ABB INDUSTRIAL DRIVES

ACS880 Synchronous machine control

Application guide

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Introduction to the manual

Contents of this chapter

This chapter contains information on the applicability, safety and target audience of the manual. It contains a list of related manuals for more information, and a list of terms used in this manual.

Applicability

This document is applicable to the externally magnetized synchronous machine control of ACS880 drive, later in this document referred to as ACS880 LV-Synchro. This applies to version 3.10 and later.

Safety

WARNING!
Obey the safety instructions of the drive. If you ignore them, injury or death, or damage to the equipment can occur.

If you are not a qualified electrician, do not do installation or maintenance work.

Depending on the drive type, you can find the safety instructions either in the drive hardware manual (ABB single drive cabinets and modules), or in the separate safety instructions manual (ABB multidrive cabinets and modules).

Target audience

This document is intended for people who design, commission, or operate the drive system.

Related documents

Name	Code
Hardware manuals	
ACS880-107 inverter units hardware manual	3AUA0000102519
Firmware manuals	
ACS880 Primary control program firmware manual. This document is valid for synchronous machine if otherwise not stated in ACS880 LV-Synchro supplement (chapter 4 of ACS880 synchronous machine control application guide (3AXD50000373581 [English]).	3AUA0000085967
ACS880 synchronous machine control application guide	3AXD50000373581
DCS880 firmware manual	3ADW000474R
Safety manuals	
ACS880 multidrive cabinets and modules safety instructions	3AUA0000102301
Option manuals	
Drive composer start-up and maintenance PC tool user's manual	3AUA0000094606
Manuals and quick guides for I/O extension modules, fieldbus adapters, etc.	

Terms and abbreviations

Term/ abbreviation	Definition
ACS-AP-I	Industrial assistant control panel
ACS-AP-W	Industrial assistant control panel with Bluetooth interface
AI	Analog input; interface for analog input signals
AO	Analog output; interface for analog output signals
DC link	DC circuit between rectifier and inverter
DCU	Drive control unit
DI	Digital input; interface for digital input signals
DO	Digital output; interface for digital output signals
DSU	Diode supply unit
EXU	Excitation unit
FWP	Field weakening point

Term/ abbreviation	Definition
IGBT	Insulated gate bipolar transistor; a voltage-controlled semiconductor type widely used in inverters and IGBT supply units due to their easy controllability and high switching frequency
INU	Inverter unit
ISU	An IGBT supply unit; type of supply unit implemented using IGBT switching components, used in regenerative and low-harmonic drives.
OL	Overload
SM	Synchronous machine

Cybersecurity disclaimer

This product is designed to be connected to and to communicate information and data via a network interface. It is Customer's sole responsibility to provide and continuously ensure a secure connection between the product and Customer network or any other network (as the case may be). Customer shall establish and maintain any appropriate measures (such as but not limited to the installation of firewalls, application of authentication measures, encryption of data, installation of anti-virus programs, etc) to protect the product, the network, its system and the interface against any kind of security breaches, unauthorized access, interference, intrusion, leakage and/or theft of data or information. ABB and its affiliates are not liable for damages and/or losses related to such security breaches, any unauthorized access, interference, intrusion, leakage and/or theft of data or information.

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General description

Contents of this chapter

This chapter describes the operating principle and requirements of ACS880 LV-Synchro.

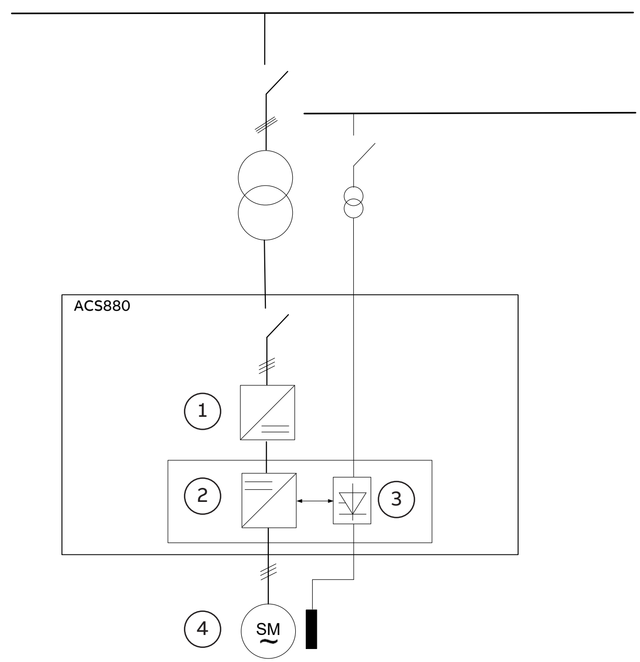
ACS880 LV-Synchro

ACS880 LV-Synchro is an option for ACS880 multidrives inverter offering. Its control is based on ACS880 primary control software. The main difference between ACS880 LV-Synchro and other machine control modes is the rotor current, which in ACS880 LV-Synchro is supplied to rotor from excitation unit EXU through brushes.

Externally magnetized variable speed synchronous machines are used in a variety of applications in industry, transportation and utilities sectors. Typically synchronous machines (SM) and SM drives are used:

- When electrical machine is so large that induction machine cannot be manufactured (~700 mm shaft height or larger).
- With diesel aggregates, which need to be able to generate charging energy for converter DC circuit.
- With diesel aggregates with direct on line by-pass connection.
- When smaller machine with longer field weakening area is beneficial compared to standard induction machine solution.
- When customer for any reason prefers synchronous machine.

A principal diagram of a synchronous machine drive

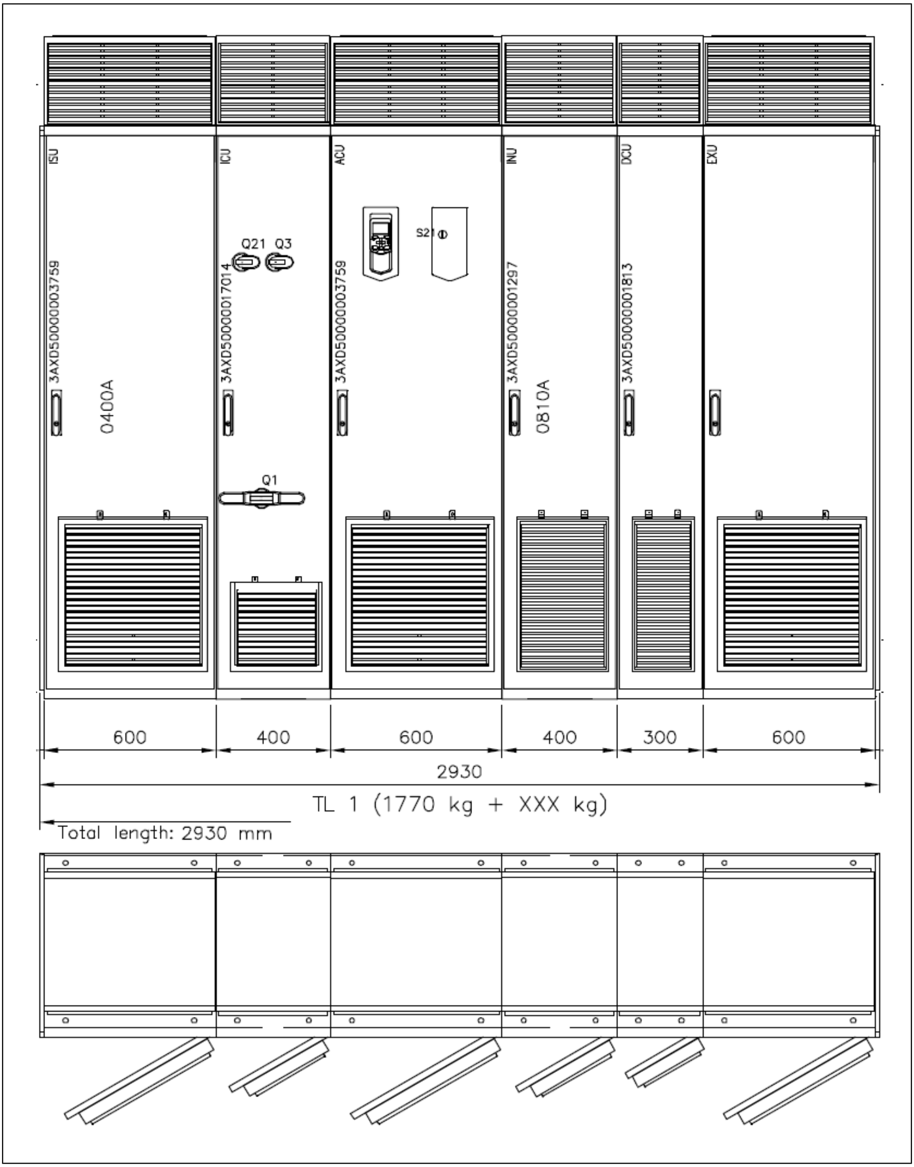


1	Supply unit
2	Inverter unit
3	Excitation unit
4	Synchronous machine with external excitation

ACS880 with LV-Synchro can be delivered with excitation unit EXU, or excitation can be arranged by customer. The non-ACS880 excitation rectifier can be used if it fulfills following requirements:

- It can be started/stopped by ACS880
- It can send to drive feedback of running status
- It can follow excitation current reference
- It can send to drive feedback of pole current actual value

Below is an example dimensioning drawing of a synchronous machine converter. The three leftmost cabinets listed from left to right are: supply unit, incoming unit and auxiliary control unit. The three rightmost cabinets listed from left to right are: inverter unit INU, drive control unit DCU and excitation unit EXU.



Main components

Synchronous machine drive consists of the following main components:

- IGBT supply unit (ISU), diode supply unit (DSU) or regenerative rectifier supply unit (RRU)
- Inverter unit (INU)
- Excitation unit (EXU)

Most of ACS880 options are available for ACS880 LV-Synchro.

Note: SM drive as standard without any additional options does not have any machine or project related control or supervision functions such as lubrication unit control, machine cooling/heating control, machine/transformer temperature supervision etc.

Interface

User interface

All the necessary communication to upper level takes place through INU (EXU fault and status bits are included in INU fault/status words).

EXU can be equipped with bus communication only for monitoring purpose. EXU control is taken care by INU.

