COMBIVERT

F5 S.C.L.

GB INSTRUCTION MANUAL **Sensorless Closed Loop ab V1.1**

00.F5.EEZ-K110

KEB

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1. General

S.C.L. means Sensorless Closed Loop and describes the encoderless operation of three-phase current synchronous motors at the KEB COMBIVERT.
The principle is based on a mathematical model of the synchronous motor. With this mathematical model the rotor position can be emulated with known motor data.
S.C.L. is not an operation mode of F5-MULTI. It is an independent software version F5E-S, which is ready to run on the hardware of F5-application controls.

This application has the following advantages:

- no encoder system in the motor
- no encoder interface in the KEB COMBIVERT
- automatic measuring function for resistance and inductance
- mass moment of inertia-dependent default setting of the speed controller

Potential applications for S.C.L.:

- Drives for heat pumps
- Compact drives for milling machines
- Marine drives
- Compressors

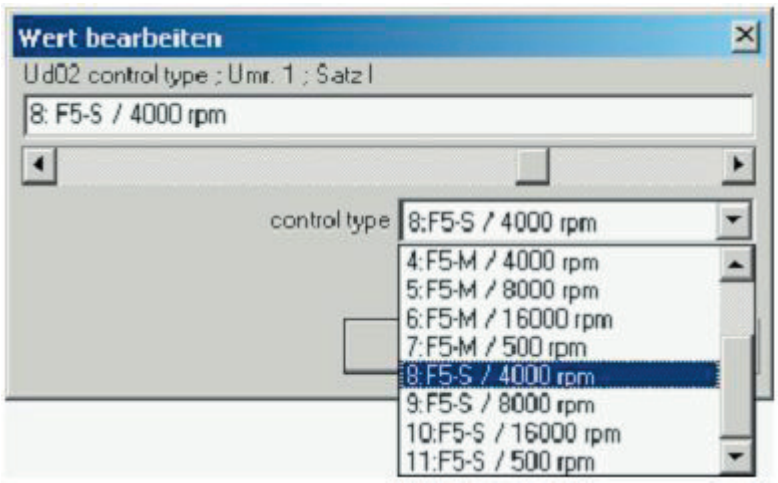
2. Initial Settings

With this software the speed of the motor can be calculated by the measured currents and the motor data (by means of a model). This calculated speed can be used as feedback for the speed controller. The necessary motor data for the model can be independently identified by the KEB COMBIVERT. Static operation at small frequencies must be avoided because the model can be unstable in this case. The usable frequency range is approx. 1:100. The speed control is deactivated at setpoint speed 0 and the motor is energized with the continuous current preset in parameter mm.10.

2.1 Activation of the encoderless operation

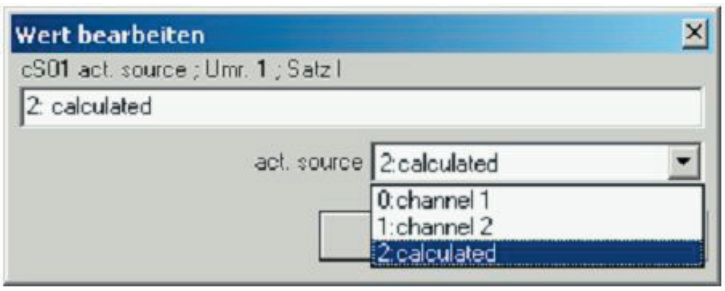
Control type (ud.02)

Parameter ud.02 (control type) must be adjusted to F5-S.



Actual value source (cs.01)

Encoderless operation is activated with cs.01 = 2 (actual speed = calculated speed).



