter — actual value of line voltage between phases T and R (C and A).

«Voltage unbalance» parameter — indication of input voltage actual unbalance.



«U input min set value» parameter defines minimum acceptable voltage of the supply line. If the supply line voltage drops below the preset value, VSD will trip.

«U input max set value» parameter defines a maximum allowable voltage in the supply line. If this value exceeds, VSD will trip.

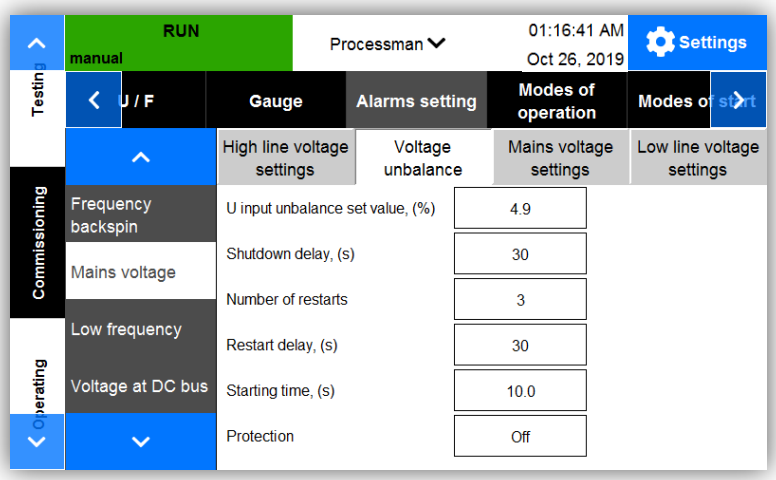


«U input unbalance set value» parameter defines allowable voltage unbalance in the supply line. If this value exceeds, VSD will trip.

«Shutdown delay» parameter — delay time for operation in voltage protections.

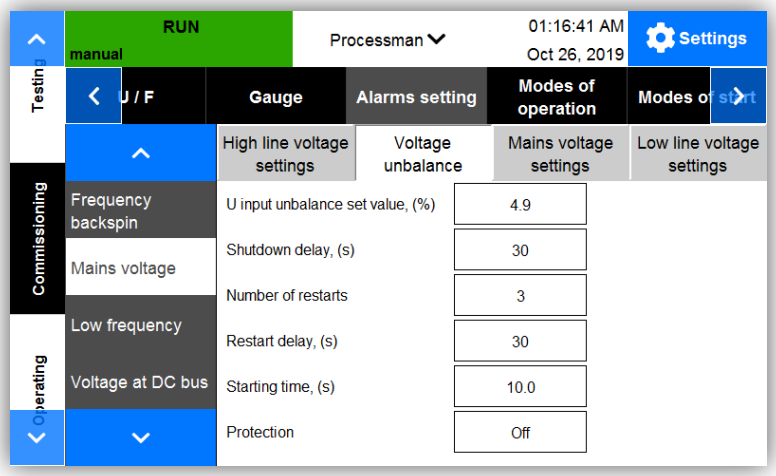
«Number of restarts» parameter — number of Automatic restarts after VSD tripping by supply line voltage protection.

«Restart delay» parameter —Automatic restart time after operation of the input voltage protections.



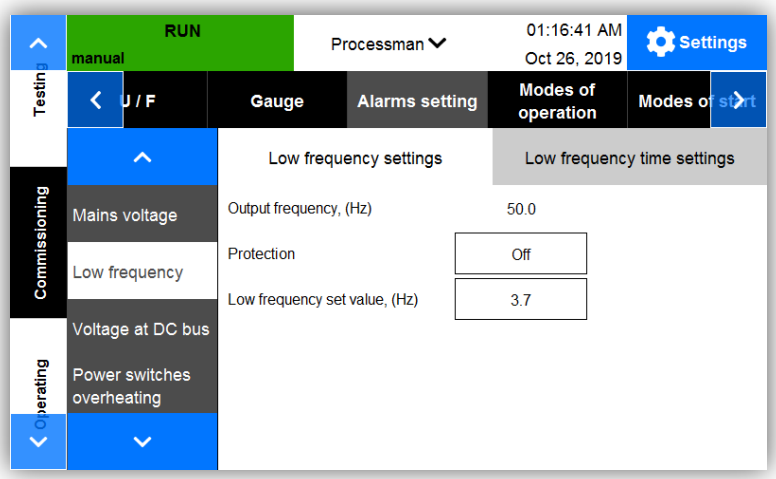
«Starting time» - this parameter sets a time bracket for protection being temporary disabled from the moment the motor starts running.
«Protection» parameter assigns one of three possible options of the protection operation:

- «Off» — protection is disabled;



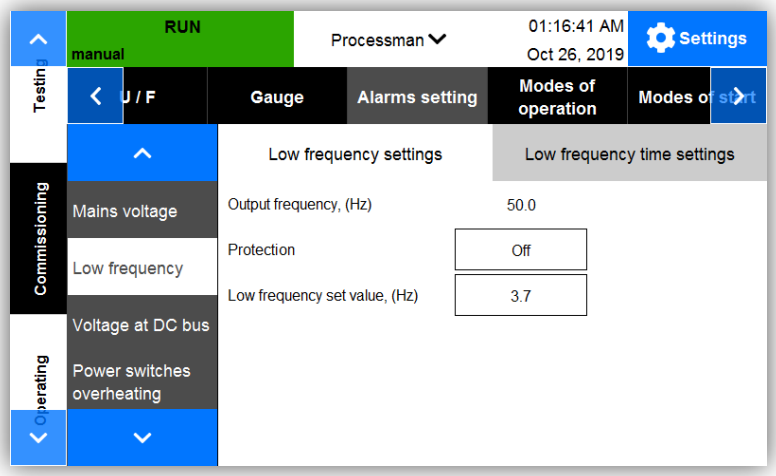
- «Lockout» — after the motor has been tripped by a protection it cannot be switched on again until it is started by operator or through VSD;
- «Automatic restart» — after the motor has been tripped by a protection it can be switched on again in a time set by «Restart delay» parameter.

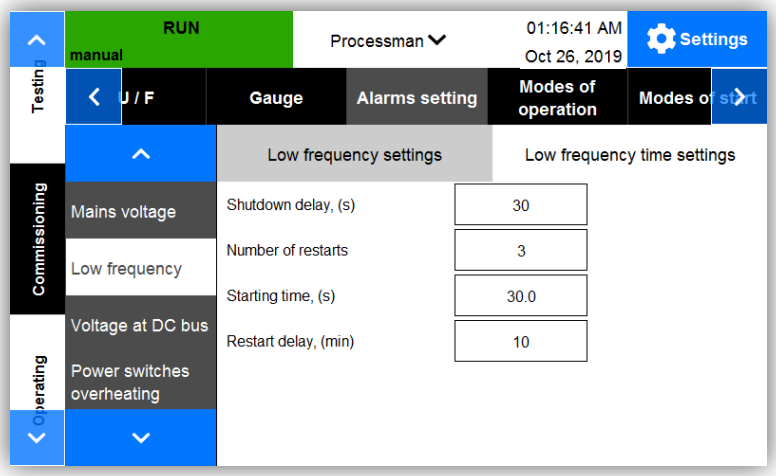
«Low frequency» protection



«Output frequency» parameter — indication of the VSD output frequency.

- «Protection» parameter assigns one of three possible options of the protection operation:
- «Off» — protection is disabled;
- «Lockout» — after the motor has been tripped by a protection it cannot be switched on again until it is started by operator or through VSD;

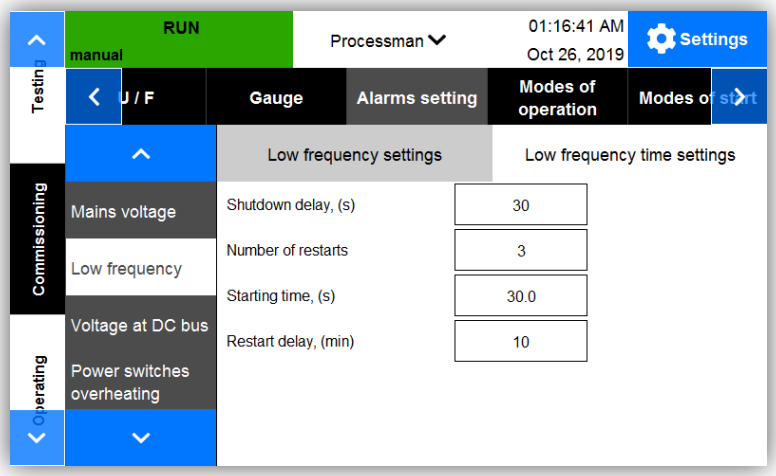




- «Automatic restart» — after the motor has been tripped by a protection it can be switched on again in a time set by «Restart delay» parameter.

«Low frequency set value» parameter — VSD minimum acceptable operating frequency. If the VSD output frequency is equal to or lower than this set value as a result of the pressure/current controller (regulator) operation the motor will be tripped and an appropriate message («MinFreq») will appear on the controller display. If one of the controllers (regulators) is selected as a source for setting output frequency, such a controller will start running only if the VSD output frequency exceeds the preset value.

«Shutdown delay» parameter — delay time for ESM tripping by low-frequency protection.

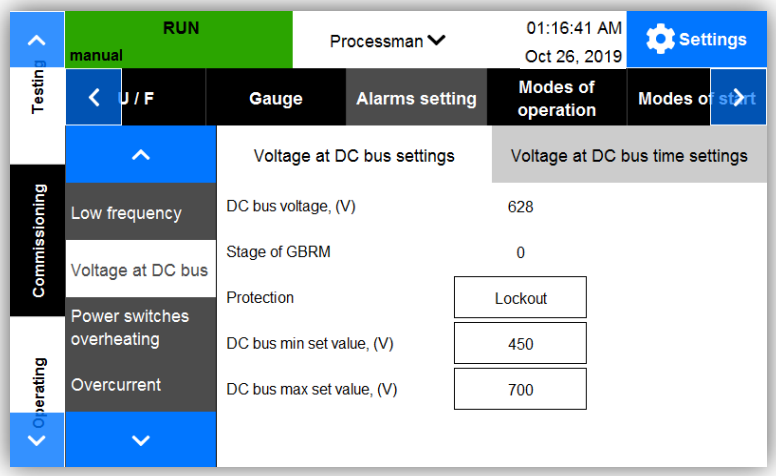


«Number of restarts» parameter — number of Automatic restarts after ESM tripping by low frequency protection.

«Starting time» - this parameter sets a time bracket for protection being temporary disabled from the moment the motor starts running. The parameter value shall not be less than the time required for the motor reaching its rated speed.

«Restart delay» parameter — delay time to Automatic restart after VSD has been tripped by low-frequency protection.

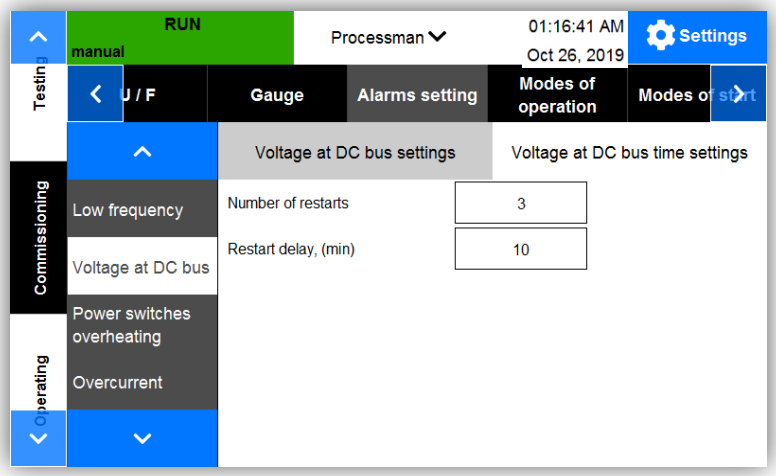
«Voltage at DC bus» protection



«DC bus voltage» parameter — indication of the VSD DC-link voltage.

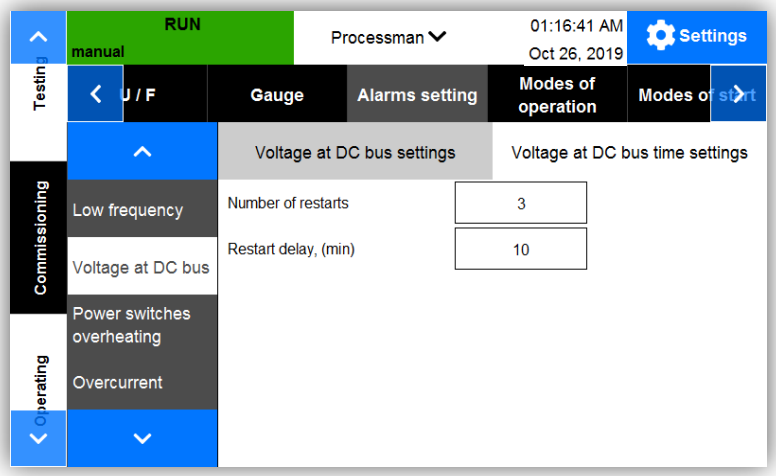
«Protection» parameter assigns one of three possible options of the protection operation:

- «Off» — protection is disabled;



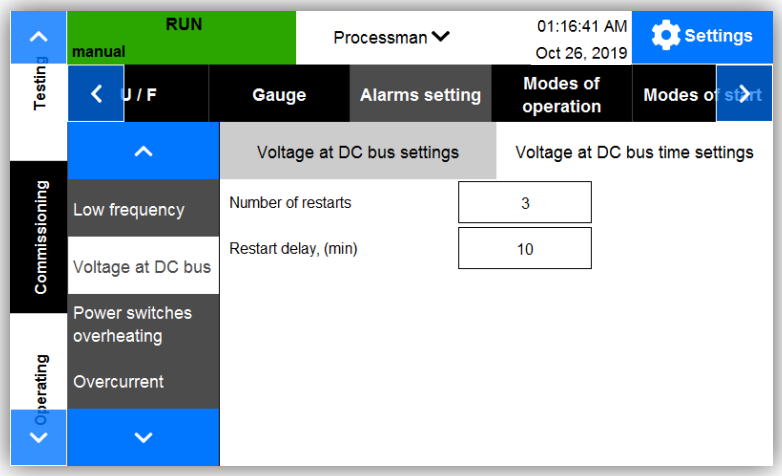
- «Lockout» — after the motor has been tripped by a protection it cannot be switched on again until it is started by operator or through VSD;
- «Automatic restart» — after the motor has been tripped by a protection it can be switched on again in a time set by «Restart delay» parameter.

«DC bus min value» parameter defines a minimum allowable voltage in DC link. If DC voltage falls below this value, the VSD will be tripped and an appropriate message («DC min») will appear on the controller display.