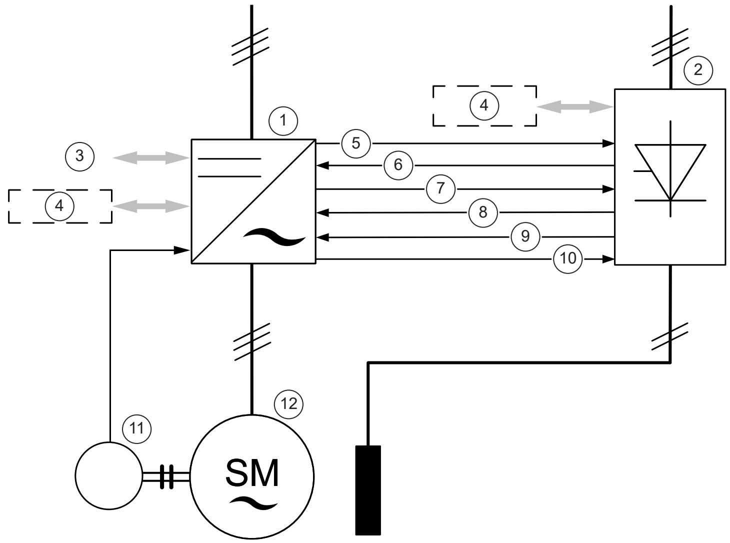
All converter units can be parametrized via ACS-AP-I or ACS-AP-W control panels or via Drive Composer Pro SW as described in the respective manuals.

Communication between components

Communication between EXU and INU is done hard wired to achieve sufficient bandwidth for excitation control. INU HW signals are:

- DO to start or stop and reset EXU
- DI for EXU running status
- AO for excitation current reference
- AI for excitation current supervision and control feedback

Communication between INU and EXU units



1	Inverter unit (INU)	7	Current reference
2	Excitation unit (EXU)	8	Current status
3	Customer interface	9	EXU fault
4	Control panel	10	Reset
5	Run command	11	Encoder
6	Run status	12	Synchronous machine

Signal	**EXU**		**INU**
Excitation current reference	AI1	←	AO1
Excitation current actual value	AO1	→	AI1
Start excitation	DI1	←	RO3
Excitation on (RDY ref.)	RO3	→	DI5
Excitation unit fault	RO2	→	DI6
Excitation unit reset	DI6	←	RO2

INU

Inverter unit must have as options MU license +N8052 for ACS880 multidrives for LV-Synchro for nxR8i, and an excitation unit cabinet.

In addition to other ACS880 motor control modes ACS880 LV-Synchro takes care of the following functions:

- Start, stop, supervision and reset of the excitation unit
- Machine model based flux and torque control
- Machine saturation model
- Excitation current reference calculation
- Autophasing function

The structure of a converter is described in HW manual.

ACS880 EXU for machines with brushes and slip rings

Excitation unit has to be equipped with a dedicated power supply, which is independent of power supply for the drive. Often it is expedient to equip excitation supply with a transformer to decrease reactive power and voltage stress for excitation winding.

Only excitation via brushes and slip rings is supported by ACS880 LV-Synchro.

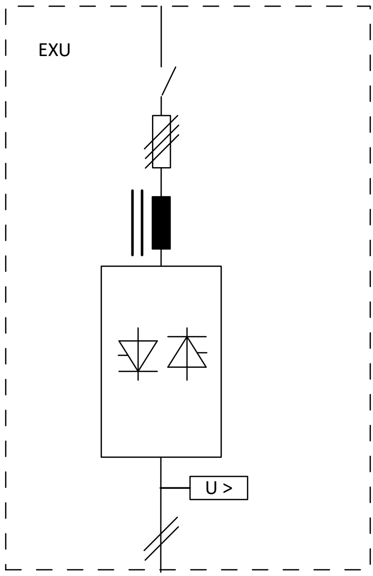
ACS880 EXU is manufactured in three different sizes:

- 500 A / 525 V (100…525 VAC) 600 mm wide
- 1000 A / 525 V (100…525 VAC) 800 mm wide
- 900 A / 690 V (315…690 VAC) 800 mm wide

The main components of EXU are:

- Main switch
- Fuses
- Commutation choke
- 4Q DC rectifier
- Overvoltage protection (crow bar)

Note: EXU does not include excitation transformer.



In selection of a suitable excitation unit the following issues must be considered:

Required torque response

- In case of low or moderate requirements for torque response typical EXU voltage selection is 525 V. Secondary voltage of the excitation transformer (not a part of EXU) is recommended to be selected so that amplitude of the main voltage is roughly 20% higher than the maximum excitation voltage. Selecting excitation voltage this way reactive current is minimized and control resolution improved.
- In case of increased requirements for torque response typical EXU voltage selection is 690 V. Secondary voltage of the excitation transformer can be increased to have faster excitation response. However the machine pole winding must withstand the highest excitation voltage.

Installation directions

- Cabling from both top and down are supported

Cooling media

- Both liquid and air cooled EXU cabinets are available

Functional safety

Following factors must be taken into consideration in designing functional safety functions of LV-Synchro.

- Safe torque off -function prevents the firing pulses from inverter unit
- Emergency stop stops the drive with selected emergency stop mode.

It is important to notice that neither of the functions must not be wired to stop the excitation unit directly. Inverter unit is let to run the flux down actively for 3 s before stopping the excitation unit. This enables fast flux de-energization and prevents possible overvoltages due to sudden disappearing of machine anchor reaction.

If it is necessary to act otherwise, the need of additional braking chopper must be considered.

Other functional safety factors of LV-Synchro follow the information provided in *ACS880 Primary control program firmware manual* (3AUA0000085967 [English]).

Encoder requirements

Encoder

ACS880 LV-Synchro needs to know rotor pole direction. For this purpose the machine has to be equipped with an encoder. After installation of the encoder, the encoder zero angle position is in arbitrary direction. To use the encoder signal for control purpose the encoder zero angle direction in relation to pole direction has to be defined and given to the control. For this purpose SW includes a function called autophasing (see more below).

The angle between rotor and encoder must be known by the drive. When the converter starts while the machine is rotating, standstill autophasing cannot be done at start. In these cases the absolute encoder or incremental encoder with zero pulse has to be used. Encoder zero channel is typically marked with ZZ or NN.

Encoders have two functions:

- Speed measurement for speed control
- Position measurement for machine control

Both functions set their own requirements for encoder resolution.

Supported encoder types

All encoder types supported by FEN encoder interface modules are compatible with ACS880 LV-Synchro. The detailed information about encoder parametrizing can be found in *ACS880 Primary control program firmware manual* (3AUA0000085967 [English]).

Autophasing

Autophasing (also called as positioning) is a function which determines and stores the rotation angle measured by encoder in relation to the physical rotor angle. The autophasing function must be run after encoder installation. In case an incremental encoder is used autophasing must be executed after every power on. The autophasing functions supported by ACS880 LV-Synchro are:

- **Turning autophasing** (Rotor is magnetized while stator winding is supplied with DC current in order to turn the rotor to the flux direction)
- **Standstill autophasing 1** (Current pulse is supplied to rotor, and induced stator current is measured. SW calculates the rotor angle from this measurement)

Note: Both supported methods are automatized.

The autophasing functions are described in *ACS880 Primary control program firmware manual* (3AUA0000085967 [English]). There are also instructions how to select autophasing method and run it.

Position detection

Encoder must satisfy the requirements for position detection accuracy set by machine control. The minimum resolution requirement is one pulse per an electrical degree of machine. When the number of pole pairs is notated with p, ticks per revolution with N and bit number with n, the requirement can be written

$N = 2^n \geq 360 * p$

Pulse number N and corresponding bit number n bit for most typical pole pairs are presented in the following table.

p	n	N
2	10	1024
4	11	2048
6	12	4096
8	12	4096
12	13	8192
16	13	8192
24	14	16384
48	15	32768
60	15	32768

Basic design requirements for synchronous machine

Variable speed machine design shall comply with IEC TS 60034-25:2014 *Rotating electrical machines - Part 25: AC electrical machines used in power drive systems - Application guide*.

Rotor structure can be salient or cylindrical type. It is preferred to have salient pole synchronous machine. It is required to have laminated rotor construction and complete mechanically robust damper winding. Damper winding must have galvanic connections between poles. Excitation circuit must be connected via brushes to external DC power supply.

In converter supply, the following side effects must be considered:

- Some additional noise will be created by the converter pulse mode voltage
- Some additional losses will be created by the converter pulse mode voltage
- Some additional damper winding stress (thermal, mechanical) will be created by the converter pulse mode voltage
- Fluctuating common mode voltages are created due to converter topology
- Converter can run the machine far above the rated machine speed, therefore maximum mechanical speed must be checked

Machine rated voltage range

Voltage at the max overload (frequent or occasional) above FWP shall not exceed the inverter maximum fundamental output voltage, which is $U_{dc}/1,73$ where notation U_{dc} means voltage in converter intermediate circuit.

According to IEC 60034 the machines are to be designed to operate at rated point irrespective of the control settings.

Pole number, frequency and speed range

Limitation of available frequency range and requirements of specific application must be considered when selecting most suitable pole number of the machine.

Minimum rated frequency (= rated voltage, field weakening point) must be higher than 4.00 Hz. If lower rated frequency is needed, contact ABB.

Machines shall be designed for operating within complete speed range. Overspeed shall be 120% of maximum operational speed.

Machine rated excitation voltage selection

Maximum excitation voltage depends on the maximum overload. Excitation current at maximum overload shall not exceed the value If (%) = Max. OL (%) + 20% (referred to rated excitation current).

In machines having excitation via slip ring unit (excitation with brushes), the slip ring unit has to be designed to be able to withstand the required field voltage and current defined above. Supply unit for excitation power is typically DCS880 DC converter.

Machine overloadability and load angle

At any defined overload point at any speed within operational speed range the machine load angle must be limited to maximum 55 degrees.

Machine insulation requirements

Due to the operation principle of the converter the machine must withstand special voltage waveforms including rapid du/dt effects. These voltage change effects set demands on the winding insulation, stator-winding design, impregnation etc. Therefore insulation for machine in converter use has to be stronger than in sinusoidal supply.

Winding has to withstand pulse voltage stresses according to IEC 60034 -15 *Rotating electrical machines – Part 15: Impulse voltage withstand levels of form-wound stator coils for rotating a.c. machines*.