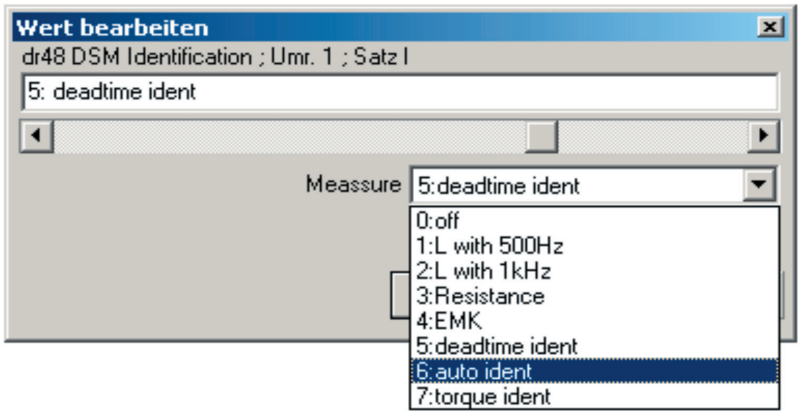
2.2 Input of the motor data

The following parameters are important for the parameterizing of the motor model:

dr.23 DSM rated current
dr.24 DSM rated speed
dr.25 DSM rated frequency
dr.26 DSM EMC voltage constant
dr.30 DSM winding resistance
dr.31 DSM winding inductance

The data for the motor model are calculated after operation of fr.10.

3. Identification of the motor data (dr.48 DSM identification)



The required data for the motor model can be automatically determined by the KEB COMBIVERT. Apart from the single functions also an automatic mode for the complete identification of the most important parameters is available.

3.1 Automatic mode

The automatic mode is started by dr.48 = 6 and following modulation release. By this the resistance, the inductance and the dead time characteristic are automatically determined for all switching frequencies. Therefore the KEB COMBIVERT gives test signals to the motor. The current which flows during parameter identification is limited by the motor rating current (dr.23). This motor rating current must be correctly entered before the calibration starts.

3.2 Resistance identification

The resistance identification is started by dr.48 = 3 and following modulation release. After identification the resistance value is displayed in dr.30.

3.3 Inductance identification

The inductance should be identified with a measuring frequency of 1 kHz (dr.48 = 2) in ideal case. The measuring current is the motor rating current. If the motor rating current cannot be achieved with the measurement, then the measuring frequency is automatically switched to 500 Hz. Even if the rated current is not achieved with this measurement, it is measured with the maximal possible current.
The inductance identification is started by dr.48 = 2 and following modulation release. After identification the inductance value is displayed in dr.31.

3.4 EMC Voltage constant

If the EMC voltage constant is unknown an approximate value can be calculated first of rated current and rated torque. For this dr.48 is adjusted to 4 when the modulation is switched off.
The exact value of the EMC constant can be re-measured during operation above 2/3 of the rated motor speed. The measurement is released by dr.48 = 4. For this the EMC adaptation with mm.00 Bit 7 must be active (default value). The identified value is displayed in dr.26.

The actual torque in the F5-S mode is generally calculated dependent on the EMC.

3.5 Determination of the dead time characteristic of the power modules

The dead time characteristic is measured in each case for the actual switching frequency, if this was selected by dr.48=5 and control release. It is possible to deposit a characteristic in the unit for each switching frequency. These characteristics can be read out via In.39 and In.40. The measured characteristic becomes active with uf.18=3 (auto Ident).

3.6 Read-in torque offset of the drive

The torque offset of the complete drive can be calibrated during no-load operation. After dr.48 = 7 and modulation release the drive accelerates with the adjusted ramp in dr.57 to a rated speed factor of 1,3. The speed limits of the oP parameters are effective. The calibrated no-load torque thereby is stored. During operation display ru.12 is corrected with this characteristic. The torque characteristic is stored in dr.58 and dr.59.

3.7 End of the identification and error messages

After completion of the identification dr.48 must be reset to value 0, otherwise the measurement is started again with each control release. The identified data are accepted by fr.10.

During the identification status "calculate drive data (cdd)" is displayed.

After completion of the identification status "calculate drive data ready (cddr)" is displayed.

Error "error calculate drive data (E.cdd)" is triggered if the measured values for resistance and inductance are not inside the valid range.