«DC bus max value» parameter defines a maximum allowable voltage in DC link. If DC voltage exceeds this value, the VSD will be tripped and an appropriate message («DC max») will appear on the controller display.

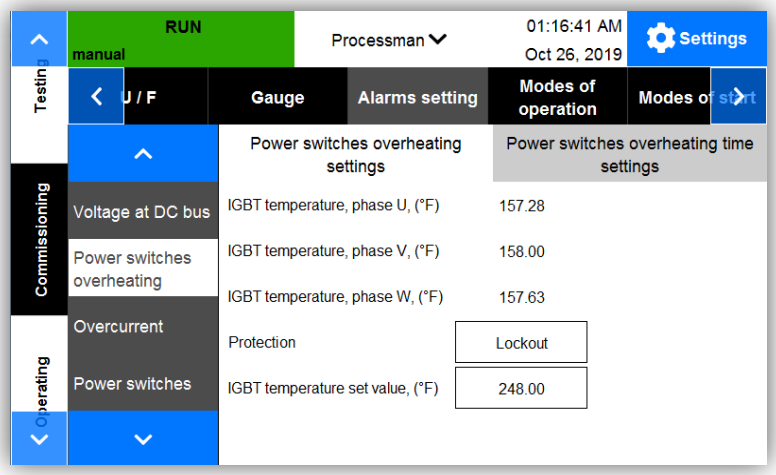
«Number of restarts» parameter — number



of Automatic restarts after VSD tripping by DC-link voltage protection.

«Restart delay» parameter — delay time to Automatic restart after VSD has been tripped by DC link voltage protection. If this protection operates, an appropriate message («DC min» or «DC max») shall appear on the controller display.

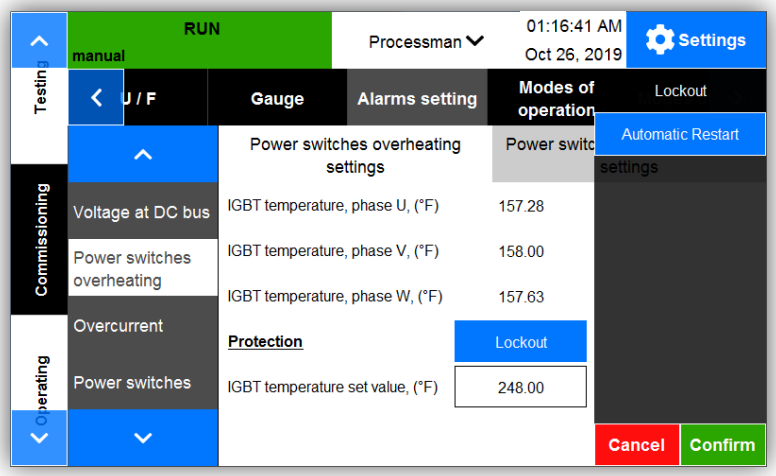
«Power switches overheating» protection



«IGBT temperature, phase U phase» parameter — indication of power modules temperature in phase U.

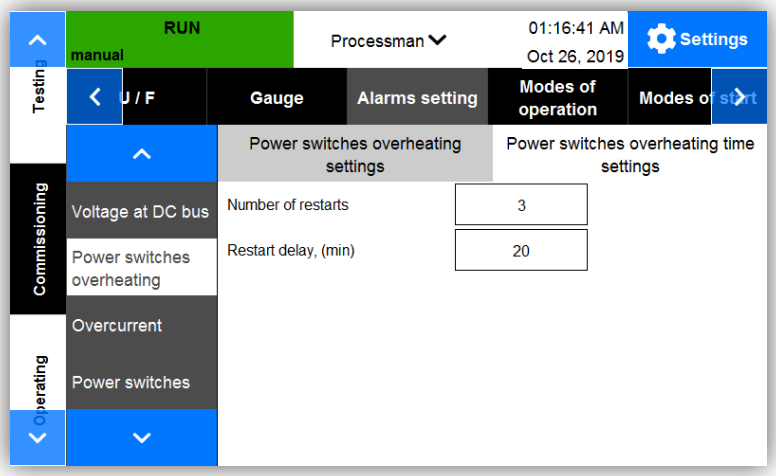
«IGBT temperature, phase V» parameter — indication of power modules temperature in phase V.

« IGBT temperature, phase W» parameter — indication of power modules temperature in phase W.

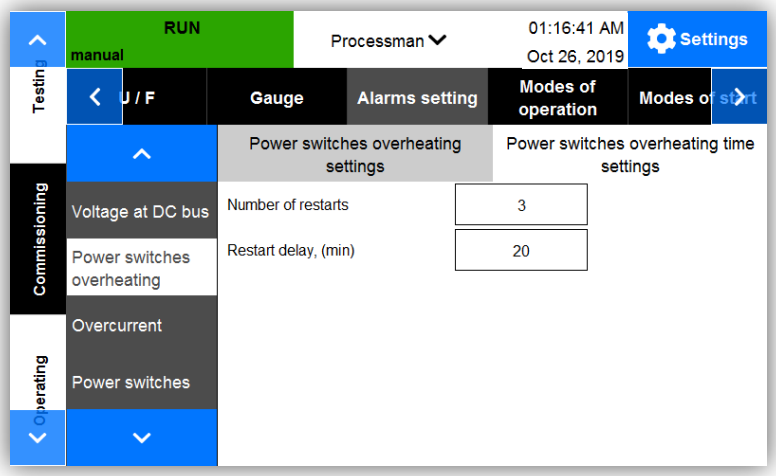


«Protection» parameter assigns one of two possible options of the protection operation:

- «Lockout» — after the motor has been tripped by a protection it cannot be switched on again until it is started by operator or through VSD;
- «Automatic restart» — after the motor has been tripped by a protection it can be switched on again in a time set by «Restart delay» parameter.



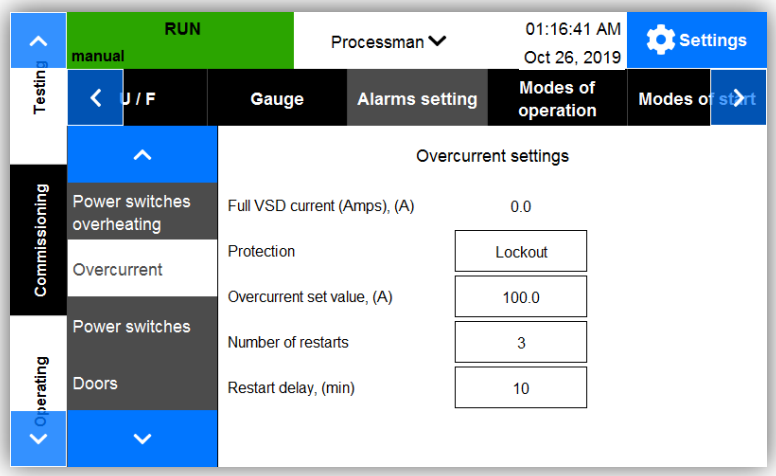
«IGBT temperature set value» parameter — maximum allowable temperature of the Variable Speed Drive power modules. If this value is exceeded the Variable Speed Drive will be tripped by power modules overheating protection. Manufacturer sets an appropriate value.

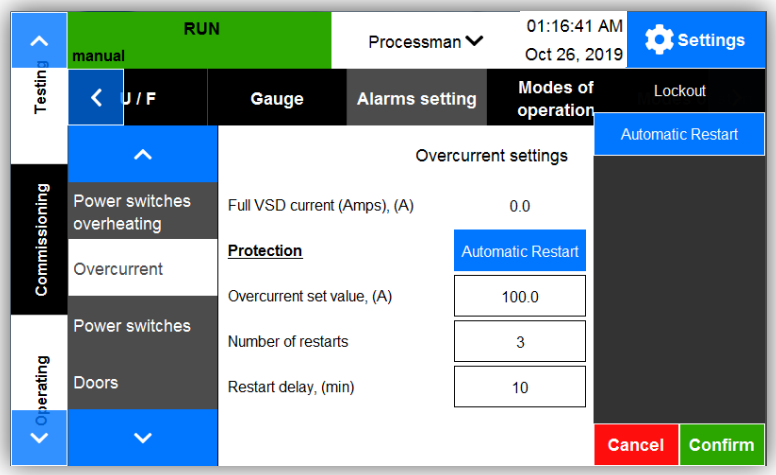


«Number of restarts» parameter — number of Automatic restarts after ESM tripping by power-switch overheating protection.

«Restart delay» parameter — delay time to Automatic restart after ESM tripping by power-switch overheating protection.

«Overcurrent» protection

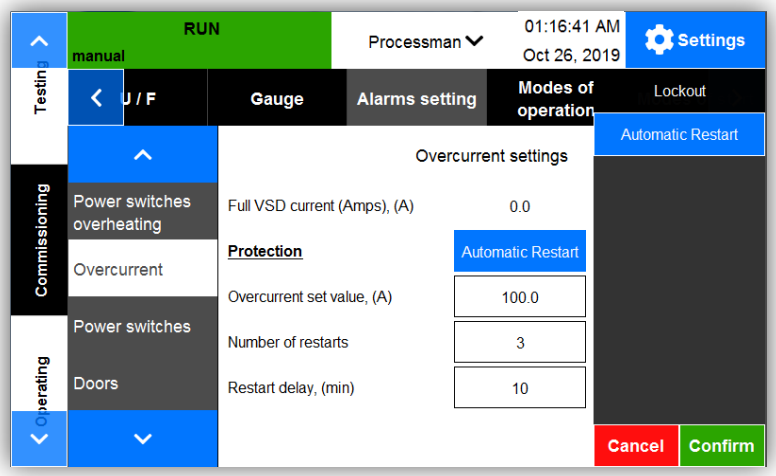




«Full VSD current (Amps)» parameter — indication of the VSD full-load (total) current actual value.

«Protection» parameter — VSD response to overcurrent protection activation; parameter assigns one of two possible options of the protection operation:

- «Lockout» — after the motor has been tripped by a protection it cannot be switched on again until it is started by operator or through VSD;

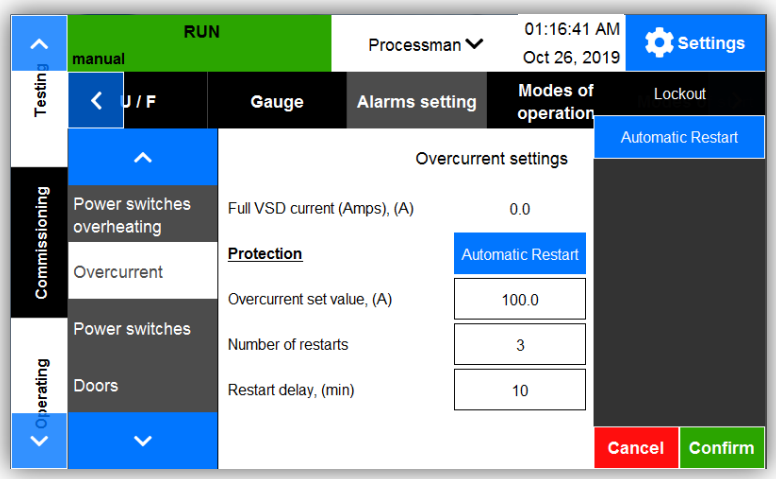


- «Automatic restart» — after the motor has been tripped by a protection it can be switched on again in a time set by «Restart delay» parameter.

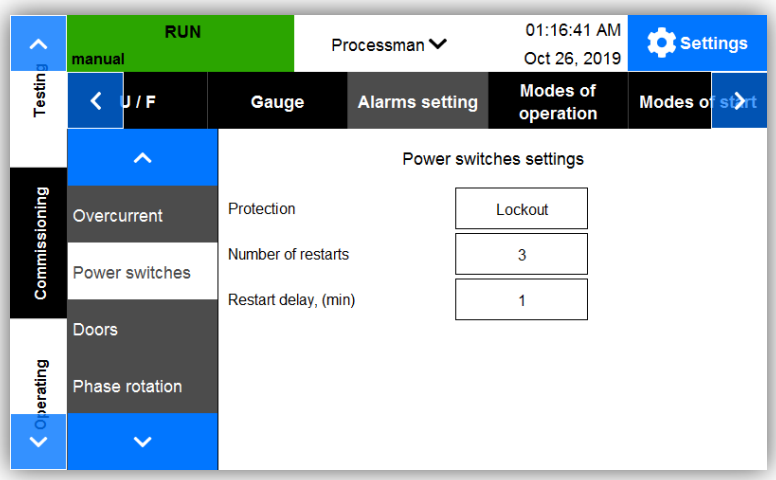
«Overcurrent set value» parameter represents the overcurrent set value. Manufacturer sets an appropriate value.

«Number of restarts» parameter — number of Automatic restarts after VSD tripping by overcurrent protection.

«Restart delay» parameter — Automatic restart delay time after the parameter has been restored. If this protection operates, an appropriate message («Overcurrent») is displayed.



«Power switches» protection



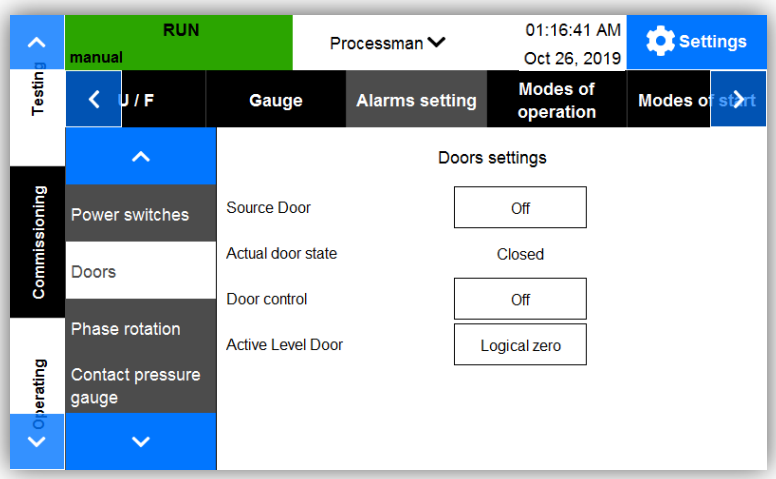
«Protection» parameter assigns one of two possible options of the protection operation:

- «Lockout» — after the motor has been tripped by a protection it cannot be switched on again until it is started by operator or through VSD;
- «Automatic restart» — after the motor has been tripped by a protection it can be switched on again in a time set by «Restart delay» parameter.

«Number of restarts» parameter — number of Automatic restarts after ESM tripping by power switch protection.

«Restart delay» parameter — delay time to Automatic restart after ESM tripping by power-switch protection.