Required machine data

Rated data to be included in the machine quotation

Topic	Notation	Value / Description	Unit
Machine type		Synchronous Machine	
Stator winding system		TBD* Y(3-phase), or YY(6-phase) acc. to inverter type, if YY preferably without phase shift between winding systems, galvanic isolation	
Rated Machine Power (at n_{fwp}, fundamental)	P_{M1}	TBD*	kW
Rated Machine Voltage (at n_{fwp}, fundamental)	U_{M1}	TBD*	V
Rated Machine Current (at n_{fwp}, fundamental)	I_{M1}	TBD*	A
Rated Machine frequency (at n_{fwp}, fundamental	f_{M1}	TBD*	Hz
Rated Power factor (at n_{fwp}, fundamental)	$\cos\varphi_{M1}$	TBD*	
Rated Efficiency (fundamental)	η_{M1}	TBD*	
Rated Excitation voltage		TBD*	Vdc
Rated Excitation current		TBD*	Adc
Space heater: • Voltage (V), 3ph / 1ph • Power (kW)		TBD*	
Cooling fans: • Voltage (V), 3ph • Power (kW) • Quantity (pcs)		TBD*	
Inertia	J_M	TBD*	kgm^2
Weight	m_M	TBD*	Kg
Dimensions		TBD*	
Cooling water flow		TBD*	m^3/h

* To Be Defined (in machine tender)

Operation points

Machine manufacturer shall during basic engineering (as soon as preliminary values are available) inform machine currents and voltages at the following operation points. In most cases the base and field weakening speeds are the same.

Load	Speed	Speed	Power	Voltage	Current	Excita-tion	Excita-tion
		rpm	kW	V	A	Vdc	Adc
100%	base						
100%	Fwp						
100%	Max						
max. frequent OL	base						
max. frequent OL	Fwp						
Max. frequent OL	Max						
Occasional OL	base						
Occasional OL	Fwp						
Occasional OL	Max						

Machine equivalent circuit parameters

Machine manufacturer shall during basic engineering (as soon as preliminary values are available) inform machine data based on equivalent circuit of synchronous machine (see drawing below). Data shall be presented in per unit (p.u)values. The base values for the used p.u. system are based on power, voltage, currents and frequency at field weakening point. P.u. transformation is presented in appendix.

Equivalent circuit data should be at 75 °C.

These values are used in inverter machine model parametrization.

Variable speed motor parameters

Date	
Calculated by	
Our reference	
Type designation	
Project name	
Revision	

Ratings:

Field weakening point

P =		kW
U =		V
I =		A
p.f. =		
n =		rpm
f =		Hz
Ur =		Vdc
Ir =		Adc

Excitation machine

S =		kVA
U =		Vac
I =		Aac
f =		Hz

St. winding:

Connection =		
Offset of stator 2 =	n/a	deg

Rotor:

Inertia, J =		kgm2

Preferred switching frequency:		Hz

Inductancecs and resistances in the equivalent circuit **at field weakening point**
(in per unit values, referred to stator, resistances at 75° C if not stated otherwise):

Motor parameters

Stator resistance Rs		
Stator leakage inductance Lsσ		
Direct axis magnetizing inductance Lmd		
Quadrature axis magnetizing inductance Lmq		
d-axis damper winding leakage inductance LDσ		
d-axis damper winding resistance RD		
q-axis damper winding leakage inductance LQσ		
q-axis damper winding resistance RQ		
d-axis subtransient inductance Ld"		
q-axis subtransient inductance Lq"		

Time constants (in seconds):

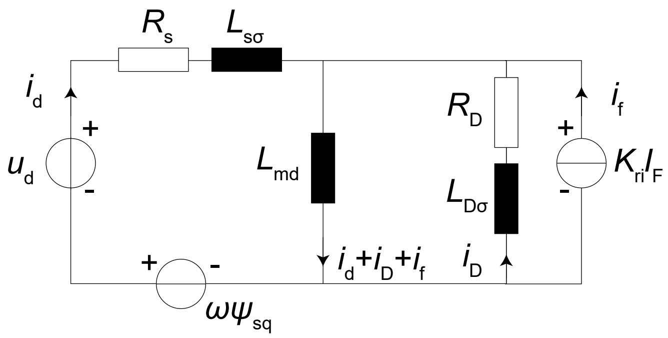
open circuit transient, d-axis Tdo´		
closed circuit transient, d-axis Td´		
open circuit subtransient, d-axis Tdo´´		
closed circuit subtransient, d-axis Td´´		
armature time constant Ta		

Stray capacitance of the winding Cs		uF
Reduction factor from rotor to stator		

Excitation machine parameters

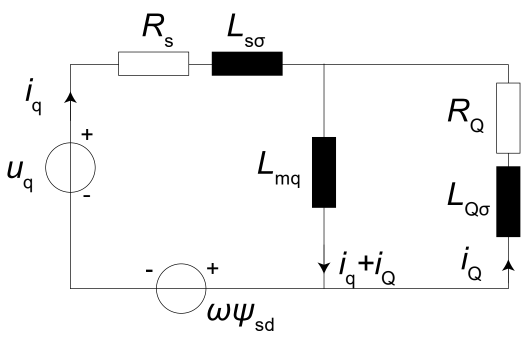
Magnetizing reactance Xe_m		Ω
Stator leakage react. Xe_ss		Ω
Reduction factor (st to rt)		

Equivalent circuit diagram on the direct-axis (d)



Parameter	Unit	Description
$L_{s\sigma}$	[pu]	Stator leakage inductance
L_{md}	[pu]	Direct axis magnetizing inductance
$L_{D\sigma}$	[pu]	Direct axis damper winding leakage inductance
R_s	[pu]	Stator resistance
R_D	[pu]	Direct axis damper winding resistance
K_{ri}		Reduction factor from rotor to stator

Equivalent circuit diagram on the quadrature-axis (q)

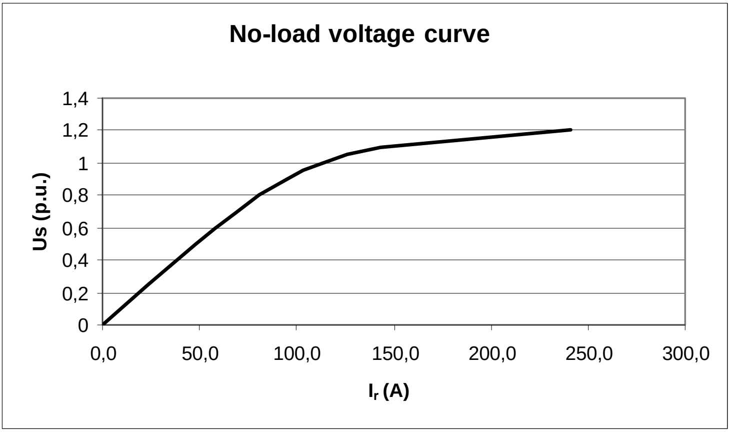


Parameter	Unit	Description
$L_{s\sigma}$	[pu]	Stator leakage inductance
L_{mq}	[pu]	Quadrature axis magnetizing inductance
$L_{Q\sigma}$	[pu]	Quadrature axis damper winding leakage inductance
R_s	[pu]	Stator resistance
R_Q	[pu]	Quadrature axis damper winding resistance

No-load voltage curve

The no-load voltage as a function of excitation current has to be included to final machine data.

Typical no-load voltage curve:



The no-load voltage curve should show U (p.u.) up to 2 x I_r rated (A or p.u.).

3

Commissioning

Contents of this chapter

This chapter describes the commissioning of ACS880 LV-Synchro. The purpose of this chapter is to guide through steps to ensure safe and reliable functioning of the system.

It is recommended to record the results of every step carried out. These will be written in commissioning report.

Note: For parameter descriptions, see *ACS880 LV-Synchro supplement (page 69)*.

Safety

Obey all safety instructions delivered with the drive.

Read the complete safety instructions before you commission the drive. The complete safety instructions are given in *ACS880 multidrive cabinets and modules safety instructions* (3AUA0000102301 [English]). Each part of the equipment may have individual instructions.

These instructions are for equipment which contains a potential hazard of electric shock and/or burn. People who have required qualification and knowledge of the equipment are allowed to do commissioning for the equipment.

Required tools for commissioning

Following softwares/tools are needed for commissioning:

Name	Remarks
Drive Composer Pro	USB cable needed
Current clamp for DC current	Needed for excitation unit testing

Preconditions for commissioning

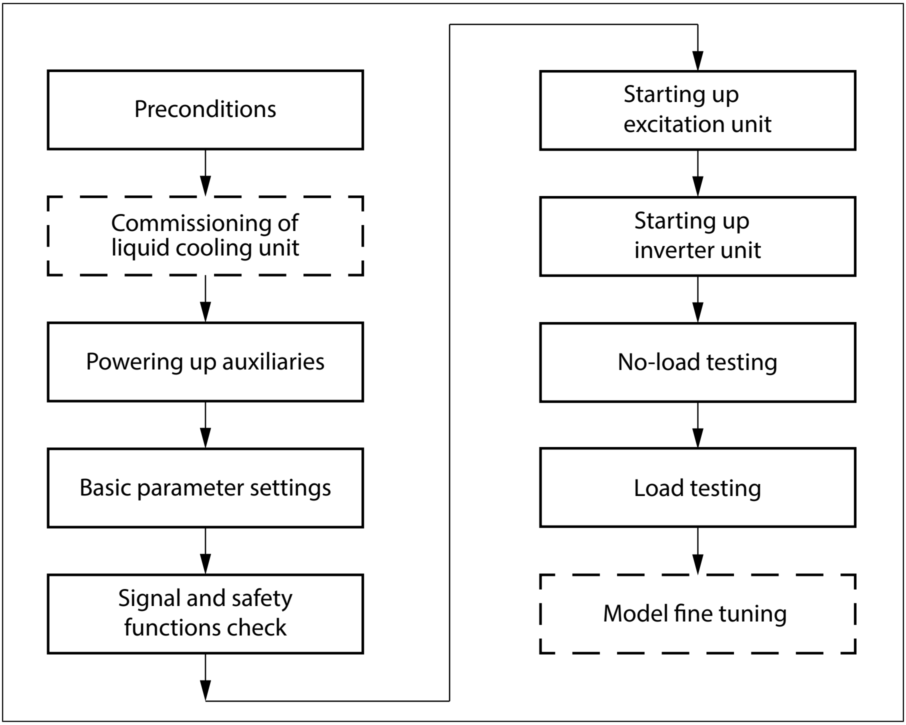
The drive must be completely installed according to local regulations and the installation must be ready to be powered up. The responsibility of proper installation belongs to installation owner. Make clear responsibilities and thus mitigate risks of juridical consequences in case of incidents due to improper installation. It is highly recommendable to require literal statement of safety and completion of installation and permission to start commissioning work.