4. Adjustment of the speed controller

4.1 Default setting of the speed controller

The speed controller can be preset with known mass-moment of inertia. New dr-parameters are created for this. The mass moment of inertia of the entire system (motor + rigidly coupled load) must be registered in dr.49. If the mass moment of inertia is unknown, then it can be determined as described in 4.2.

The desired control characteristic can be preset in dr.50 with setting of value 2 for (hard controller) to 10 for (soft controller). If the motor adaption was executed next with Fr.10, the values for the speed controller are entered into parameters S.06 and S.09. If the controller parameters should not be overwritten, dr.50 must set to 19 (off) (default value).

4.2 Determination of the mass moment of inertia

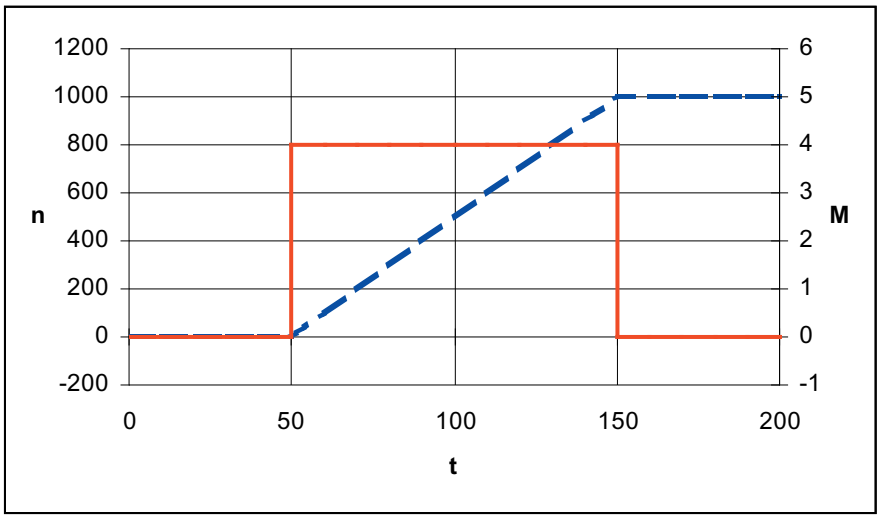
If the moment of inertia of the system is unknown, it is possible to determine it with an acceleration test. For this the system must be accelerated with defined, constant torque. It must be guaranteed that no significant and acceleration-independent load torque occurs by the application.

The following formula is valid:

$$J_L = M * \frac{\Delta t}{\Delta v} \qquad \text{dr.49 [kg cm}^2\text{]} = M\,[\text{Nm}] * \frac{\Delta t\,[\text{s}]}{\Delta v\,[\text{rpm}]} * 95493$$

Example: A drive was accelerated in 100 ms with 4 Nm up to 1000 rpm.

$$\text{dr.49 [kg cm}^2\text{]} = 4\,\text{Nm} * \frac{0{,}1\,\text{s}}{1000\,\text{rpm}} * 95493 = 38{,}2\ \text{kg cm}^2$$



5. Motor start

Starting the motor as well as operation at small speed is a critical range which should be passed very fast. The size of this range cannot be indicated universally valid. It is strongly dependent on the used motors. The usable

speed range is approx. 1:100.

Two modes exist for the start:

5.1 Starting with standstill current

Standstill current (mm.10)

After switching the control release the motor is supplied with continuous current which aligns the rotor into its correct position. This standstill current can be adjusted in parameter mm.10. In order that this threading procedure occurs as gently as possible, the current is not suddenly preset. The current is increased by a ramp. The time for this ramp is the half value of parameter Pn.35 (premagnetizing time).
The standstill current must be selected in such way, that a rotor motion is also possible with load.
Half of the current-dependent load torque is acceptable as mechanical load (e.g. 1/4 of the rated torque at 1/2 rated current at standstill).