«Doors» protection

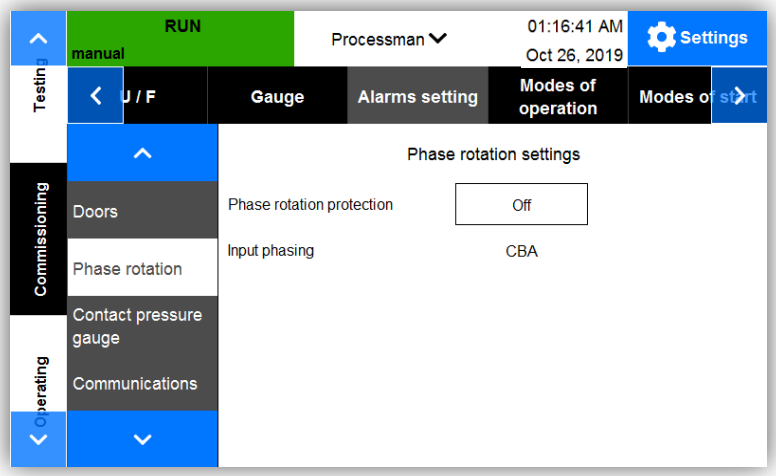


«Source door» – is intended to select receiving a physical signal from door sensor.

«Actual door state» – displays actual door state. It can be opened or closed.

«Door control» – allow to set protection by tripping VSD when door is open.

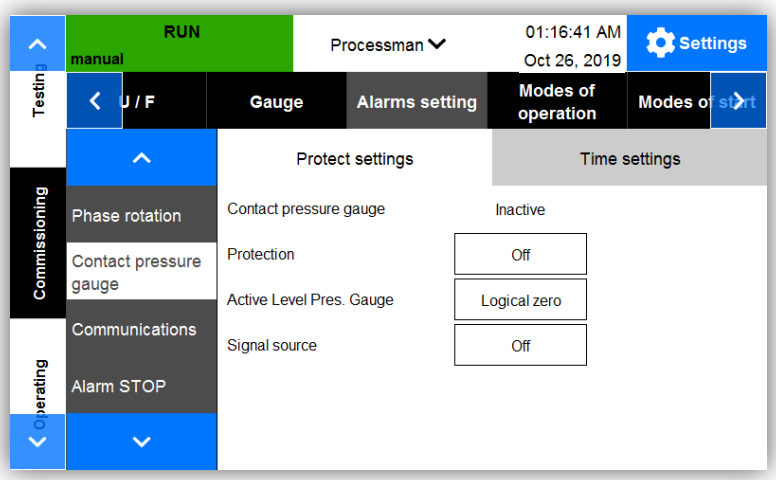
«Phase rotation» protection



«Phase rotation protection» parameter allows turning on or off input phase rotation alarm.

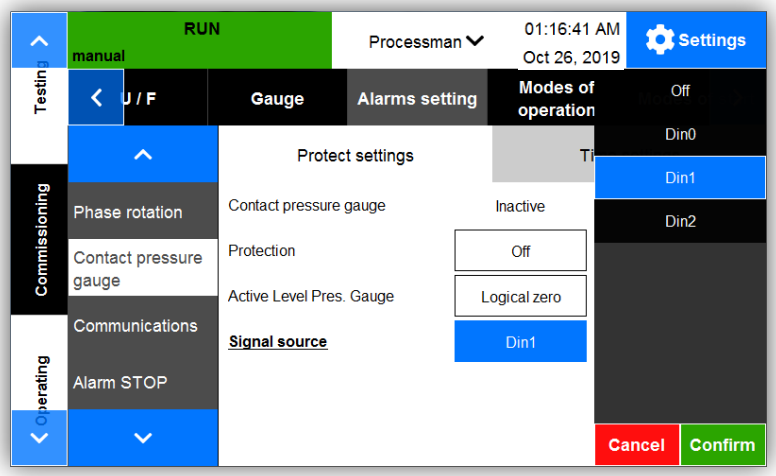
«Input phasing» – displays actual input voltage phasing. If input phasing not «ABC» and «Phase rotation protection» set to «ON», the VSD will trip.

«Contact pressure gauge» protection

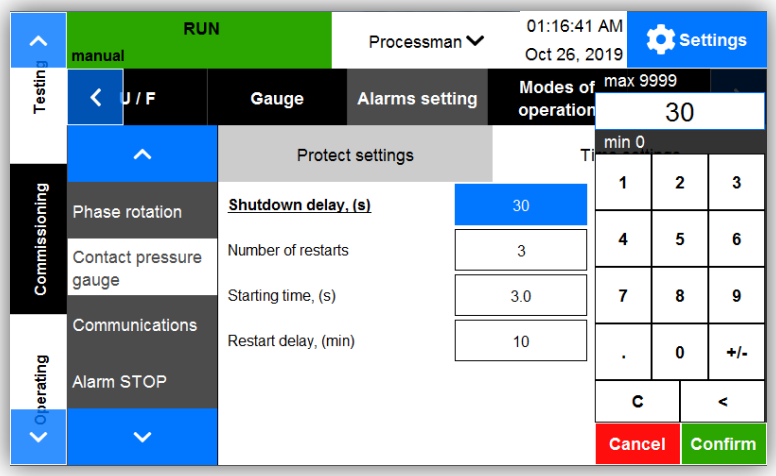


«Protection» parameter assigns one of three possible options of the protection operation:

- «Off» — protection is disabled;



- «Lockout» — after the motor has been tripped by a protection it cannot be switched on again until it is started by operator or through VSD;
- «Automatic restart» — after the motor has been tripped by a protection it can be switched on again in a time set by «Restart delay» parameter.

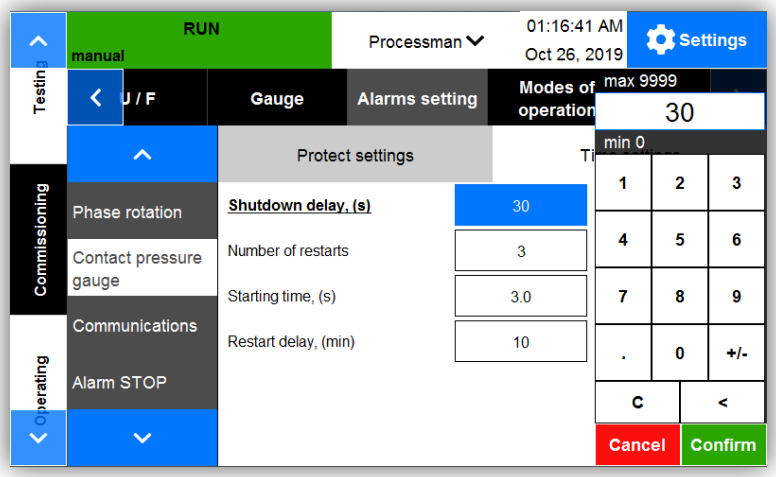


«Active Entry Level» – allows to set VSD trip logic level.

«Signal source» – is intended to choose physical signal from contact pressure gauge.

«Shutdown delay» parameter — delay time for VSD tripping by contact pressure gauge protection.

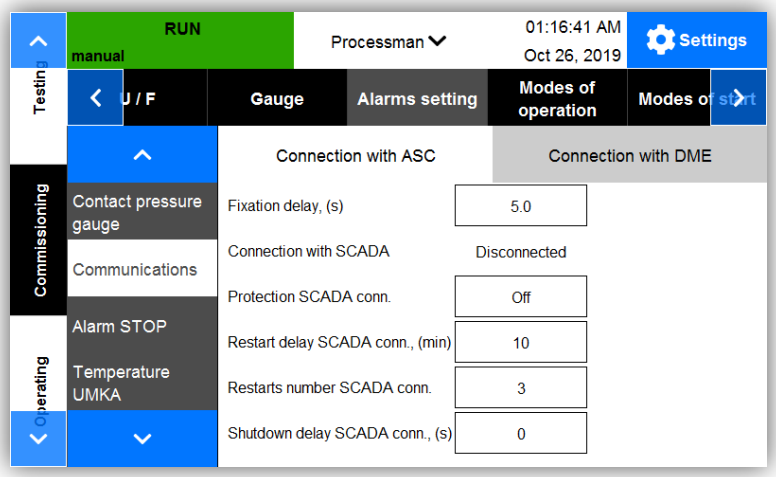
«Number of restarts» parameter — number of Automatic restarts after ESM tripping by contact pressure gauge protection.



«Starting time» - this parameter sets a time bracket for protection being temporary disabled from the moment the motor starts running. The parameter value shall not be less than the time required for the motor to reach its rated speed.

«Restart delay» parameter — delay time to Automatic restart after VSD has been tripped by contact pressure gauge protection.

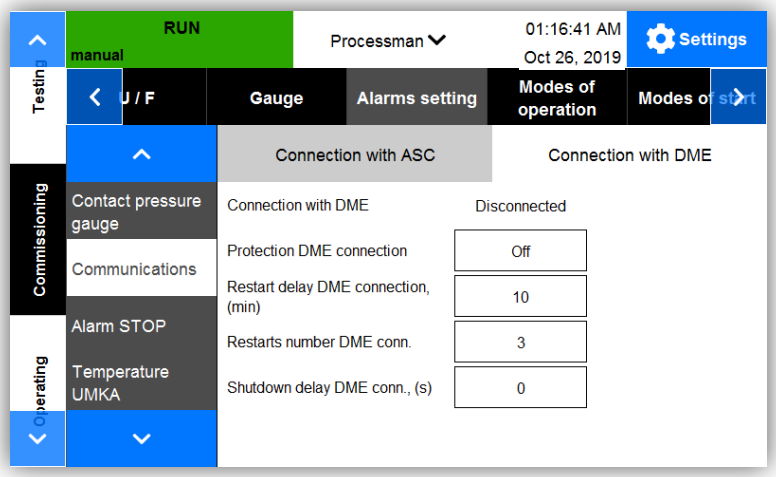
«Communications» protection



«Communications» menu allows to set protections that can trip VSD if UMKA losts connections with ACS and/or downhole measurement equipment.

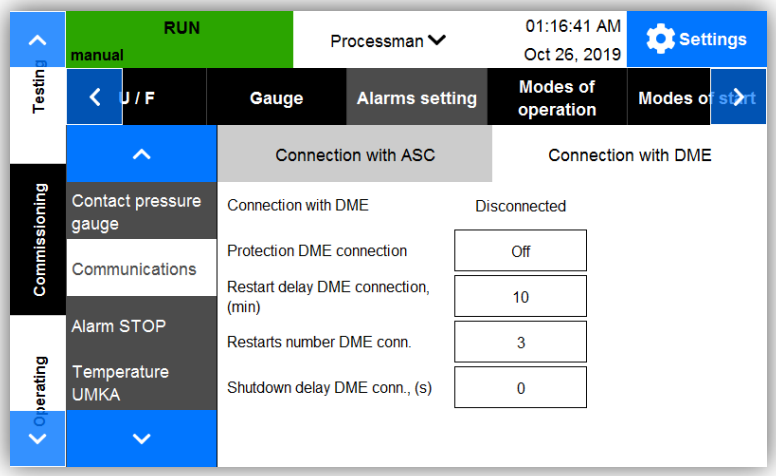
«Fixation delay» – this parameter sets a time bracket for protection being temporary disabled from a moment the UMKA loses its connection with ACS.

«Connection with SCADA», «Connection with DME» – displays actual connection with ASC and DME.

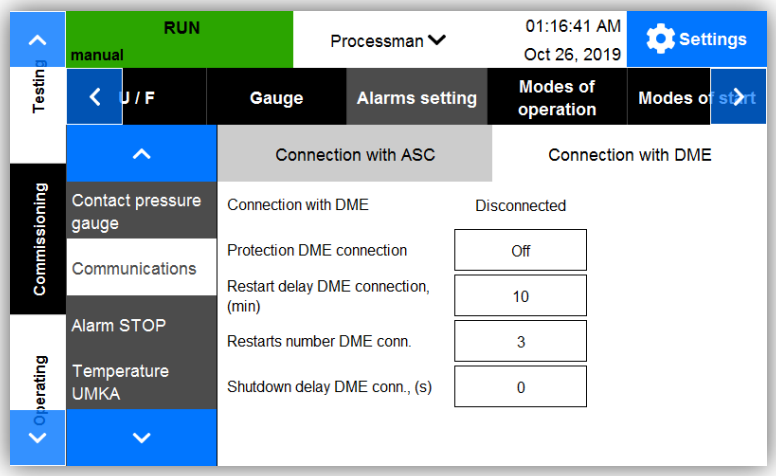


«Protection SCADA connection», «Protection DME connection» – parameter assigns one of three possible options of the protection operation:

- «Off» — protection is disabled;
- «Lockout» — after the motor has been tripped by a protection it cannot be switched on again until it is started by operator or through VSD;
- «Automatic restart» — after the motor has been tripped by a protection it can be switched on again in a time set by «Restart delay» parameter.



«Restart delay SCADA», «Restart delay DME» parameters — delay time to Automatic restart after VSD has been tripped by lost connection with SCADA or DME.

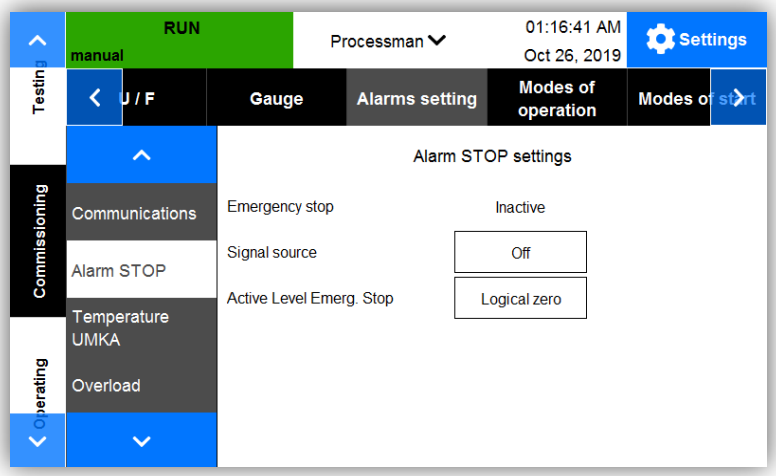


«Number of restarts SCADA», «Number of restarts DME» parameters — number of Automatic restart after VSD tripping by lost connection with SCADA or DME.