The following preconditions must be fulfilled before commissioning:

- Converter, transformer and motor are installed according to the mechanical and electrical installation instructions
- Water for cooling system is available (in case of liquid cooled drive)
- Insulation resistance and continuity tests for cables have been completed and test reports available
- Supply network and electrical machine(s) are safe to operate and ready to be powered on
- Auxiliary supply voltage is available and all related cabling work is done
- Grounding cables and cable screens are connected
- *Confirmation of safety and completion* document has been signed by the representative of electrical installation company (An example of form is attached as *Appendix 2*).

Commissioning procedure

The recommended order of commissioning process is presented below. The order of sections in this document follows the same philosophy.



Powering up auxiliaries

Project specific circuit diagrams must be available before powering up auxiliary voltage supplies. This way the circuits can be safely powered up and any mistakes avoided.

Liquid cooling unit (in case of liquid cooled drive)

Note: Liquid cooling unit must be commissioned prior to powering up.

Refer to the manual of the liquid cooling unit.

Excitation unit

1. Before powering up the main or auxiliary supply for first time check that all circuit breakers are switched off.
2. Check the voltage level of incoming auxiliary supply.
3. Make sure that all protective devices (circuit breakers, timer relays etc.) have been set according to the documentation.
4. After this auxiliary supply and circuit breakers can be switched on one by one.

Converter

Follow the same procedure as described for excitation unit.

Communication

Communication between INU and EXU must be done hardwired as described in section *Communication between components (page 16)*.

Basic parameter settings

Note: In this chapter all parameters in the tables with bold text are project specific. Check the project data for correct settings.

Inverter unit - ACS880 parameter settings for LV-Synchro

Activation of ACS880 LV-Synchro

First of all INU must be set in ACS880 LV-Synchro configuration by setting bit 3 TRUE in parameter *95.21*

Parameter index	Parameter name	Setting	Remarks
95.21	HW options word 2	LV synchro	Bit 3

After choosing ACS880 LV-Synchro configuration the inverter may give following faults/warnings, but these can be ignored at this point:

- Motor Speed Feedback (7301)
- License missing (64A5)

Encoder settings

See *ACS880 Primary control program firmware manual* (3AUA0000085967 [English]) and *ACS880 LV-Synchro supplement (page 69)*.

Motor data (valid also for generator)

Motor data will be entered in parameter group *99. Motor Data*:

Parameter index	Parameter name	Setting	Remarks
97.68	**Nominal excitation current**		**From motor data**
99.04	Motor control mode	DTC	
99.06	**Motor nominal current**		**From motor data**
99.07	**Motor nominal voltage**		**From motor data**
99.08	**Motor nominal frequency**		**From motor data**
99.09	**Motor nominal speed**		**From motor data**
99.10	**Motor nominal power**		**From motor data**

Parameter index	Parameter name	Setting	Remarks
99.11	Motor nominal cos phi		From motor data

Equivalent circuit parameters

All electrical machine equivalent circuit parameters are given in relative values (per unit). Definition of used p.u. values is given in *Appendix 1*.

Parameter index	Parameter name	Setting	Remarks
98.02	Rs user	Will be written after ID run or can be taken from motor design data	Stator resistance
98.15	Position offset user	Will be written after ID run (positioning)	Offset between encoder zero position and rotor d-axis
98.70	Lmd user	Calculated by drive software from no-load curve	Direct axis magnetizing inductance
98.71	Lmq user		Quadrature axis magnetizing inductance
98.72	Lssigma		Stator leakage inductance
98.73	LDsigma user		D-axis damper winding leakage inductance
98.74	LQsigma user		Q-axis damper winding leakage inductance
98.75	RD user		D-axis damper winding resistance
98.76	RQ user		Q-axis damper winding resistance
98.77	Rotor to stator reduction factor	Equation (9)	
98.90	Saturation modeling method		1. Disabled 2. Salient pole motor 3. Non-salient pole motor Choose the type of synchronous motor

Evaluation of equivalent circuit parameters for stator circuit

It is always preferred to use values given by manufacturer. However in some cases there is not available equivalent circuit data for machine, but only short circuit impedances and time constants (x''_{sd}, x'_{sd}, x_{sd}, x''_{sq}, x_{sq}, R_{s1}). These values are typically given for synchronous machines in p.u. values except stator resistance R_{s1}, which is given in ohms. There can be tried approximated values (units are p.u. on both sides of equations).

Lssigma	$L_{s\sigma} \approx 0,8 * x''_{sd}$	(1)
Rs user	$R_s = R_{s1}\dfrac{\sqrt{3} * I_N}{U_N}$	(2)
LDsigma user	$L_{D\sigma} \approx x''_{sd} - L_{s\sigma}$	(3)
LQsigma user	$L_{Q\sigma} \approx x''_{sq} - L_{s\sigma}$	(4)
RD user	$R_D \approx 4 * R_s$	(5)
RQ user	$R_Q \approx 3 * R_s$	(6)

Transfer ratio between rotor and stator

To calculate transfer ratio aka reduction factor as presented in this paragraph, no-load and short-circuit curves must be presented in a coordinate system, where the x-axis is rotor current in amperes and y-axis shows stator voltage and short-circuit current divided with their nominal values, see the figure in section *Saturation model (page 35)*.

No-load factor Gradient of No-load curve at origin	$K_0 = \dfrac{U_{s0}}{I_{\mathrm{r}0}}$	(7)
Short-circuit factor Slope of short circuit curve	$K_{sc} = \dfrac{I_{sc}}{I_r}$	(8)
Rotor to stator reduction factor	$K_{ri} = \dfrac{K_0 K_{sc}}{K_0 - L_{s\sigma}K_{sc}} I_N \approx 1,2 K_{sc} I_N$	(9)

Example from saturation model figure below

Slope of short circuit curve K_{sc} is 1.51 p.u /163 A = 0.00925 [p.u./A]

Gradient of No-load curve K_0 is 0.49/34.1 = 0.014929 [p.u./A]

Manufacturer gives for $L_{s\sigma}$ value 0.166

In this case the curves were given in coordinate system, where on vertical axis is p.u. values and on horizontal amperes. This yields for reduction factor value K_{ri}= 0.0103 [p.u./A]. To get unity p.u./A cancelled as the converter expects, the result must be multiplied with rated current 2092 A. This yields final value of K_{ri}=21.6.

A reasonable value of K_{ri} is necessary to be able to start the drive. If a short circuit curve is not available, then a rough estimate of reduction factor can be calculated according to equation (10).

Rotor to stator reduction factor estimate	$$K_{ri} = \frac{1}{x_{sd} I_{rN}} I_N$$	(10)

where I_N is the nominal motor current[A], x_{sd} is the d-axis reactance [p.u.] ($X_{sd} = L_{sd}$) and I_{rN} is the nominal rotor current [A], which can be found in the motor data sheet.

Note: Due to the roughness of this estimation K_{ri} must be fine tuned at no-load tests as instructed in *Motor no-load test (page 58)*.

Saturation model

Motor no-load voltage curve must be available for entering the saturation model parameters. It can be found either in motor design data sheet or test report by manufacturer.

Below is an example figure of no-load and short-circuit curves from a motor test report.

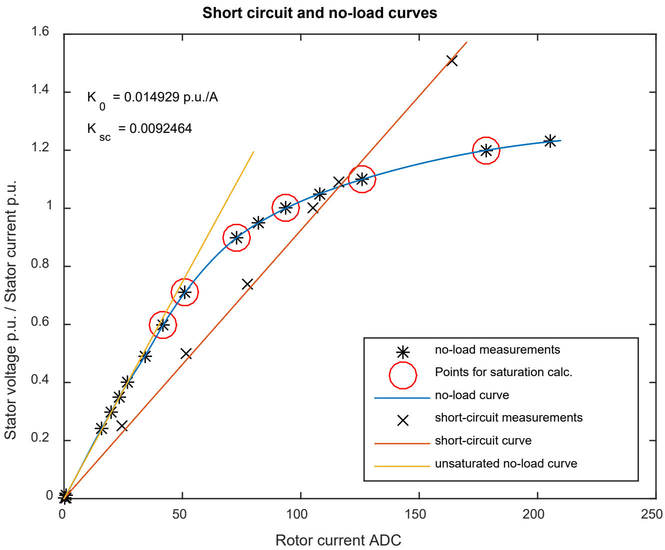
U_N=690 V
I_N=2091 A
I_r=105.3 A

No-load curve

I_{r0} [A]	U_{s0} [p.u.]
205.6	1.23
178.4	**1.20**
126.0	**1.10**
107.9	1.05
93.6	**1.00**
82.2	0.95
73.1	**0.90**
51.1	**0.71**
42.0	**0.60**
34.1	0.49
27.0	0.40
23.3	0.35
20.0	0.30
15.8	0.24
0.7	0.01

Short-circuit curve

I_r [A]	I_s [p.u.]
163.6	1.51
115.8	1.09
105.3	1.00
77.6	0.74
51.4	0.50
24.7	0.25
0.7	0.00



Choose six points from no-load curve around the value U_{s0} [p.u.] = 1.00. These points are used to model the degree of magnetic saturation by the software.

Below is an example of parameter settings based on the figure above. The chosen points are marked with red circle in figure and bolded in table. The turn in no-load curve (in figure) is the part which is important for the saturation model.