Stabilization current (mm.01)

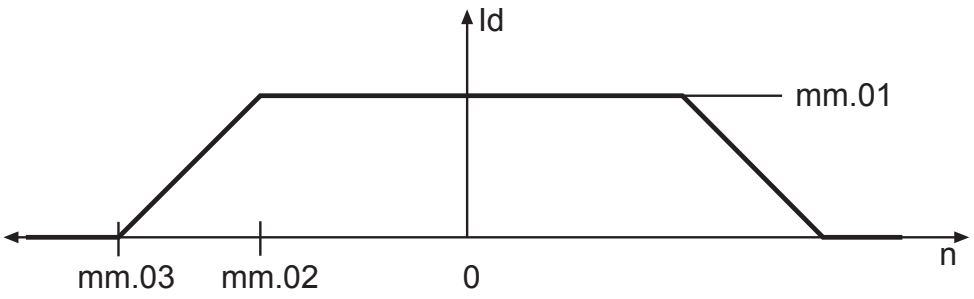
An additional stabilization current (parameter mm.01) can be preset during the starting phase (operation with small speed). This is a reactive current, which has no affect to torque-generation. It only affects stabilizing to the motor model.

Lower speed limit / stabilization current (mm.02)

mm.01 is active from speed 0 up to this limit.

Upper speed limit / stabilization current (mm.03)

No current is necessary for stabilization above this limit. The stabilization current is linearly decreased between lower and upper speed limit.



Starting ramp (mm.08, mm.09)

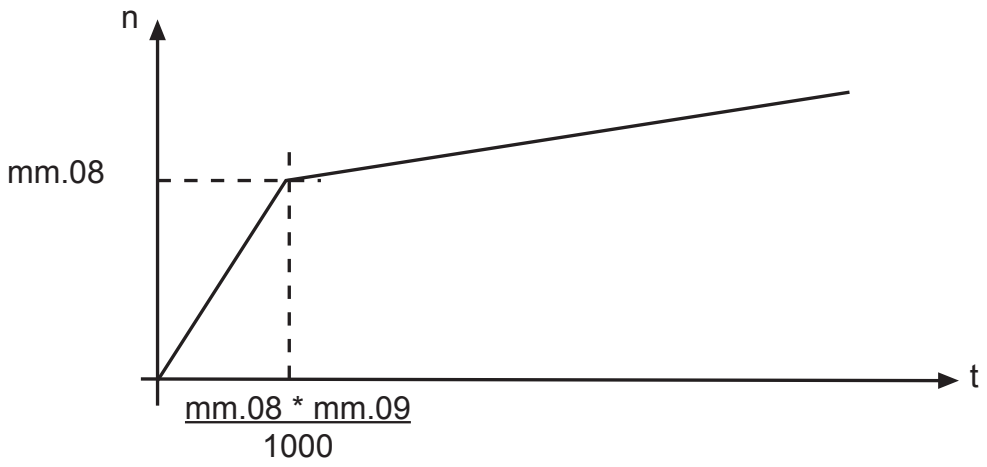
In order to leave the lower speed range during starting as fast as possible, a ramp is installed which has priority against the ramp generator in the OP parameters.

Starting ramp / speed (mm.08)

An additional speed ramp is active up to this speed.

Starting ramp / time (mm.09)

Acceleration/deceleration time for the starting range. The time refers to a speed change of 1000 rpm in the operating mode 4000 rpm.



5.2 Starting with speed search function

If the motor rotates when the modulation is switched on, the actual speed can be determined with the speed search function (SSF). Next the drive accelerates to the adjusted setpoint speed.

Activation of the speed search function:

The speed search function is activated by Pn.26. The brake control of Pn.34 must not be deactivated. If the motor rotates only with low speed during speed search, starting occurs automatically as described under point 5.1.

6. Model-specific parameters

A new parameter group was created with the mm parameters. The following described parameters have a factory-installed initial setting. A change of these values is not absolutely necessary.