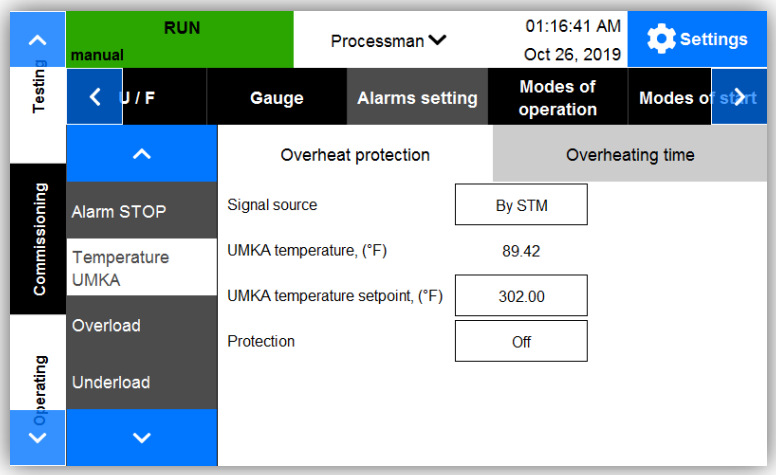
«Shutdown delay SCADA», «Shutdown delay DME» parameter — delay time for VSD tripping by lost connection with SCADA or DME.

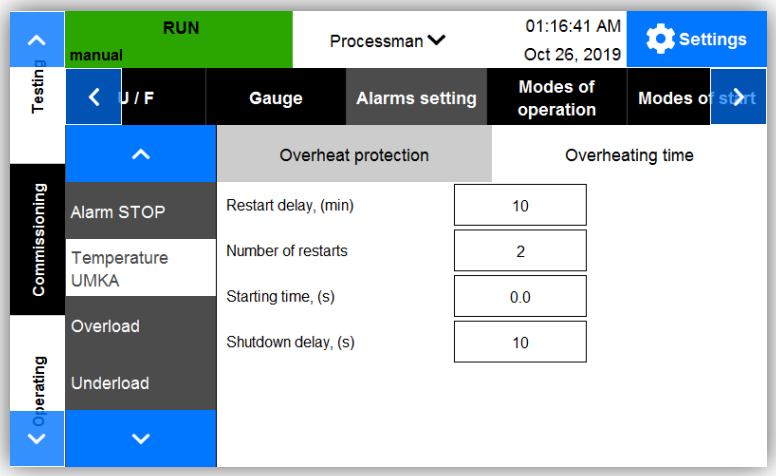
«Alarm STOP» protection

This menu allows enabling or disabling the ability to stop the VSD by pressing the emergency stop button «Emergency stop».



«Temperature UMKA» protection





«UMKA temperature» – displays actual temperature of UMKA07 controller.

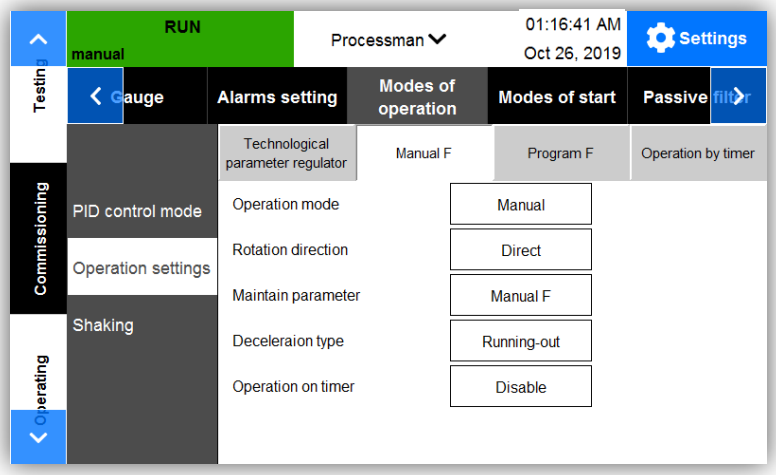
«Protection» parameter assigns one of three possible options of the protection operation:

- «Off» — protection is disabled;
- «Lockout» — after the motor has been tripped by a protection it cannot be switched on again until it is started by operator or through VSD;
- «Automatic restart» — after the motor has been tripped by a protection it can be switched on again in a time set by «Restart delay» parameter.

Modes of operation

This second-level menu offers to adjust VSD settings making them suitable for use in various technological modes. Moreover, there is a possibility of setting and switching modes when ESM is in operation.

«Operation settings» protection



«Operating mode» parameter assigns an operating mode of the Variable Speed Drive. Actual mode of operation is also shown in the status line («Manual» or «Auto»).

Operating mode parameter may be set to:

- «Manual» — manual mode of operation. In this mode, the Variable Speed Drive «start» and «stop» actions are performed manually without automatic restart opportunity if VSD trips. Thus, the VSD can be started or stoped by pressing «Start» or «Stop» buttons on UMKA07 keyboard. Same can be performed remotely via ACS or the signal from digital input;
- «Manual local» — local manual mode of operation. In this mode VSD can be started or stopped only by pressing «Start» or «Stop» buttons on UMKA07 keyboard. Remote starts or stops via ACS or the signal from digital input are disabled;
- «Manual remote» — remote manual mode of operation. In this mode VSD starts or stops only via ACS or by signal from digital input. «Start» or «Stop» buttons on UMKA07 keyboard are disabled;

- «Auto» — automatic mode of operation. In automatic mode, the VSD can be started manually by pressing the «START» key. It is also can be started automatically: upon expiry of the «Automatic restart» parameter after the VSD has been powered («min restart time» parameter), or upon expiry of the «Automatic restart» parameter after one of the protections has been operated. Moreover, the VSD can be started remotely. After tripping caused by protection operated, the automatic reclosing is performed (if such a function is provided by the protection settings);
- «Auto local» – local automatic restart mode. In this mode, only manual local start and stop of the VSD are allowed (via buttons on UMKA07 keyboard);
- «Auto remote» – remote automatic restart mode. In this mode, only remote start and stop of the VSD are allowed (via ACS or by a signal from digital input);
- «Rotation direction» – parameter assigns the phase sequence at the converter output (direction of motor rotation):
  - «Direct» setting — forward UVW phase rotation;
  - «Reverse» setting — backward WVU phase rotation.
- «Maintain parameter» represents the method of controlling the VSD output frequency at starting as well as the actual mode of operation. To activate this mode it is necessary to select an adjustable parameter from the list of values.

«Maintain parameter» may be set to:

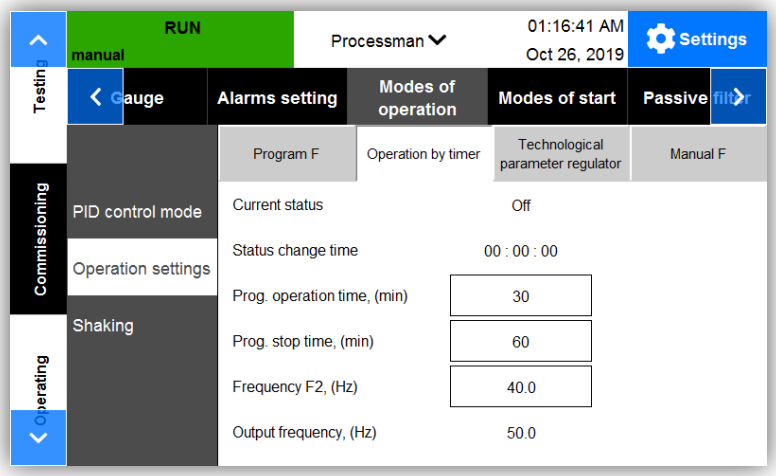
- «Manual F» — output frequency is assigned manually with the help of «Frequency setting» parameter;
- «Program F» — output frequency is changed by the preset time program according to settings in «Program F» mode;
- «Amperes reference» — output frequency is controlled by predefined current regulation function;
- «Intake Pressure» — output frequency is controlled by predefined intake well pressure regulation function. Set value of the pressure regulation parameter is given in menu «Technological parameter regulator».

- «Discharge pressure» — output frequency is controlled by predefined discharge well pressure regulation function. Set value of the pressure regulation parameter is given in menu «Technological parameter regulator»;
- «Annulus pressure» — output frequency is controlled by predefined annulus pressure regulation function. Set value of the pressure regulation parameter is given in menu «Technological parameter regulator»;
- «Line Pressure» — output frequency is controlled by predefined function regulating pressure in line. Set value of the pressure regulation parameter is given in menu «Technological parameter regulator»;
- «Wellhead pressure» – output frequency is controlled by predefined wellhead pressure regulation function. Set value of the wellhead pressure regulation parameter is given in menu «Technological parameter regulator»;
- «Compensator pressure» – output frequency is controlled by predefined compensator pressure regulation function. Set value of the compensator pressure regulation parameter is given in menu «Technological parameter regulator»;
- «Annulus level» — output frequency is controlled by predefined annulus level regulation function. Set value of the level regulation parameter is given in menu «Technological parameter regulator»;
- «Active Power EMS» – output frequency is controlled by predefined electrical submersible motor active power regulation function. Set value of the active power regulation parameter is given in menu «Technological parameter regulator»;
- «Intake Temp» – output frequency is controlled by predefined intake well temperature regulation function. Set value of the regulation parameter is given in menu «Technological parameter regulator»;
- «Discharge Temp» – output frequency is controlled by predefined discharge well temperature regulation function. Set value of the ESM temperature regulation parameter is given in menu «Technological parameter regulator».

«Deceleration type» parameter may be set to:

- «Running-out» — after the stop command has been received in the control system for any reason - the output inverter of VSD is turned off, the output voltage of VSD becomes 0 V. Motor is coasting;
- «Dynamic» — after the «stop» command, VSD starts to lower the output frequency to 0 Hz, with the tempo set by the «Deceleration rate» parameter in the «Modes of start» menu. When the output frequency reaches 0 Hz, the inverter of the VSD will turn of

«Operation by timer»

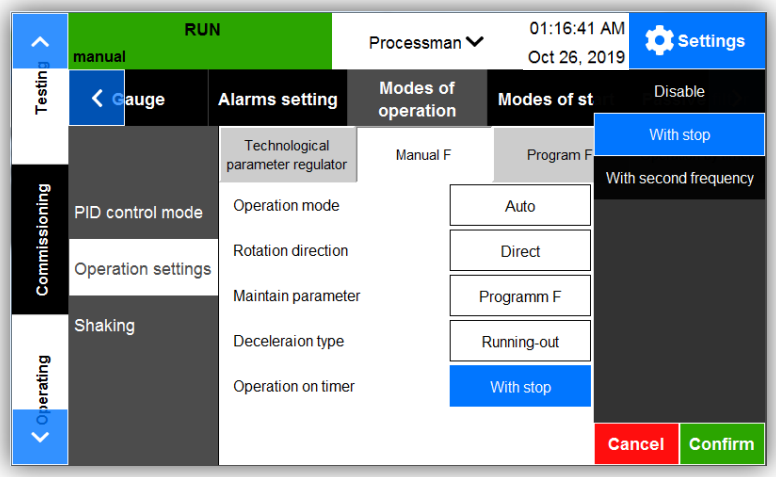


This mode allows to set the cyclic operation of the VSD within a user-defined time.

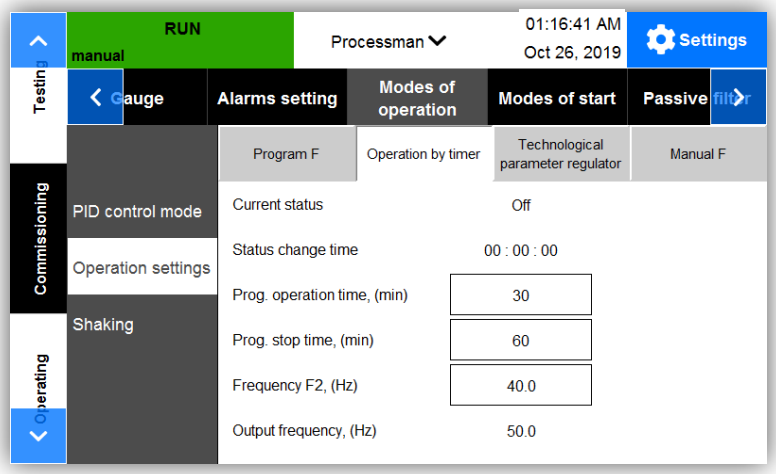
This mode includes two main operating modes (mode selection is performed in the «Manual F» menu):

«With stop» – an operation algorithm in which, after the VSD operation time specified by the user, the VSD is at a standstill for the required time.

«With second frequency» – in this mode, the output frequency of the VSD varies between two preset values.



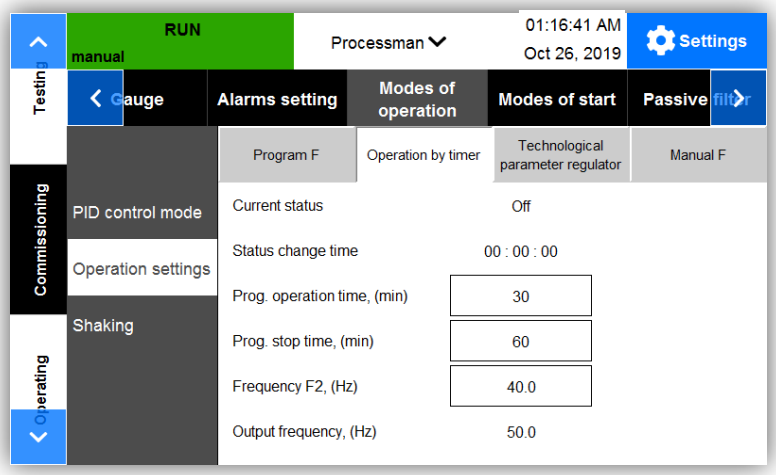
If either of the two described modes is



selected, an accessible menu «Operation by timer» opens. In this menu, it is possible to adjust the operating time of the algorithm and set the values of its operating frequencies.

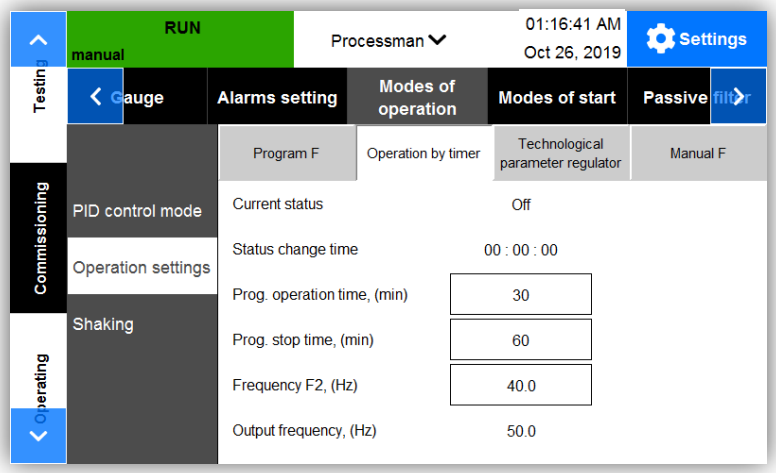
«Current status» – displays the current state of this mode.

«Status change time» – the parameter displays the remaining time until the frequency changes (if «With second frequency» mode is selected), or before the change of the VSD state (if «With stop» mode is selected).



«Prog. operation time» – VSD operating time in «With stop» mode, or operating time at the reference frequency in «With second frequency» mode.