Parameter index	Parameter name	Setting	Remarks
98.90	**Saturation modeling method**		1. **Disabled** 2. **Salient pole motor** 3. **Non-salient pole motor** **Choose the type of synchronous motor**
98.78	**IF no-load 1 (A)**	**42.0**	**No-load IF corresponding US = 0.60**
98.79	**IF no-load 2 (A)**	**51.1**	**No-load IF corresponding US = 0.71**
98.80	**IF no-load 3 (A)**	**73.1**	**No-load IF corresponding US = 0.90**
98.81	**IF no-load 4 (A)**	**93.6**	**No-load IF corresponding US = 1.00**
98.82	**IF no-load 5 (A)**	**126.0**	**No-load IF corresponding US = 1.10**
98.83	**IF no-load 6 (A)**	**178.4**	**No-load IF corresponding US = 1.20**
98.84	**US no-load 1 (p.u.)**	**0.60**	**US p.u value chosen from motor no-load curve**
98.85	**US no-load 2 (p.u.)**	**0.71**	**US p.u value chosen from motor no-load curve**
98.86	**US no-load 3 (p.u.)**	**0.90**	**US p.u value chosen from motor no-load curve**
98.87	**US no-load 4 (p.u.)**	**1.00**	**US p.u value chosen from motor no-load curve**
98.88	**US no-load 5 (p.u.)**	**1.10**	**US p.u value chosen from motor no-load curve**
98.89	**US no-load 6 (p.u.)**	**1.20**	**US p.u value chosen from motor no-load curve**

Linear no-load curve

If no-load curve is not given, motor can be started by creating a linear no-load curve. This is done by setting the values as below.

- set the following stator voltage values in parameters *98.84…98.89*:
  0.5, 0.6, 0.8, 1.0, 1.1, 1.2 [p.u]
- set the following estimated excitation current values in parameters *97.78…97.83*:
  $0.4I_{rN}$, $0.5I_{rN}$, $0.7I_{rN}$, $0.8I_{rN}$, $0.9I_{rN}$, $1.0I_{rN}$ [A]; (I_{rN} from motor type plate).

Note: Always when no-load curve is estimated with a linear one, it is important to execute fine tuning of no-load curve at first start. The procedure is instructed later in this guide.

Limits

Parameter index	Parameter name	Setting	Remarks
21.06	Zero speed limit (rpm)		Can be adjusted during commissioning if neces-sary
30.11	Minimum speed (rpm)		From motor data
30.12	Maximum speed (rpm)		From motor data
30.17	Maximum current (A)		From motor data
30.19	Minimum torque 1 (%)		From motor data
30.20	Maximum torque 1 (%)		From motor data
30.26	Power motoring limit (%)		From motor data
30.27	Power generating limit (%)		From motor data
31.30	Overspeed trip margin (rpm)	= Motor mechanical overspeed – motor maximum speed	Deviation between mo-tor mechanical over-speed and maximum speed
97.61	Excitation running state source	DI5	
97.69	Minimum excitation current (A)	Eg. (nominal speed / maximum speed) * no-load excitation current	From motor data
97.70	Maximum excitation current (A)		From motor data
97.72	Maximum flux deviation (%)	5%	For smoother starting lower values can be used. Due to scaling error or noisy signal the value may have to be left to 5%
97.74	Excitation current trip margin (%)	50%	
97.75	Excitation current safety margin	-200%	Not in use in normal operation because it is unnecessary and limits the performance in field weakening area.

Input and outputs

Excitation current control

The ACS880 inverter feeds the stator winding of the synchronous machine to control the air gap torque and the stator flux. The ACS880 inverter also calculates an excitation winding current that would produce unity power factor in the steady state. This is then used as the current reference for the excitation device that feeds the excitation winding of the synchronous machine. During start-up the excitation device builds up the air gap flux before the ACS880 inverter starts modulation.

Communication with the excitation device

Fast communication link between the ACS880 inverter and the excitation device is needed through standard DIO and AIO. Hardwired inputs are typically connected between INU and EXU. Communication between EXU and INU is done hardwired to achieve sufficient bandwidth for excitation control. The signals between EXU and INU are completely connected at drives factory, in case excitation unit is inbuilt in same multidrive with inverter unit.

The ACS880 inverter gives the run command (see par. *97.63 Excitation run command*) and the current reference (see par. *97.66 Excitation current reference*) to the excitation device. The run command is set when the current reference is more than zero and will remain set always when the ACS880 inverter is modulating. In order to protect the excitation device from overvoltages the run command will be held set and the current reference will be held at minimum for 500 ms after the ACS880 inverter has stopped modulation. The excitation device gives the running status (see par. *97.62 Excitation running state*) and the current feedback (see par. *97.65 Excitation current feedback*) to the ACS880 inverter. The running status and the current feedback are used for supervision purposes (see fault 7100 Excitation). The current feedback is also used for calculation of the air gap flux generated by the excitation winding current.

For communication diagram, see *Communication between INU and EXU units (page 17)*.

Parameters

Group 10 Standard DI, RO			
Param No	**Param name**	**Setting**	**Declaration**
10.13	DI5 On Delay	0	Excitation On (-> 97.62)
10.14	DI5 Off Delay	0	
10.15	DI6 On Delay	0	Excitation Fault (-> 31.01)
10.16	DI6 Off Delay	0	
10.27	RO2 Source	Project specific	Excitation unit reset
10.28	RO2 On Delay	0	No on delay
10.29	RO2 Off Delay	5	0.5 s off delay
10.30	RO3 Source	2	Ready Run
10.31	RO3 Off Delay	0	

Group 10 Standard DI, RO			
Param No	**Param name**	**Setting**	**Declaration**
10.32	RO3 On Delay	0	

Group 12 Standard AI			
Param No	**Param name**	**Setting**	**Declaration**
12.15	AI1 Unit selection	10: milli Amperes	Excitation current actual value SEE Jumper J1
12.16	AI1 filter time	0.100	0.1 ms
12.17	AI1 Min	0	0 mA
12.18	AI1 Max	20.000	20 mA
12.19	AI1 Scaled at AI1 min	0	0
12.20	AI1 Scaled at AI1 max	IF_max, Project specific	Excitation current at max overload

Group 13 Standard AO			
Param No	**Param name**	**Setting**	**Declaration**
13.12	AO1 Source	4: Motor current in A	Excitation current reference, see Jumper J5
13.15	AO1 Unit selection	10: milli Ampere	
13.16	AO1 filter time	0.100	0.1 ms
13.17	AO1 Source Min	0	0 mA
13.18	AO1 Source Max	20.000	20 mA
13.19	AO1 out at AO1 src min	0	0
13.20	AO1 out at AO1 src max	IF_max, Project specific	Excitation current at max overload

Group 31 Fault functions and fault levels			
Param No	**Param name**	**Setting**	**Declaration**
31.01	External event1 source	8: DI6	Source of external event 1: Excitation unit fault
31.02	External event1 type	1: Warning	Type of external event 1

Group 97 Motor control			
Param No	**Param name**	**Setting**	**Declaration**
97.61	Excitation running state source	6: DI5	Run feedback from EXU
97.64	Excitation current feedback source	1:AI1	Excitation current feedback

Excitation unit – DCS880 parameter settings for LV-Synchro

Instructions has been done for DCS880 firmware version: DCSF1x2.05.0.0

Note: All described signals may not be used, see hardware connections in use.

These settings are pre-set at drives factory during testing phase.

It is important to confirm that EXU start/stop has a 3 second stop delay ensuring the active de-charging of magnetic energy, which is stored in machine inductances.

Group 10 Standard DI, RO			
Param No	**Param name**	**Setting**	**Declaration**
10.05	DI1 On Delay	0.5	*1 s, EXU Start
10.06	DI1 Off Delay	3	*1 s, EXU Stop 3 s delay
10.07	DI2 On Delay	0.5	*1 s, Aux supply supervision
10.08	DI2 Off Delay	0.5	*1 s, Aux supply supervision
10.09	DI3 On Delay	0.5	*1 s
10.10	DI3 Off Delay	0.5	*1 s
10.11	DI4 On Delay	0.5	*1 s, Main Switch On
10.12	DI4 Off Delay	0.5	*1 s, Main Switch On
10.13	DI5 On Delay	0.5	*1 s, Run Enable
10.14	DI5 Off Delay	0.5	*1 s, Run Enable
10.15	DI6 On Delay	0.5	*1 s, Reset
10.16	DI6 Off Delay	0.5	*1 s, Reset
10.24	RO1 Source	Other set [06.09b3]	Main contactor on command
10.25	RO1 On Delay	0.5	*1 s
10.26	RO1 Off Delay	0.5	*1 s
10.27	RO2 Source	Tripped (-1)	Fault to INU
10.28	RO2 On Delay	0.5	*1 s
10.29	RO2 Off Delay	0.5	*1 s
10.30	RO3 Source	5: Ready reference	Run status to INU
10.31	RO3 On Delay	0.5	*1 s
10.32	RO3 Off Delay	0.5	*1 s

Group 11 Standard DIO, FI, FO			
Param No	**Param name**	**Setting**	**Declaration**
11.05	DIO1 function	1: Input	Overvoltage protection
11.09	DIO2 function	1: Input	Main contactor on status

Group 12 Standard AI			
Param No	**Param name**	**Setting**	**Declaration**
12.15	AI1 Unit selection	10: Milliamperes	Excitation current reference, see Jumper J1, DCS880 HW manual for setting instructions
12.16	AI1 filter time	0.100	*1 s
12.17	AI1 Min	0	0 mA
12.18	AI1 Max	20.00	20 mA
12.19	AI1 Scaled at AI1 min	0	0 A
12.20	**AI1 Scaled at AI1 max**	**IF_max, Project specific**	**Excitation current at max overload i.e. 150 % = 1.5×I_f nom (A) overload needed.** **Note: Must be set same as 13.18**

Group 13 Standard AO			
Param No	**Param name**	**Setting**	**Declaration**
13.12	AO1 Source	Motor current	Excitation current at max overload, see Jumper J5, DCS880 HW manual for setting instructions
13.15	AO1 Unit selection	10: Milliamperes	mA
13.16	AO1 filter time	0.100	*1 s
13.17	AO1 Source Min	0	0 A
13.18	**AO1 Source Max**	**IF_max, Project specific**	**Excitation current at max overload i.e. 150 % = 1.5×I_f nom (A) overload needed.** **Note: Must be set same as 12.20**
13.19	AO1 out at AO1 src min	0	0 mA
13.20	AO1 out at AO1 src max	20.00	20 mA

Group 20 Start/Stop/Direction			
Param No	**Param name**	**Setting**	**Declaration**
20.01	Command location	0: Local I/O, default	Control from local I/O or overriding control system. Source for the control word (On/Off1, Run/Stop and Reset).
20.02	ON/Off source	3: DI1	ON/Off = Run/Stop