Parameter mm.00 Adjustments

Bit	Meaning	Explanation
0	Align and stabilization current off / on	Activation of mm.01 and mm.10
1	Model stabilization off / on	Serves for regulation of the model
2	RS Adaption off / on	Regulates the model at low setpoint values
3	Speed source	0: Encoder 1
		1 : Model
		For test purposes the model can be operated with the values of encoder 1.
4	High-speed model	This model is especially reasonable at larger frequencies.
5	Observer high-speed model	Serves for regulation of the high-speed model
6	Current controller with	0: measured current
		1 : Model currents
7	Adapt EMC voltage constant off / on	Activates the adaptation of the EMC voltage constant
8	Current offset adaption off / on	Current offset adjustment during operation
9	Starting without model off / on	

Speed calculation / time (mm.04)

Time for speed calculation.

Speed calculation / filter (mm.05)

Filter for the calculated speed.

RS Adaption factor (mm.06)

This value affects the resistance adaptation and thereby the behavior during load transfer and small speeds.

Observer influence (mm.07)

For the adjustment of the observer.

7. Example

The start-up steps and the application of S.C.L. are described in the following programming example.

Start-up steps F5-SCL at synchronous motors

- activate F5E-S parameter configuration with ud.02 = 8-11
- initialize parameter with Fr.01 = -4 (default values)
- enter motor data (dr.23 to dr.28)
  An approximate value for EMC can be calculated with dr.48 = 4, if the EMC is unknown
- execute auto identification with dr.48 = 6
- switch on dead time compensation uF.18 = 3
- activate adaption to the motor with Fr.10 = 1 or 2
- determine and preset mass moment of inertia if necessary. Activate Fr.10 = 1 or 2 again
- determine no-load characteristic and identify EMC if necessary. Activate Fr.10 = 1 or 2 again
- Adaption of the remaining parameters to the application
- Test run for a check of the adjustment and wiring

8. Parameter overview

Para.	Addr.	RO	PG	E	Min. value	Max. value	Step range	Default
cs.01	0F01h	-	x	-	0	2	1	0
dr.48	0630h	-	-	x	0: off	7	1	0
dr.49	0631h	-	-	-	0,05 kgm^2	21474836,47 kgcm^2	0,01 kgcm^2	1 kgcm^2
dr.50	0632h	-	-	-	1,9	10,0	0,1	1,9 : off
dr.57	0639h	-	-	-	0 s	300 s	0,01 s	10 s
dr.58	063Ah	-	-	x	0	19	1	0
dr.59	063Bh	-	-	-	-320 Nm	320 Nm	0,01 Nm	0 Nm
In.20	0E14h	-	-	x	0	34	1	0
In.39	0E27h	-	-	x	0	329	1	0
In.40	0E28h	-	-	-	0	255	1	0
Pn.26	041Ah	-	x	x	0	31	1	0
mm.00	1400h	-	-	-	0	1023	1	191
mm.01	1401h	-	-	-	0,0A	In.18*1,25	1	dr.23/2
mm.03	1403h	-	-	-	0 rpm	32000 rpm	1 rpm	dr.24/8
mm.04	1404h	-	-	-	0,0 ms	8191,875 ms	0,125 ms	0,125 ms
mm.05	1405h	-	-	-	0,0 ms	8191,875 ms	0,125 ms	1 ms
mm.06	1406h	-	-	-	0	65535	1	100
mm.07	1407h	-	-	-	0,0 %	27,5 %	0,01 %	2 %
mm.08	1408h	-	-	-	0 rpm	4000 rpm	0,125 rpm	0 rpm [1)]
mm.09	1409h	-	-	-	0,01 s	300 s	0,01 s	5 s
mm.10	140Ah	-	-	-	0,0A	In.18*1,25A	0,1A	dr.23/2

[1)]: depending on ud.2/ indication for ud.2 = 8
RO: Read only parameters (read only)
PG: Programmable parameters
E: Enter-Parameter

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