«Prog. stop time» – the time VSD is in a «stop» state («With stop» mode), or the operating time at the frequency.

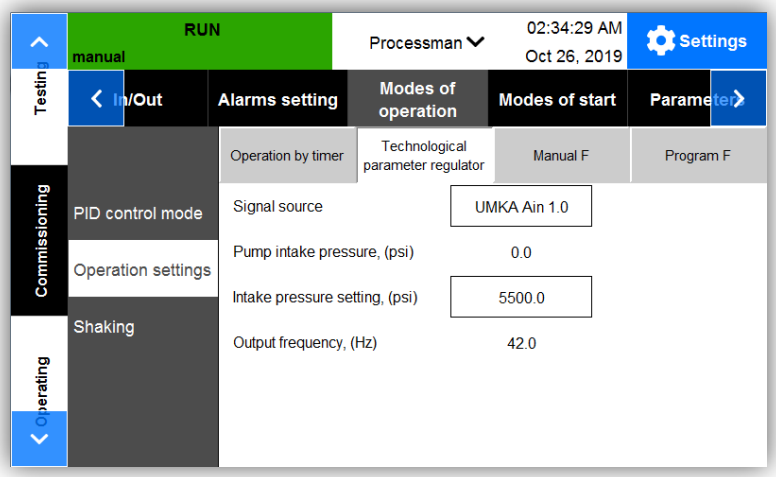


«Frequency F2» («With second frequency» mode).

«Output frequency» – displays current output frequency VSD.

«Technological parameter regulator»

This menu offers to select a technological parameter, the set value of which VSD will seek to maintain. The speed and accuracy of maintaining this parameter is set in the "PID control mode" menu.



«Maintain parameter current value» – displays the current value of the supported parameter.

«Maintain parameter setpoint» – allows to set the value of the supported parameter.

«Output frequency, Hz» parameter – displays the current output frequency of the VSD.

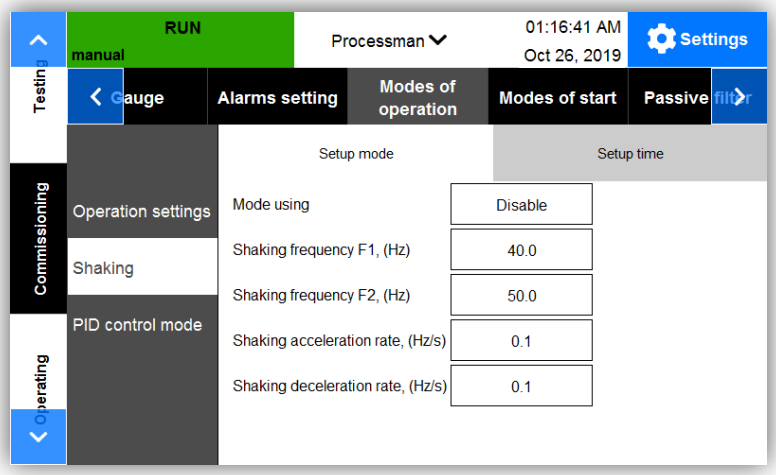
«Power-on start»

This mode allows to start the VSD after supply voltage is restored. «Power-on start» – allows to enable or disable automatic start of the VSD after restoration of the supply voltage.

«Restart delay» – delay time to Automatic restart after VSD has been tripped due to 100% of voltage loss.

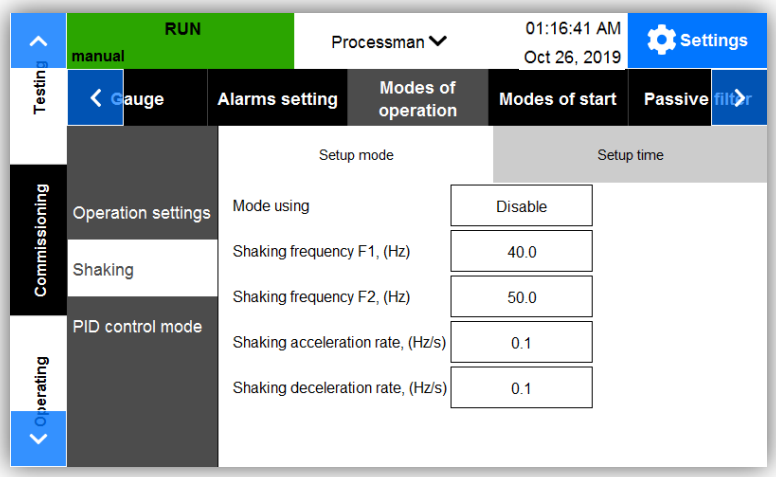
«Shaking»

This second-level menu is intended for changing the ESM operation frequency to remove or reduce amount of deposits formed on the motor in the process of operation.



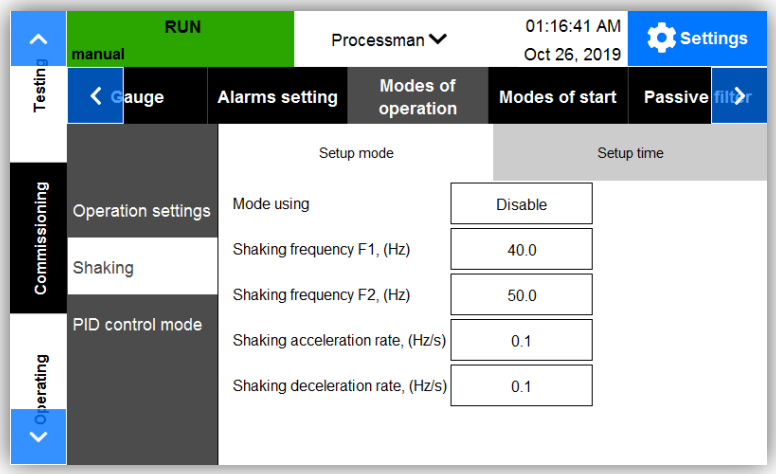
«Mode using» parameter defines if the «Shaking» mode will be enabled. This parameter shall be set to — «Disable» or «Permit».

«Shaking frequency F1» parameter — level of frequency down to which the VSD output frequency will be decreased at the beginning of the shaking cycle.



«Shaking frequency F2» parameter — level of frequency up to which the VSD output frequency will be increased in the shaking cycle. In any case, the output frequency cannot exceed «Low frequency clamp» parameter.

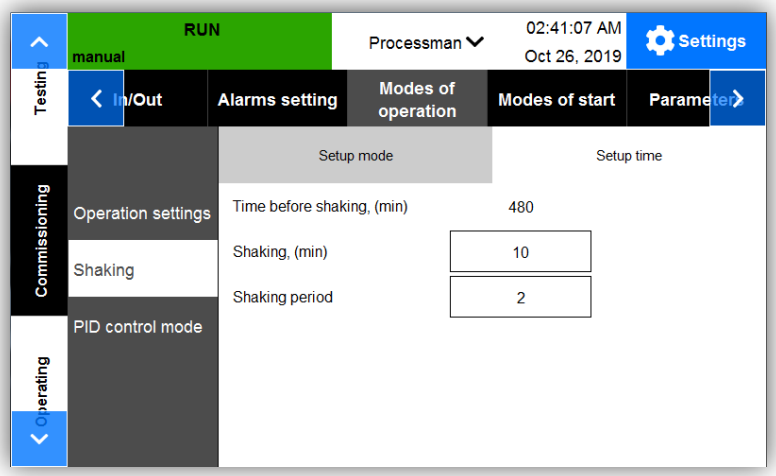
After adjusting the frequency preset by «Shaking frequency F2» parameter, the VSD frequency will be changed over again to that preset by «Shaking frequency F1» parameter.



After debugging all the shaking cycles the frequency value will be changed to the one defined by VSD operating mode.

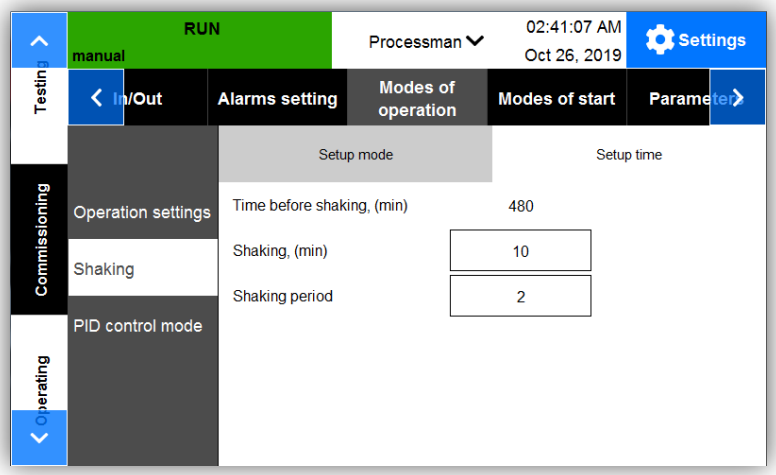
«Shaking acceleration rate» parameter assigns the rate of the frequency increase in the shaking mode.

«Shaking deceleration rate» parameter assigns the rate of the frequency decrease in the shaking mode.



«Time before shaking» parameter — indicates the time remained to start «Shaking» mode.

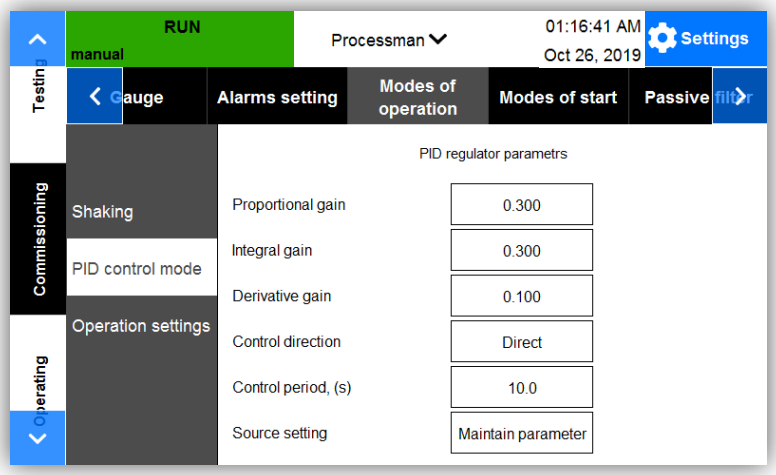
«Shaking period» parameter - defines the shaking cyclicity. For example, if this parameter is equal 1, this means that 1 «Shaking» cycle will consist of achieving «F1 frequency», then «F2 frequency», 1 time full cycle. At the end of the algorithm, the output frequency of the VSD will be equal to the frequency specified by the operator.



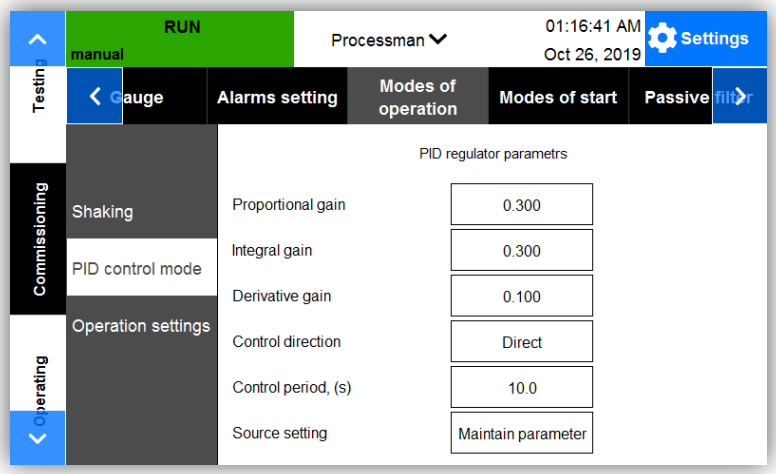
«Amount of shakings» parameter assigns the number of frequency changes in one shaking cycle.

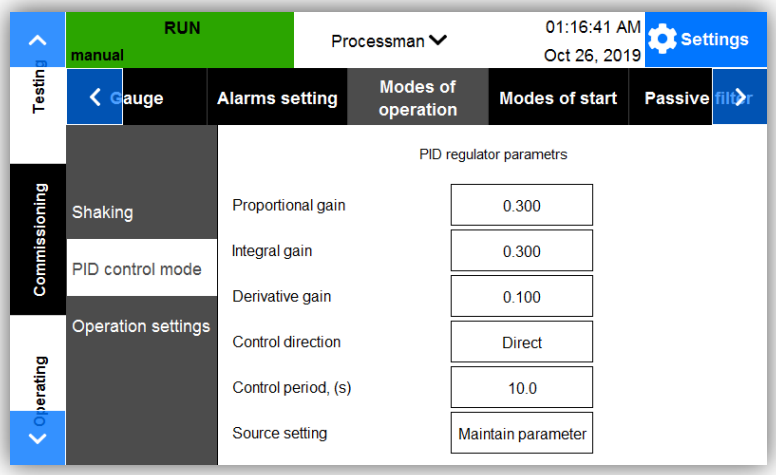
«PID control mode»

Third-level menu «PID control mode» comprises the following parameters:

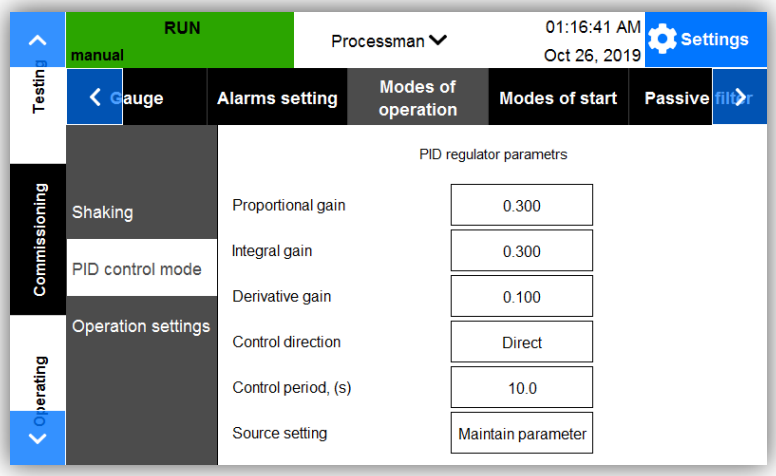


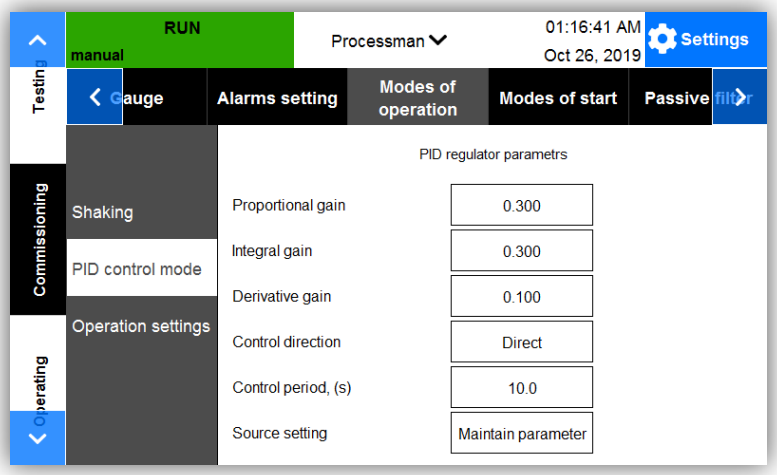
- «Proportional Gain» parameter assigns a value to the PID-regulator proportional component (Kp). The higher is this value more is the frequency change at the Variable Speed Drive output when the parameter value is deviating from the preset one. And, therefore, the higher is the rate of change of the parameter current value. This can lead VSD to stop.