Group 20 Start/Stop/Direction			
Param No	**Param name**	**Setting**	**Declaration**
20.04	Off2 Source1 (emergency off)	1: inactive	Not used
20.05	Emergency stop source	1: inactive	Not used
20.06	Run/Stop source	3: DI1	Main Cont. On St
20.08	Off2 source 2 (emergency off)	1: inactive	Not used
20.13	Fault reset source	8: DI6	Reset from INU
20.15	Hand/Auto source	None	Control via input boards
20.33	Mains contactor control mode	0: On	ISU CONT ON cmd -> EXU CONT ON 10.1.4 DI Status INU RUN -> EXU PULSE ENABLE
20.34	Mains contactor acknowledge source	5: DI3	Main Cont. On Status or set 20.34 main contactor
20.47	Overvoltage protection trigger source	11: DIO1	Overvoltage protection device

Group 21 Start/Stop/Mode			
Param No	**Param name**	**Setting**	**Declaration**
21.01	Start mode	1: Flying start	Flying start
21.02	Off1 mode	0: Coasts stop	Coasts stop
21.04	Off2 Source1 (emergency off)	0: Coasts stop	Coasts stop

Group 22 Speed reference selection			
Param No	**Param name**	**Setting**	**Declaration**
21.11	Speed reference 1 source	0: Zero	-

Group 27 Armature current control			
Param No	**Param name**	**Setting**	**Declaration**
27.22	Current reference source	4: AI1 scaled	12.12 scaled value
27.24	Current reference slope	120	%/ms maximum value
27.27	Current control mode	0: Standard	Current control type
27.28	M1 Current control feedback mode	0: Peak	Current controller feedback type
27.29	**M1 Current proportional gain**	**Project specific**	**Will be automatically set after field autotune executed**

Group 27 Armature current control			
Param No	**Param name**	**Setting**	**Declaration**
27.30	**M1 Current integration time**	**Project specific**	**Will be automatically set after field autotune executed**
27.31	M1 discontinuous current limit	0	% of I_f nominal
27.32	M1 armature resistance	0	Excitation winding resistance
27.33	M1 armature inductance	0	Excitation winding inductance
27.34	Mains compensation time	10	***1 ms, Mains compensation filter time constant**
27.38	Reversal delay	5	ms
27.40	Zero current time out	20	ms

Group 30 Control limits			
Param No	**Param name**	**Setting**	**Declaration**
30.34	**M1 current limit bridge 2**	**Project specific**	**From machine data, to be set higher than max overload**
30.35	**M1 current limit bridge 1**	**Project specific**	**From machine data, to be set higher than max overload**
30.44	Minimum firing angle	15	Degrees, default value
30.45	Maximum firing angle	150	Degrees, default value
30.46	Maximum firing angle mode	Fix + single	Allows DC current suppression when max firing angle is reached

Group 31 Fault functions and fault levels			
Param No	**Param name**	**Setting**	**Declaration**
31.01	External event 1 source	4: DI2	Auxiliary supply fault
31.02	External event 1 type	3: Warning or fault	No auxiliary supply
31.03	External event 2 source	inactive (true)	Overvoltage protection, see par 20.47
31.04	External event 2 type	No action	Covered 20.47
31.05	External event 3 source	6: DI4	Main Switch On status
31.06	External event 3 type	3: Warning or fault	Main Switch On status
31.07	External event 4 source	7: DI5	Run Enable
31.08	External event 4 type	3: Warning or fault	Run Enable

Group 31 Fault functions and fault levels			
Param No	**Param name**	**Setting**	**Declaration**
31.14	Fault stop mode fault level 3	0: Coast stop	Fault mode 3 stopping mode
31.15	Fault stop mode fault level 4	0: Coast stop	Fault mode 4 stopping mode
31.21	Mains phase loss	2: Warning	Warning or fault
31.41	Main fan fault function	1: fault	In case fan exists and par 20.38 set
31.44	Armature overcurrent level	300	%, to be set 25 % higher than overcurrent level, e.g. 30.35 M1 current limit bridge 1
31.45	Maximum current rise level	325	%/ms maximum setting, no limitation
31.46	Current ripple function	2: Warning	Bridge HW failure
31.47	Current ripple level	90%	Setting for field exciter
31.50	Armature voltage over-voltage	1000%	Disables function, HW overvoltage device covers
31.51	Mains loss mode	1: Delayed	
31.52	Mains loss down time	500	ms
31.53	Mains loss level 1	80	% of nominal mains voltage, default
31.54	Mains loss level 2	60	% of nominal mains voltage, default

Group 95 HW configuration			
Param No	**Param name**	**Setting**	**Declaration**
95.25	Set type codeUnit selection	S02-0xxx-0x	Check if the type code is correct, otherwise correct it following the instructions in DCS880 firmware manual
95.44	PLL deviation level	10	Degrees, to suppress mains synchronization lost

Group 96 System			
Param No	**Param name**	**Setting**	**Declaration**
96.02	Unit selection	**Project specific**	SI system or other
96.32-39	Drive time	**Project specific**	Drive time source

Group 99 Motor data			
Param No	**Param name**	**Setting**	**Declaration**
99.06	Operation mode	1:Large exciter	
99.10	**Nominal mains voltage**	**Project specific**	**V, project specific**
99.11	**M1 Nominal current**	**Project specific**	**AC Supply voltage of excitation bridge**
99.12	**M1 Nominal voltage**	**Project specific**	**According to given motor excitation nominal current**

Signal check

Note: Prior to powering up the converter, all safety- and protection-related I/Os must be tested.

Motor signals

Refer to the project documentation for motor input and output signals.

Verify correct signalization and functionality of I/Os by pulling a wire or making a jumper. After testing restore connection or remove jumpers and reset existing alarms and faults.

Safety functions check

Note: Prior to powering up the converter, all safety- and interlock-related functions must be tested.

Functional safety

Following issues are to be taken in consideration in designing functional safety functions.

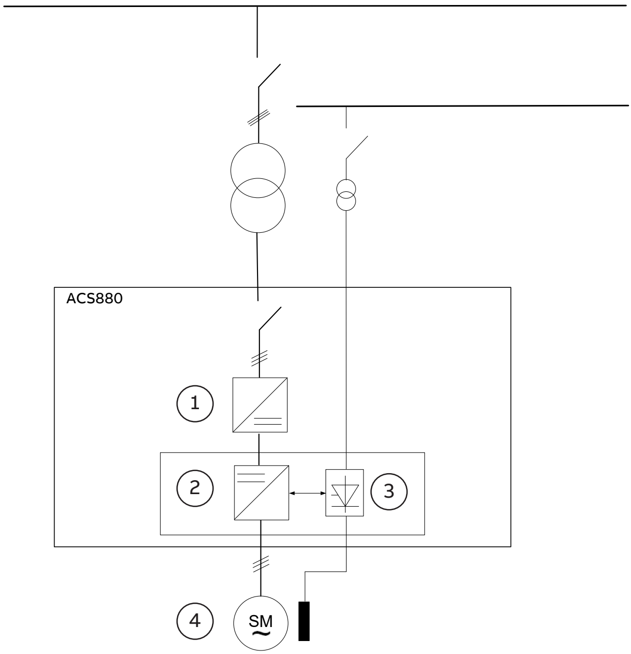
- STO function works with same principle as in permanent magnet drive. It prevents the firing pulses from INU unit, and runs actively flux down for 3 s before stopping EXU. This enables fast flux de-energization and prevents possible overvoltages due to sudden disappearing of machine anchor reaction.
- Emergency stop stops drive with selected emergency stop mode and runs actively flux down for 3 s before stopping EXU.

In case it is necessary to act otherwise than described above, the need of additional breaking chopper has to be considered.

Interlocks

Before powering up the converter test the interlocks without main power (transformer not powered, DC link discharged…) between all main circuit/charging circuit breakers if applicable.

A principal diagram of a synchronous machine drive



1	Supply unit
2	Inverter unit
3	Excitation unit
4	Synchronous machine with external excitation

Starting up excitation unit

Functional testing of excitation unit DCS

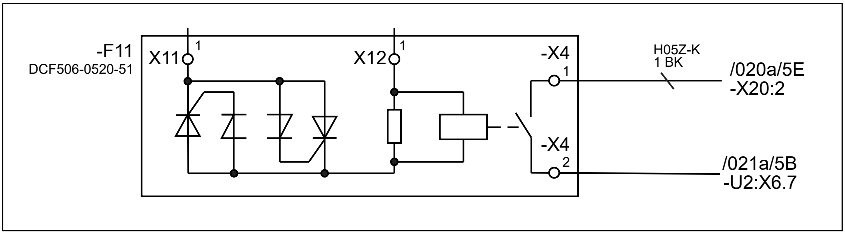
Note: Before testing the excitation unit make sure that all motor and excitation unit cable connections have been completed and junction boxes are closed. Working on stator side is not allowed when excitation is under testing due to danger caused by possible back voltage.

Auxiliary supply voltage monitoring

Monitoring of auxiliary equipment supply voltage is connected in the digital input of the excitation unit. Switch off the circuit breaker and check that an alarm is generated. Status of digital input can be seen in *8.05 DI StatWord*.

Overvoltage protection

Overvoltage protection device can be tested by shorting connectors X4:1 and X4:2 (figure below).



When the connectors are shorted should an overvoltage protection alarm appear in excitation unit alarm/event list. The status of DI7 can also be seen in parameter *8.05 DI StatWord* of excitation unit.

After the test, remove shorting.

Functional test of current controller

The steps below consider that the user is controlling the excitation unit with Drive Composer Pro.

Put a current clamp in the output of the excitation unit.