- «Integral gain» parameter assigns a value to the PID-regulator integral component (Ki). This value contributes to nullification of the averaged value of the actual parameter deviation from the preset value and defines the rate (time) of response to the change of the parameter being supported. The higher is the value of integral component the faster deviation of the supported parameter from the preset value goes down to zero. This can lead VSD to stop.





- «Derivative gain» parameter assigns a value to the PID-regulator differential component (Kd). This value impacts the output frequency change depending on the rate of change of the parameter being supported. The faster the parameter is being changed the higher shall be the values of proportional and integral components, and the higher is the probability that the system is overcontrolled. Differential component helps to gain stable damping of the parameter fluctuations. This can lead VSD to stop.

Setting begins from proportional coefficient (Kp); integral coefficient is zero. First, it's necessary to assign a minimum value of Kp and to check up the result. If current value of the parameter is being changed slowly, Kp shall be increased. This operation shall be repeated until the required result is achieved – overcontrol from 5 to 10 %. Alternatively, there may be assigned maximum value of Kp with subsequent checking of the result. If big overcontrol or instability is observed in the system it's necessary to decrease the Kp value and to check up the result. If time and mode of achieving the stable state are acceptable then setting of Kp is assumed to be completed.

Setting of integral coefficient (Ki) shall be started from setting of minimum integral value. If there are some problems at setting, it's necessary to decrease the Kp value. If no changes in deviation are observed then Ki value shall be decreased. If control becomes unstable at the time, Kp value shall be decreased. Repeat this operation until suitable parameters are set.

Setting of differential coefficient (Kd) shall be started from setting of its minimum value. Then increase it steadily and analyze the system stabilization time. Such increase shall be performed until acceptable stabilization time is achieved. Impact of the regulator coefficients on the control system response are given below:

Regulator coefficient	The time of reaction to the effects of	Hunting	Time of stabilization	Residual error
K_I	Reduces	Increases	No effect	Reduces
K_P	Reduces	Increases	Increases	Nullifies
K_d	Changes little	Reduces	Reduces	Changes little

«Control direction» parameter defines the direction of the frequency change at the VSD output when the parameter value is deviating from the preset one.

«Control direction» parameter may be set to:

- «Direct» — direct relation of control. If «Maintain parameter current value», «Maintain parameter setpoint» output frequency will be decrease.
- «Reverse» — inverse relation of control. If «Maintain parameter current value» > «Maintain parameter setpoint» output frequency will be decrease.

Example: VSD is in operation with connected telemetry system which is used for measuring the intake pressure. Let us select item «Intake Pressure» for «Maintain parameter» and value of 600 psi — for «Maintain parameter setpoint».

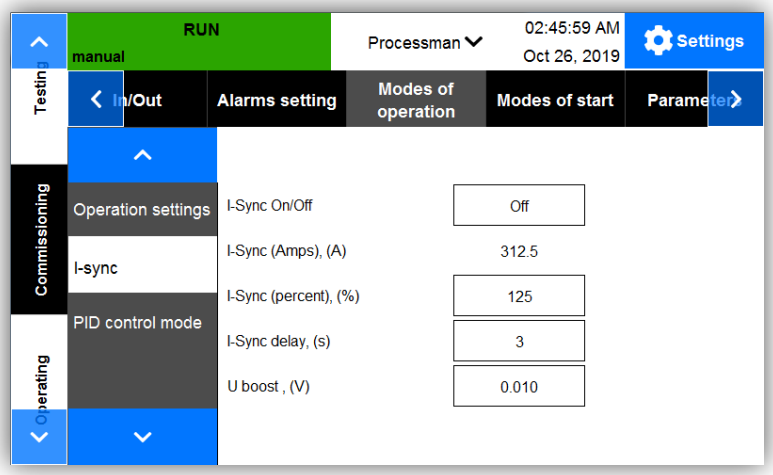
If telemetry informs that the pressure is 700 psi and if «Direct» option of «Control direction» parameter is chosen, the frequency starts decreasing (down to the value not lower than the «Low frequency clamp» parameter). If «Reverse» option is set, the frequency starts increasing (up to the value not exceeding the «High frequency clamp» parameter).

«Control period» parameter sets the resolution of a regulator to compare the current value with the preset one and to correct the VSD output frequency. If information of the parameter being supported enters the regulator discretely in certain periods of time

then «Control period» parameter shall be set to a value not less than the specified period.

«I-sync»

This mode allows starting the VSD with current limitation.



«I-sync» – allows to enable or disable the current limiting mode in VSD.

«I-sync, Amps» – motor current limit setting in amperes.

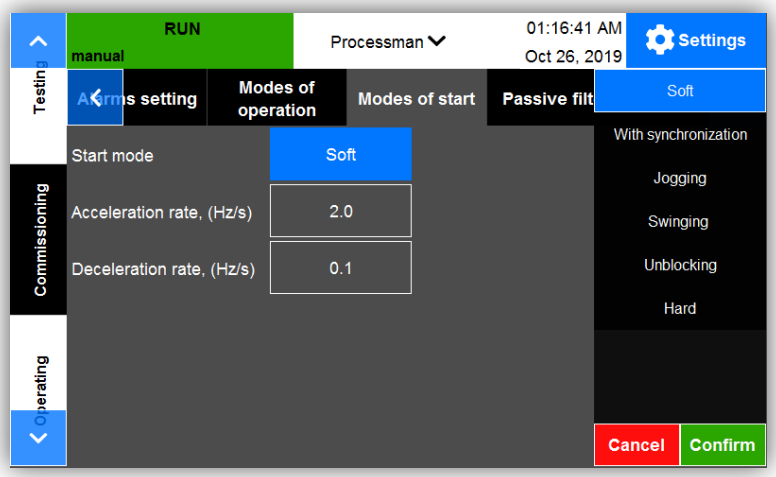
«I-sync, setpoint» – motor current limit setting as a percentage of the rated motor current set by the «Motor nominal Current (Amps)» parameter in the «Installation parameters» menu.

«I-sync delay » – this parameter allows to set the operating time current limit at start.

«I-limit Prop U, V» parameter – sets the value of the current limiting factor at start.

«Modes of start»

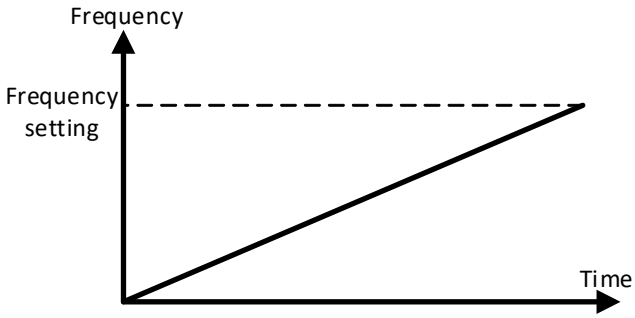
This second-level menu allows setting the start-up mode for a Variable Speed Drive operating under various conditions.



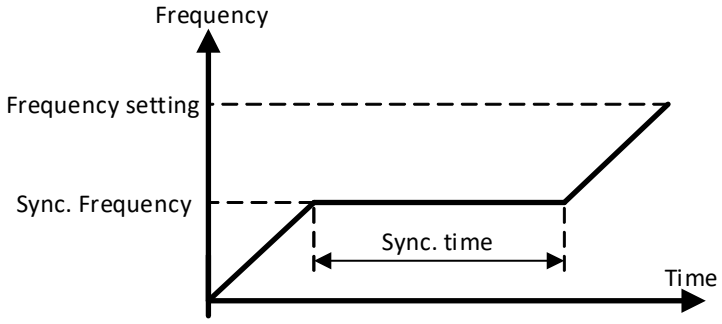
There are 6 start modes in VSD:

- Soft
- With synchronization
- Jogging
- Swinging
- Unblocking
- Hard

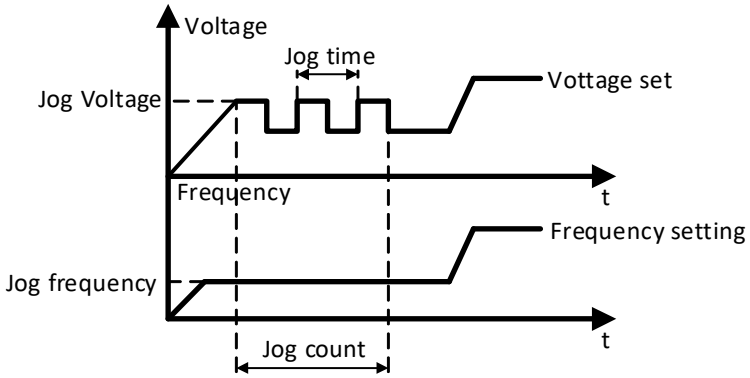
At soft starting («Startup mode» parameter is set to «Soft») the frequency gets increased delicately with a preset run-up time up to the value assigned by frequency reference, current or process parameter. Subsequently, the selected parameter shall be maintained.



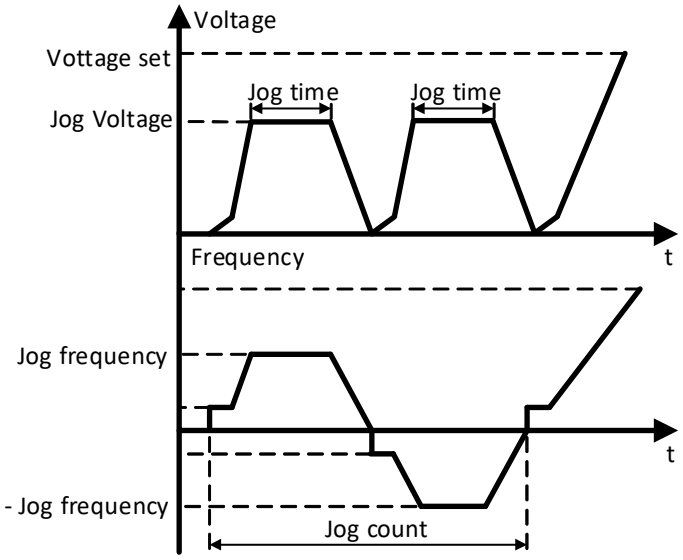
At starting with synchronization («Startup mode» parameter is set to «With synchronization») the VSD output frequency is increased with synchronization. After starting the output frequency is increased with a preset run-up rate up to the synchronization frequency, then — for a time of synchronization — the output frequency remains unchangeable (no increase) following which the frequency shall be increased with a preset run-up rate up to the rated value.



At jogging («Startup mode» parameter is set to «Jogging») a sequence of higher voltage pulses is applied to the motor during its acceleration with low frequency specified by «Jog frequency» parameter. Voltage value is defined by «Jog voltage». Number of «kicks» is determined by «Jog count» parameter.



At starting with reversible rotation («Startup mode» parameter is set to «Swinging») start-up of the Variable Speed Drive is performed intermittently with changing the direction of rotation. Prior to acceleration, a sequence of pulses shall be applied to the submersible motor. Voltage of pulses is defined by «Jog voltage» parameter and frequency — by «Jog frequency» parameter.



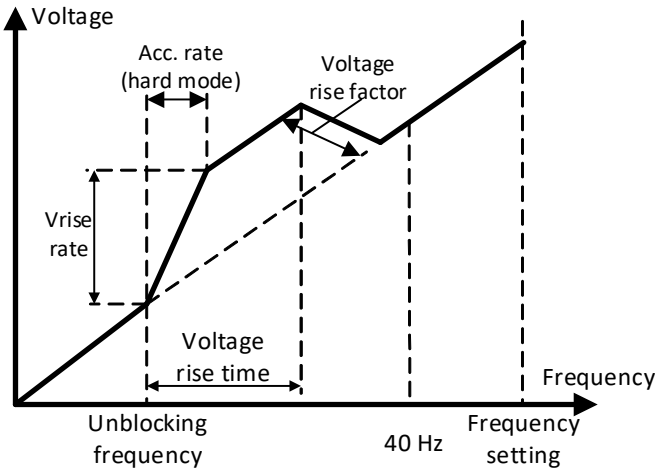
The special «Unblocking» mode is offered to unblock the motor achieving maximum torque at low Speed of rotation («Startup mode» parameter is set to «Unblocking»). When starting ESM in «Unblocking» mode after acceleration at a frequency depending on the ESM slip frequency, a current regulator will be switched for 2 seconds to ensure the ESM rotation at the above-specified frequency with maintaining voltage is half of the rated one. This will guarantee a maximum torque at low frequency. From then the ESM is accelerated normally.

Hard start of the motor («Startup mode» parameter is set to «Hard») is performed as follows: after pressing «START» button the VSD output frequency and voltage start increasing as per adjusted U/F characteristic with a rate specified by «Acceleration rate» parameter. If output frequency reaches the level of unblocking one («Unblocking frequency» parameter) output voltage is increased by a value specified by «Voltage rise factor» parameter with a rate specified by «Voltage rise rate» parameter.

Rate of frequency increase is also changed to that specified by «Acceleration rate (hard start)» parameter. Lifetime of increased voltage and different rate of acceleration is set by «Voltage rise time» parameter, but in any case it expires when output frequency reaches the value of 40 Hz.

If taking into account the impact on the motor, this mode (if appropriately set) may be compared to the motor direct-line starting.

This function is intended for unblocking electric submersible pump.



If «Startup mode» is set to «Hard» the following parameters are accessible:

- «Acceleration rate» parameter defines rate of the VSD output frequency increase when accelerating the motor (Hz/s).
- «Deceleration rate» parameter defines rate of the VSD output frequency decrease at motor decelerating. Its principle is similar to that of «Acceleration rate» parameter. Deceleration rate is calculated by formula 2.9. Motor deceleration with a rate specified in «Deceleration rate» parameter is possible only if the output frequency is controlled (is being decreased). Method of deceleration is set in «Modes of operation» — «Manual/Automatic» — «Deceleration method» menu.
- «Acceleration rate» (hard start)» parameter assigns the acceleration rate for hard start. Recommended value for this parameter is 10 – 50 Hz/s.
- «Voltage rise factor» parameter assigns value of the voltage rise factor. For this parameter we recommend to use factory setting.
- «Unblocking frequency» parameter assigns the unblocking frequency value. For this parameter we recommend to use factory setting.
- «Voltage rise rate» parameter assigns value of the voltage increase rate. For this parameter we recommend to use factory setting.
- «Voltage rise time» parameter defines the voltage increase time. For this parameter we recommend to use factory setting.
- «Unlocking» parameter provides the possibility of enabling/disabling the VSD start. If this parameter is set to «On» a Variable Speed Drive may be started only through VSD or manually by operator provided that «Locked» parameter is set to «No» (i.e. unlocked).
- «Locked» parameter provides the possibility of disabling the VSD start. If station is locked it may be started only through VSD or manually by operator who may unlock the Variable Speed Drive by entering into the system as the «Process man» using appropriate password.

Parameters of start-up modes may be changed when the motor is in operation but they become valid only during the next starting (by Automatic restart, operator, external VSD or program).

«Acceleration rate» parameter defines rate of the VSD output frequency increase when accelerating the motor (Hz/s). Time to

intended frequency is calculated by the following formula if automatic control is not provided:

$$T = \frac{(Frequency_{setpoint} - Frequency_{start})}{Acceleration\ rate}$$

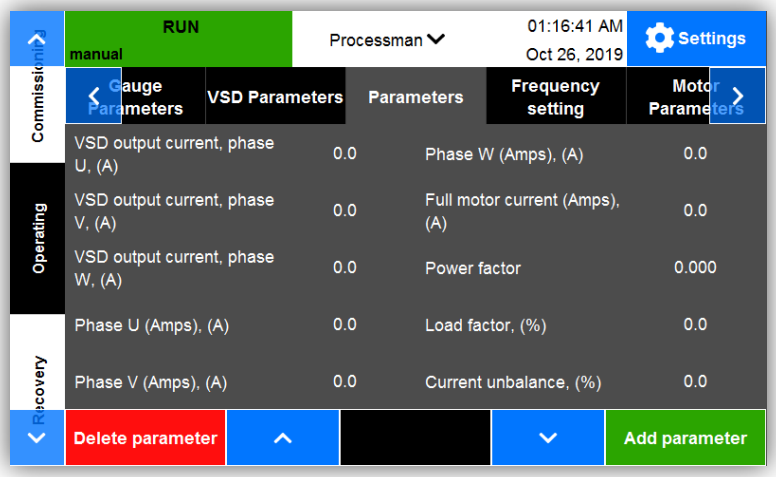
Example: If to set 2 Hz/s the motor will be accelerated from starting frequency (1.5 Hz) to the intended on (60 Hz) for the time T = (60-1.5)/2=29.25 s.

- «Deceleration rate» parameter defines rate of the VSD output frequency decrease at motor decelerating. Its principle is similar to that of «Acceleration rate» parameter. Motor deceleration with a rate specified in «Deceleration rate» parameter is possible only if the output frequency is controlled (is being decreased). Method of deceleration is set in «Modes of operation» – «Manual/Automatic» – «Deceleration method».
- «Unlocking» parameter provides the possibility of enabling/disabling the VSD start. If this parameter is set to «On» a Variable Speed Drive may be started only through VSD or manually by operator provided that «Locked» parameter is set to «No» (i.e. unlocked).
- «Locked» parameter provides the possibility of disabling the VSD start. If station is locked it may be started only through VSD or manually by operator who may unlock the Variable Speed Drive by entering into the system as the «Processman» using appropriate password.

«Operating» menu

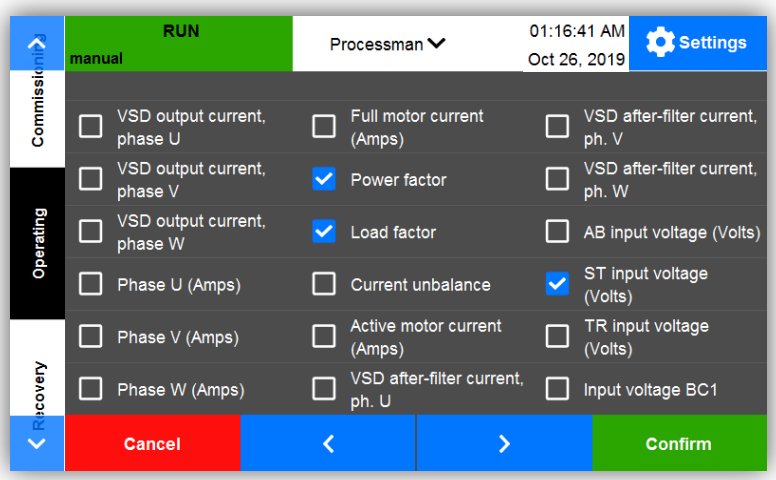
«Parameters»

This menu is designed to display the current values of the VSD parameters, motor, well.

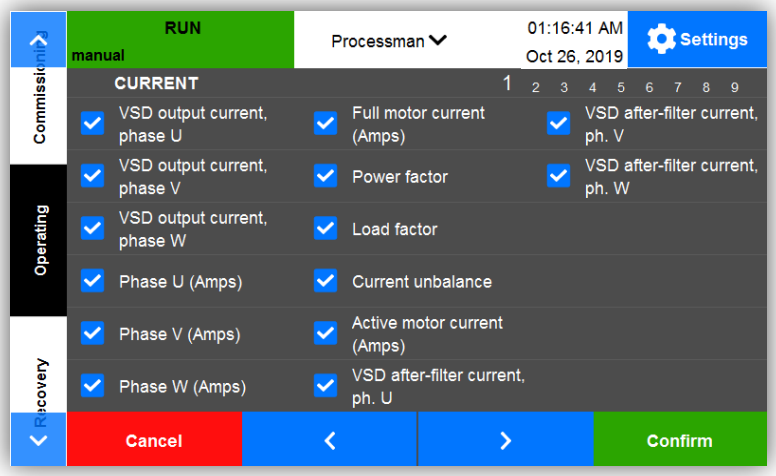


The user can independently configure the number of parameters that will be displayed on the UMKA07 controller screen.

Up to 10 parameters can be displayed on the screen at the same time. Use the up and down buttons to scroll through the list.



«ADD parameter» allows to add more parameters to display. All available parameters are divided into 9 logical groups.: 1st group – Current's; 2nd group – Voltage and frequency; 3rd group – Insulation, Motor electric power, IGBT inverter temperature; 4th group – Process Parameters; 5th group – Sensors and Scada (communication status with telemetry and ACS, as well as data from them); 6th group – Discrete outputs; 7th group – Analog outputs; 8th group –

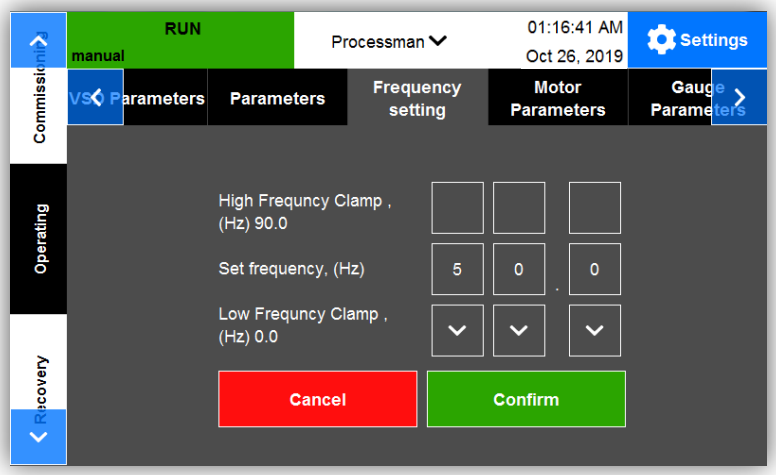


Analog inputs; 9th group – Digital inputs.

The selected parameters are added to the screen in the same sequence in which they are selected.

«Full screen» The mode allows to maximize the use of the display screen for increased number of displayed parameters.

«Frequency setting»



This menu allows you to set the output frequency of the VSD. The frequency is set by editing each of the numerical digits.

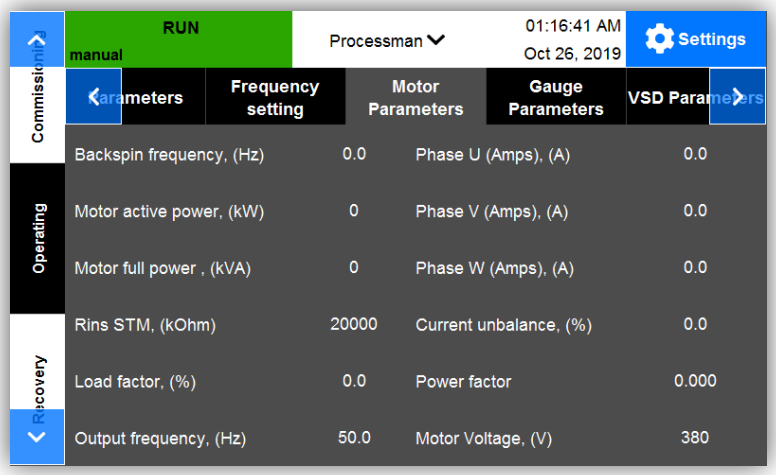
The maximum output frequency for an induction motor is limited to 90 Hz, for a PM motor 200 Hz.

In order for the reference frequency to take effect, it is necessary to press the «Confirm» button after setting the output frequency on the screen.

The «Cancel» button cancels the frequency change to the value that was set at the time the «Confirm» button was last pressed.

«Motor parameters»

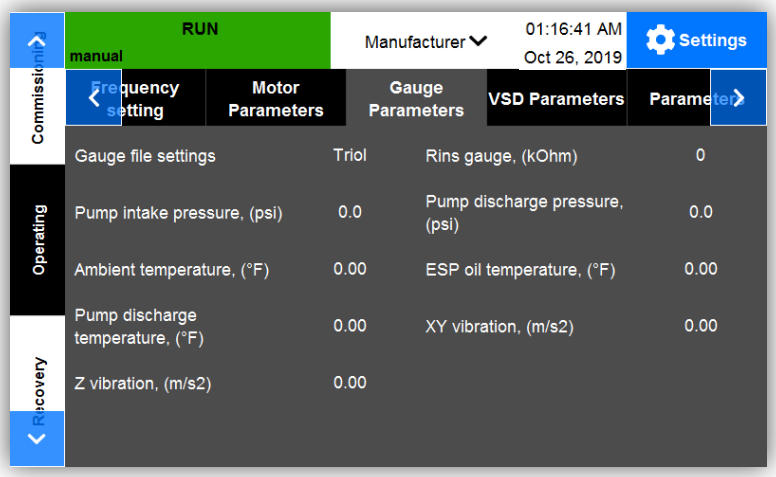
This tab displays the current values of motor parameters, such as:



- backspin frequency;
- motor active power;
- motor full power;
- insulation resistance;
- load factor;
- efficiency;
- frequency;
- phase U;
- phase V (Amps);
- phase W;
- current unbalance;
- power factor;
- motor Voltage.

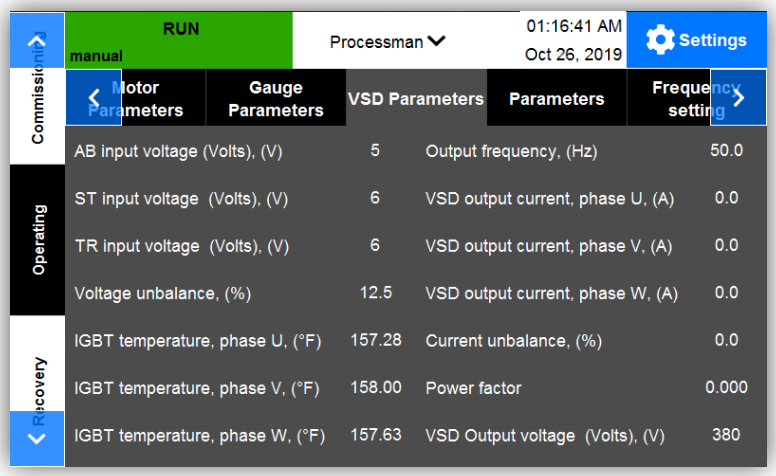
«Gauge parameters»

This tab displays the current data values from telemetry. The number and type of parameters depend on the telemetry make/model. Parameters may be as follows:



- Gauge type;
- Intake pressure;
- Amb. (Intake) temperature;
- Discharge temperature;
- Motor temperature;
- XY vibration;
- Z vibration;
- Insulation resistance.

«VSD parameters»

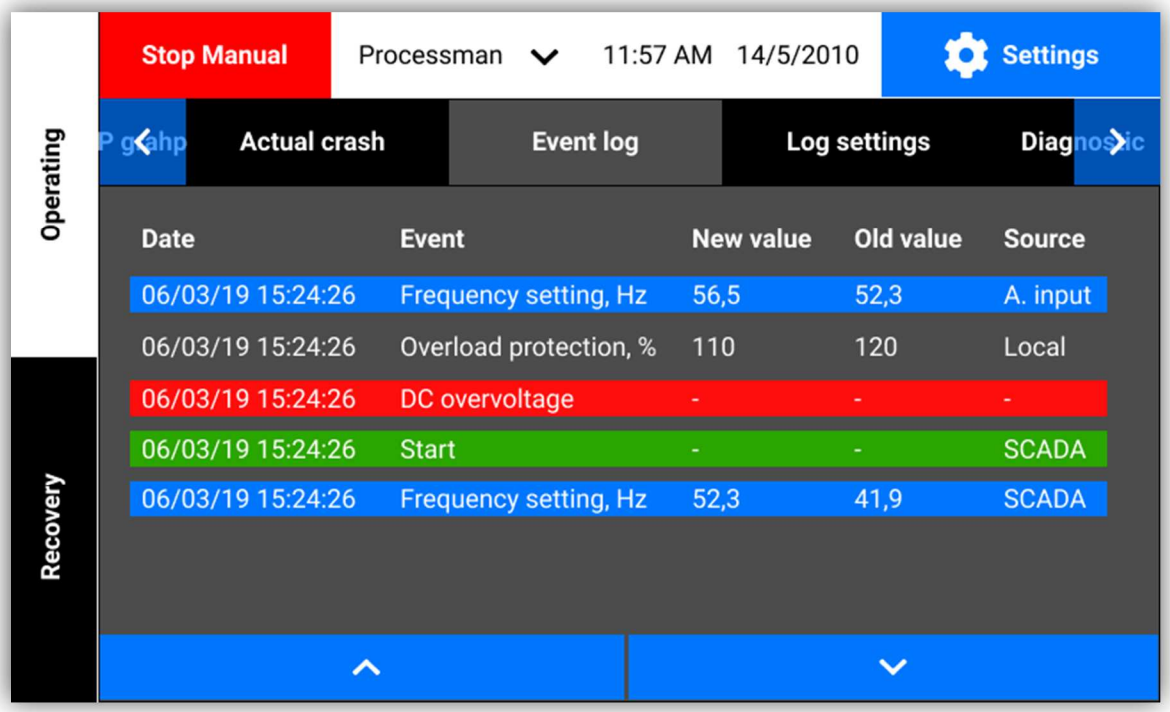


This menu displays the current values of the VSD parameters.