1. Prepare to monitor the following signals with Drive Composer Pro:
   - *27.02 Used current reference [%]*
   - *01.41 Reactive current [%]*
   - *01.10 Motor Current in A*
2. During the following steps check that the *01.10 Motor Current in A* value is not more than two times the mean current *01.41 Reactive current* – in case the current is not stable there is a shorted exciting winding. Possible reasons are:
   - faulty gate and cathode connections
   - broken thyristor
   - blown fuse
3. Excitation unit must be in remote mode if Drive Composer Pro is used for controlling
4. Take control of excitation unit with Drive Composer Pro and set reference to 10% of nominal excitation current
5. Start the excitation unit from Drive Composer Pro
6. Make sure that the reading of current clamp matches with the current reference value

7. Read the current values also from the control panel
8. If the excitation current values match with each other, increase current reference to 30%
9. Make sure that the measured current matches with new reference and that the values are correctly on the control panel
10. Stop the excitation unit and set current reference to 0%
11. Release control of excitation unit from Drive Composer Pro

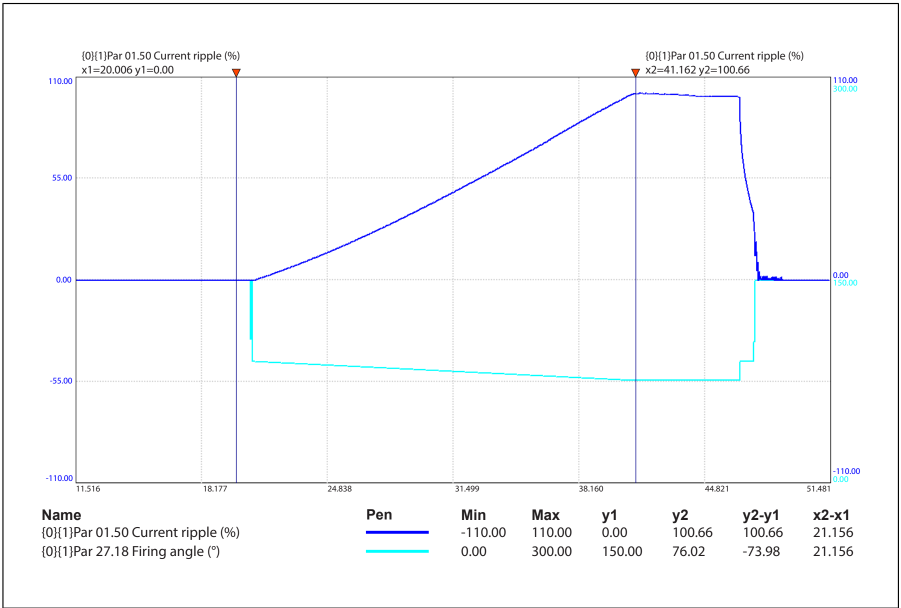
Current controller tuning

Current controller auto-tuning

1. Prepare to monitor the following signals with Drive Composer Pro:
   - *01.41 Reactive current [%]*
   - *01.50 Current ripple [%]*
   - *01.51 Current ripple filtered [%]*
   - *27.18 Firing Angle [deg]*
   - *27.02 Used current reference [%]*
2. Take control of excitation unit with Drive Composer Pro
3. Set 10 % reference in Drive Composer Pro reference window
4. To execute autotuning select parameter *99.20* and set 1: Field current autotuning
5. Press the green start button in Drive Composer Pro. Start button must be pressed within 20 seconds after selection of field autotune, otherwise you will get a message “autotuning failed”
6. After autotuning has been completed, inspect the parameters of field current controller. There should be now some values.
   - *27.29 M1 current proportional gain*
   - *27.30 M1 current integration time*

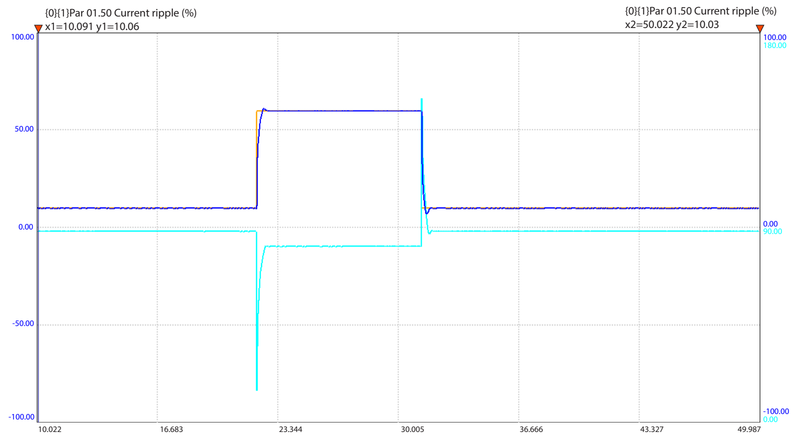
An example of autotuning curve is presented below.

Note: The field current is taken up to set nominal field current value in parameter 99.11 during autotuning sequence.



Performance of current controller

1. Prepare to monitor the following signals with Drive Composer Pro:
   - *01.41 Reactive current [%]*
   - *01.50 Current ripple [%]*
   - *01.51 Current ripple filtered [%]*
   - *27.18 Firing Angle [deg]*
   - *27.02 Used current reference [%]*
2. Excitation unit is set in remote control mode from the control panel
3. Take control and start excitation unit with Drive Composer Pro
4. Set reference to 10% of nominal excitation current
5. Make a step to reference by setting for example 50% in reference
6. Return reference back to 10%



Name	Pen	Min	Max	y1	y2	y2-y1	x2-x1
{0}{1}Par 01.50 Current ripple (%)		-100.00	100.00	10.06	10.03	-0.03	39.931
{0}{1}Par 27.2 Used current reference (%)		-100.00	100.00	10.00	10.00	0.00	39.931
{0}{1}Par 27.18 Firing angle (°)		0.00	180.00	88.57	88.55	-0.02	39.931

7. If current control performance is not satisfying, it can be tuned manually with the parameters:
   - *27.29 M1 current proportional gain*
   - *27.30 M1 current integration time*
8. In case current controller needs tuning, repeat steps 4 and 5 after changing controller settings
9. Stop excitation unit and set current reference to 0%
10. Release control from Drive Composer Pro.

Starting up inverter unit

Note: Make sure that ISU, INU and EXU are in remote control mode

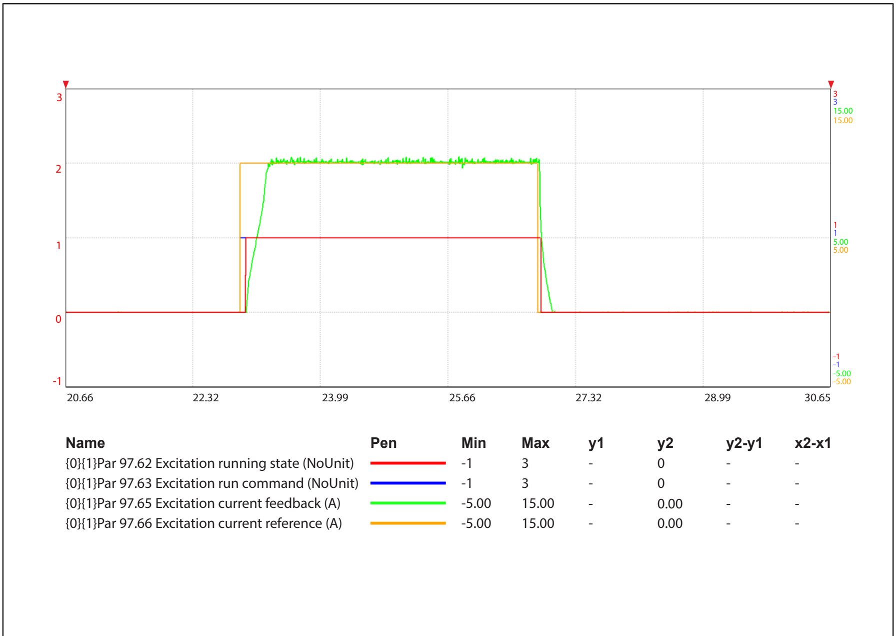
The ACS880 has two main control locations: remote and local. The control location is selected with the Loc/Rem key on the control panel or in the PC tool. See *ACS880 Primary control program firmware manual* (3AUA0000085967 [English]).

Excitation control from INU

Control of excitation unit from INU can be tested by setting excitation mode to constant excitation. One should record signals from INU as well as from EXU to see that the reference and actual values are matching.

Parameters for excitation unit interface test are presented in the table below.

Parameter index	Parameter name
97.62	Excitation running state
97.63	Excitation run command
97.65	Excitation current feedback
97.66	Excitation current reference



1. Make sure that excitation unit is in remote mode
2. Set *97.60 Excitation mode* to Constant excitation

3. Prepare to measure excitation current with a current clamp
4. Prepare to monitor the following signals with Drive Composer Pro:
   - *97.62 Excitation running state*
   - *97.63 Excitation run command*
   - *97.65 Excitation current feedback* (A)
   - *97.66 Excitation current reference* (A)
5. Set excitation current reference in parameter *97.67 Constant excitation current reference*. INU will command excitation unit automatically on when reference is higher than zero.
6. Try different excitation current reference levels and check that feedback is matching with the reference as well with the value measured with the current clamp
7. In case excitation current feedback is not matching with the reference check the scaling of analogue outputs/inputs and nominal values
8. After testing, set excitation current reference back to zero and the excitation unit will stop
9. Set excitation mode to controlled.

INU Identification run

Before INU identification run the ACS880 LV-Synchro must be in local mode in order for the standstill ID run to be executed.

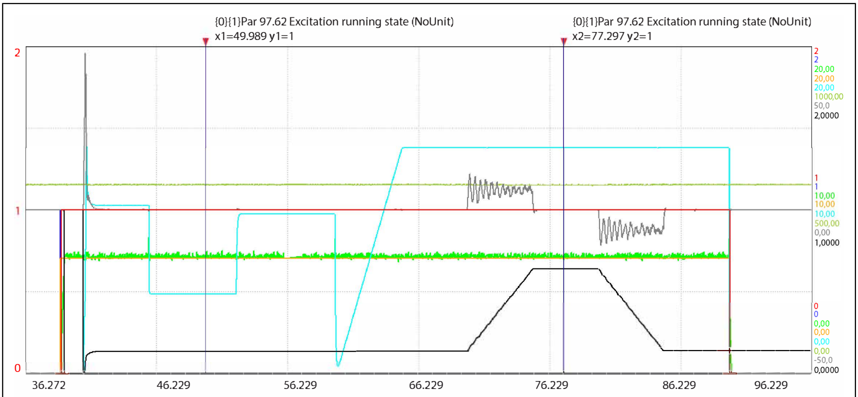
Note: Any other ID run method is not possible but autophasing and current measurement calibration can still be used.