«Recovery» menu

This menu includes the following second-level menus:

- «Actual crash» – the list of current Alarms showing a set-point of protection value and actual value of the parameter;
- «Crash log» – the list of all shutdown events during VSD operation offering to view the operation parameter emergency values and the emergency graph with the last 4 sec parameter changes. The emergency graph includes the value of DC bus voltage, Output voltage, Output full current and Output active current;
- «Event log» – the list of all events like a Start, Stop, Shutdown, Setting changes;
- «Start-up graphs» - depicts parameter changes within 30 sec from the start;
- «Log settings» - adjusting the records period and settings of custom registers.



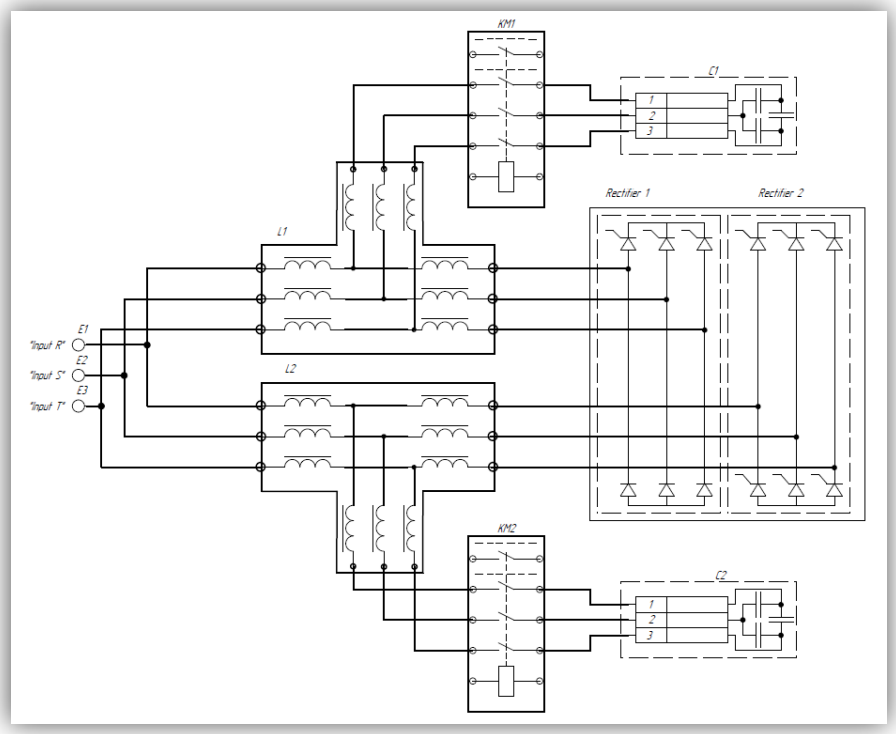
Appendix A

Modbus map

Appendix B

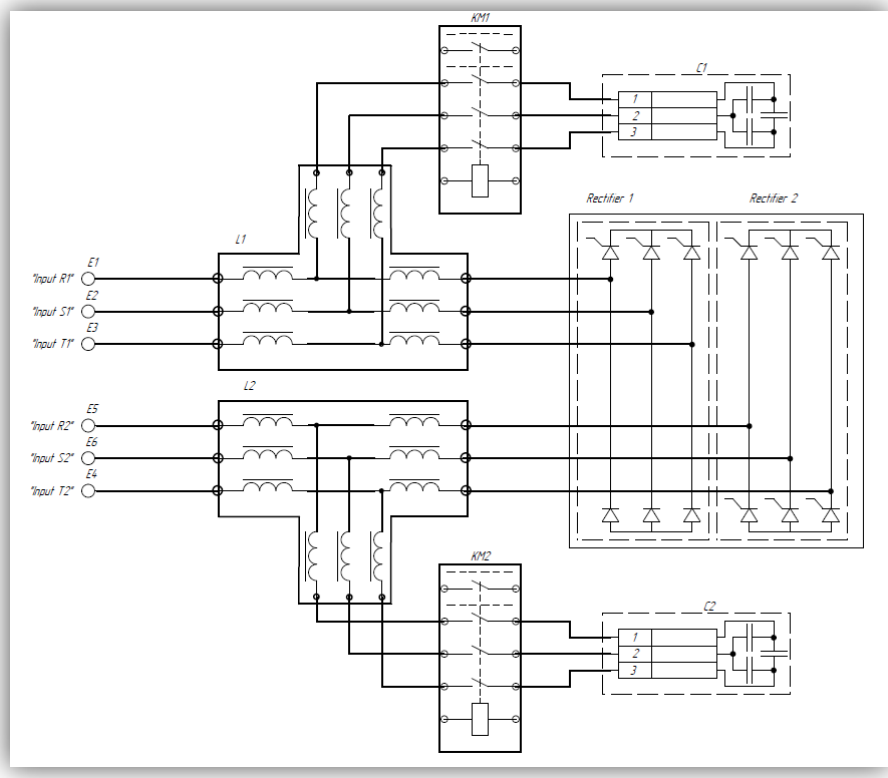
Control of the contactors PF

Algorithm description

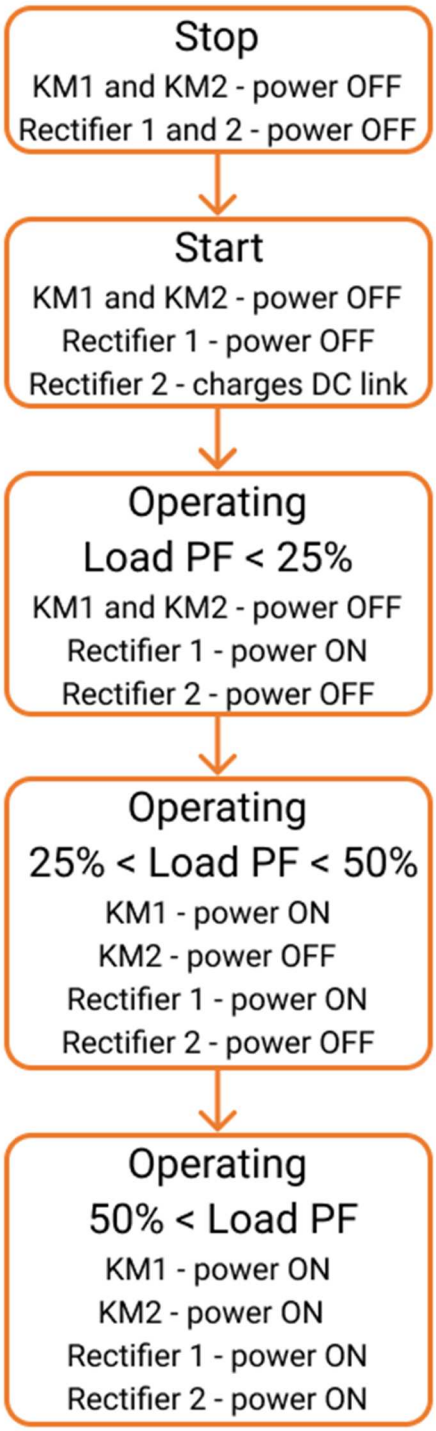


• Simplified circuit diagram of passive filter (PF) with half power mode:

Simplified circuit diagram of passive filter (PF) by 6 pulse VSD AK06-CP with half power mode.

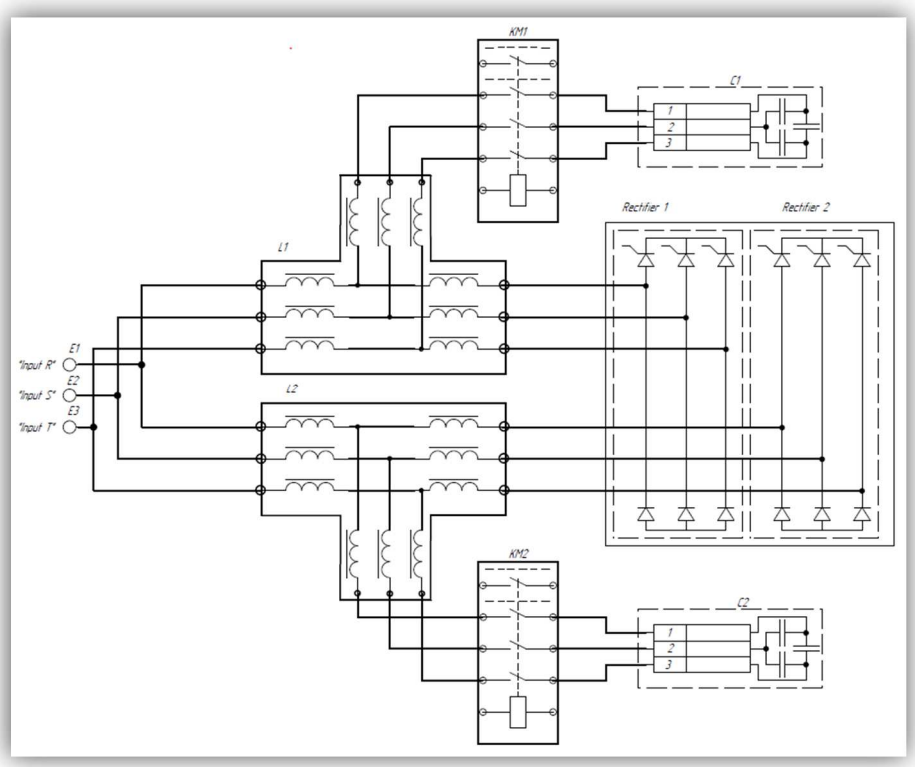


Simplified circuit diagram of passive filter (PF) by 12 pulse VSD AK06-CP with half power mode.



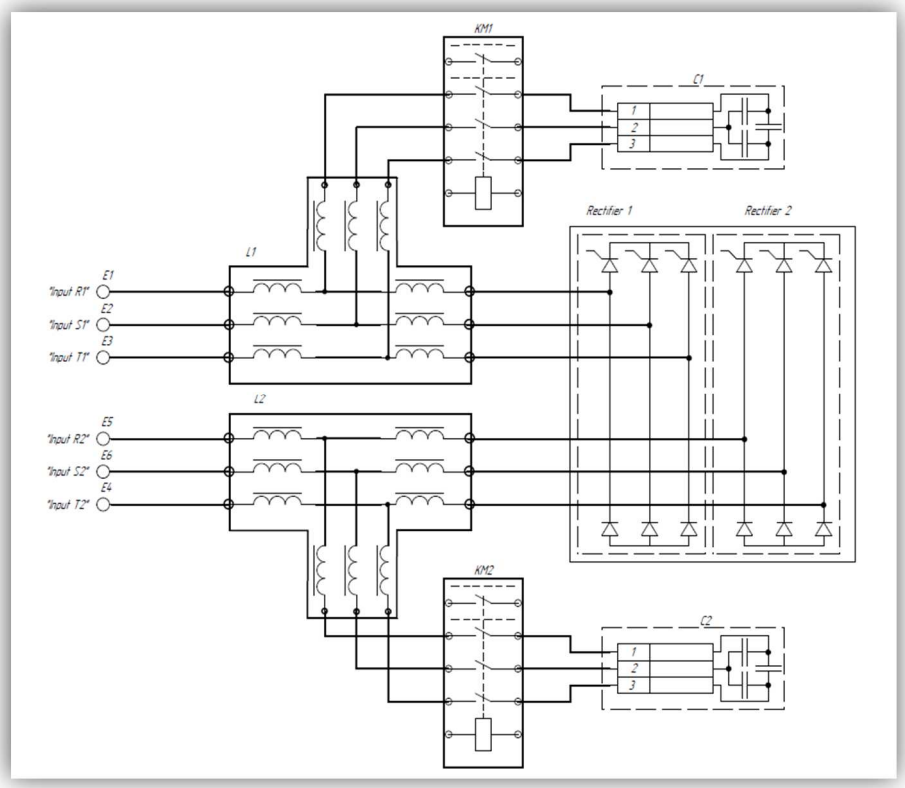
- **PF operating conditions with half power mode**:

Load PF - the total load of the rectifier by the active input current. That current is the current through the PF .

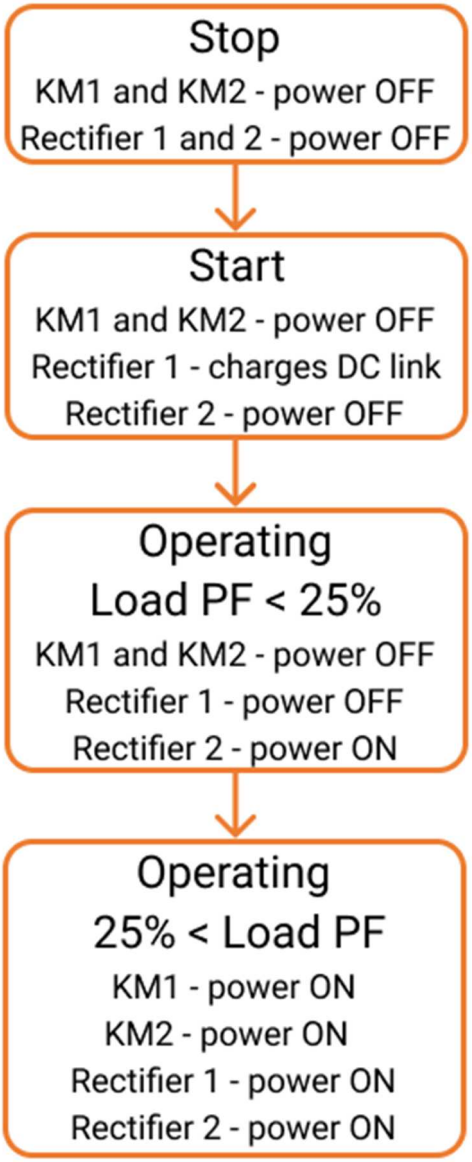


• Simplified circuit diagram of passive filter (PF) with apparent power mode:

Simplified circuit diagram of passive filter (PF) by 6 pulse VSD AK06-CP with apparent power mode.



Simplified circuit diagram of passive filter (PF) by 12 pulse VSD AK06-CP with apparent power mode.



- **PF operating conditions with apparent power mode:**

Load PF - the total load of the rectifier by the active input current. That current is the current through the PF .