A standstill identification run for a machine is mandatory prior to first start. ID run will position the encoder and check the direction of pulse encoder. In case the speed feedback from encoder is not matching with estimated value, an autophasing fault will be generated. If Standstill 1 autophasing mode is selected then encoder rotation direction will not be checked. This can only be checked when turning autophasing is used.

1. Prepare to monitor the following signals from INU:
   - *01.07 Motor current* (A)
   - *01.11 DC voltage* (V)
   - *90.10 Encoder 1 speed* (rpm)
   - *90.11 Encoder 1 position* (rev)
   - *97.62 Excitation running state*
   - *97.63 Excitation run command*
   - *97.65 Excitation current feedback* (A)

- *97.66 Excitation current reference* (A)

2. Choose “standstill” from parameter *99.13 ID run requested*
3. Start INU from Drive Composer Pro control panel
4. After ID run parameters listed below will be written automatically. Check that they are updated after ID run
   - *98.02 Rs user*
   - *98.15 Position offset user*



Name	Pen	Min	Max	y1	y2	y2-y1	x2-x1
{0}{1}Par 97.62 Excitation running state (NoUnit)		0	2	1	1	0	27.308
{0}{1}Par 97.63 Excitation run command (NoUnit)		0	2	1	1	0	27.308
{0}{1}Par 97.65 Excitation current feedback (A)		0,00	20,00	7,34	7,09	-0,25	27.308
{0}{1}Par 97.66 Excitation current reference (A)		0,00	20,00	7,07	7,07	0,00	27.308
{0}{1}Par 1.7 Motor current (A)		0,00	20,00	4,87	13,79	8,92	27.308
{0}{1}Par 1.11 DC voltage (V)		0,00	1000,00	576,74	575,68	-1,06	27.308
{0}{1}Par 90.10 Encoder 1 speed (rpm)		-50,00	50,00	0,00	0,00	0,00	27.308
{0}{1}Par 90.11 Encoder 1 position (rev)		0,00000000	2,00000000	0,13726808	0,63909864	0,50183056	27.308

In case the speed encoder channels are not matching with the rotation direction of the machine, an autophasing fault will occur.

Motor parameter must be entered manually and ID run will check only the stator resistance.

Note the influence from semiconductors and cables.

Autophasing

Autophasing is an automatic measurement routine to determine the rotor angular position and identify *98.15 Position offset user*. There are two autophasing modes available for LV Synchro motors: ‘Turning’ and ‘Standstill 1’, which can be selected from *21.13 Autophasing mode*. Note that the ‘Standstill 2’ and ‘Turning with Z-pulse’ modes in *21.13* selection list do not support LV Synchro motors. Default is ‘Turning’ mode and the

‘Standstill 1’ mode can be used if the motor cannot be turned freely (for example, when the load is connected).

Drive will always try to run autophasing during start-up if increment encoder is used and autophasing has not been completed since last power-up. Turning autophasing requires that machine shaft must rotate freely. This is not normally possible when machine is coupled. For this reason it can't normally be used with increment encoder.

Standstill 1 autophasing mode requires fast excitation dynamic response. *97.73 Excitation current ramp time* is not complied during standstill 1 autophasing. Autophasing may fail with very slow excitation response.

The autophasing is started in three situations:

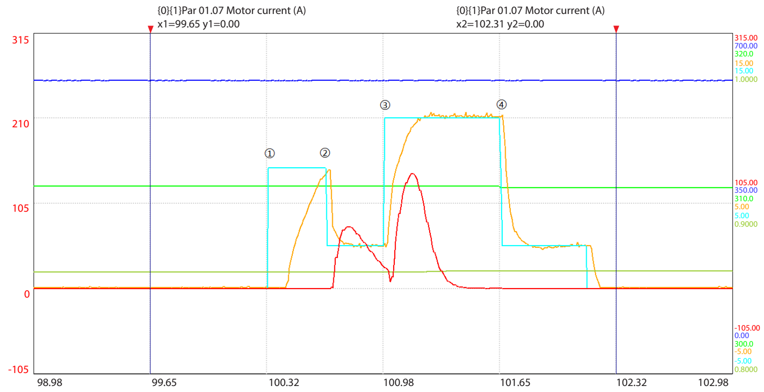
1. ID Run. Autophasing (either turning or standstill 1 autophasing selected by *21.13*) is a part of the ID run routine and it will be executed automatically in the end of the ID run.
2. Requested autophasing. Autophasing can be requested from *99.13 ID run request* by selecting ‘Autophasing’ from the list. Starting the drive will execute autophasing automatically if autophasing mode is selected.
3. Starting the drive with unknown rotor position. Autophasing will be automatically started if the drive is started with unknown rotor position. The drive will start to run after autophasing is completed.

Standstill autophasing

For standstill autophasing perform the following steps:

1. Test excitation unit as in *Excitation control from INU (page 52)*, and additionally check the excitation current dynamic response:
    - Prepare to monitor the following signals with Drive Composer Pro
        - *97.65 Excitation current feedback* (A)
        - *97.66 Excitation current reference* (A)
    - Set *97.60 Excitation mode* to Constant excitation
    - Set *97.73 Excitation current ramp time* to zero
    - Set *97.67 Constant excitation current reference* to the same value as *97.69 Minimum excitation current*
    - Wait until the excitation current feedback reaches the minimum excitation current reference and then set *97.67 Constant excitation current reference* to the same value as *97.68 Nominal excitation current*
    - Check that the excitation current feedback follows excitation current reference and the dynamic response from minimum excitation current to nominal excitation current is not too slow.

2. Make current measurement calibration if current measurement calibration or an ID run has not been done:
    - Set *99.13 ID run requested* to Current measurement calibration
    - Start the drive and current measurement calibration will be executed automatically.
3. Request standstill autophasing:
    - Set autophasing mode in *21.13* to Standstill 1
    - Request autophasing by setting *99.13* to Autophasing
    - Prepare to monitor the following signals with Drive Composer Pro:
        - *01.07 Motor current* (A)
        - *97.65 Excitation current feedback* (A)
        - *97.66 Excitation current reference* (A)
        - *98.15 Position offset user* (deg)
        - *90.11 Encoder 1 position* (rev), **note**: according to encoder settings.
    - Start autophasing by starting the drive
    - Autophasing will start and finish in a few seconds. Check that *98.15 Position offset user* is updated after autophasing and write down the value
    - Repeat standstill autophasing as above for several times. Check that *98.15 Position offset user* values from each autophasing does not vary too much.
4. An example of a standstill autophasing is shown in figure below



Name	Pen	Min	Max	y1	y2	y2-y1	x2-x1
{0}{1}Par 01.07 Motor current (A)	red	-105.00	315.00	0.00	0.00	0.00	2.66
{0}{1}Par 01.11 DC voltage (V)	blue	0.00	700.00	601.87	602.10	0.23	2.66
{0}{1}Par 98.15 Position offset user (deg)	green	300.0	320.0	311.0	310.9	-0.1	2.66
{0}{1}Par 97.65 Excitation current feecback (A)	orange	-5.00	15.00	0.06	0.06	0.00	2.66
{0}{1}Par 97.66 Excitation current reference (A)	cyan	-5.00	15.00	0.00	0.00	0.00	2.66
{0}{1}Par 90.11 Encoder 1 position (rev)	light green	0.80	1.00	0.86	0.86	0.00	2.66

A successful autophasing should be similar as the example and has the following processes as in the figure:

1. Drive started
2. Standstill autophasing started, excitation current reference steps to minimum excitation
3. Excitation current reference steps to nominal excitation
4. Autophasing done and drive stopped.

There will be two stator current spikes induced by the excitation step changes. The second spike may end much faster than in the example figure but the autophasing can still succeed.

An autophasing fault (3385 Autophasing) can occur in the following cases:

1. Motor axis is not in standstill. Standstill 1 autophasing must be performed with a motor in standstill.
2. No motor current or very small (less than 5% of motor nominal current) motor current is monitored during standstill autophasing. Check if the excitation dynamic response is very slow. It is recommended to tune the gains of excitation control to a faster dynamic response. Otherwise check if excitation unit works normally or if the motor is disconnected.

3. The first motor current spike induced during autophasing is very high and ends to zero very fast and there is no second spike followed, and the excitation current reference didn't step to nominal excitation. Try to temporarily reduce the difference between *97.69 Minimum excitation current* and *97.68 Nominal excitation current*, and request autophasing again.

Note that there can be a very small torque produced during standstill autophasing and axis may be turned by a very small angle. This can happen when there is asymmetry in the motor damper winding or stator winding, and this depends on the initial rotor position before autophasing.

Motor no-load test

Following tests are applicable for motor application. Also generators are recommended to run first in motor mode when it is possible.

Prepare to monitor the following signals from INU:

- *06.01 Main control word*
- *06.11 Main status word*
- *01.01 Motor speed used* (rpm)
- *01.07 Motor current* (A)
- *01.10 Motor torque* (%)
- *01.24 Flux actual* (%)
- *19.01 Actual operation mode*
- *97.65 Excitation current feedback* (A)
- *97.66 Excitation current reference* (A)

Note that the amount of monitored signals affect the sample time (up to 26 signals with 1 ms / signal). If faster sample time is needed, eg. for troubleshooting, leave out signals which are not relevant.

First run

Note: This test is applicable for motor application.

Before starting the first time it is recommended to set limits to safe values, eg. 50% of nominal values. Slow acceleration/deceleration ramp time is recommended, eg. 60 seconds.

1. Prepare to monitor the following signals:
   - *01.01 Motor speed used* (rpm)
   - *01.07 Motor current* (A)
   - *01.10 Motor torque* (%)

- *01.11 DC voltage* (V)
- *01.24 Flux actual* (%)
- *97.65 Excitation current feedback* (A)
- *97.66 Excitation current reference* (A)

2. INU must be in speed control. Check parameters:

Parameter index	**Parameter name**	**Setting**	**Remarks**
19.16	Local control mode	Speed	Select speed as local control mode
19.17	Local control disable	No	Set to Yes after commissioning to lock local run

3. Take local control with panel or Drive Composer Pro and set a low speed reference
4. Start INU. If no abnormal behavior is observed speed reference can be increased to rated speed.
5. Check no-load curve as instructed in section *Model tuning (page 63)*.
6. Run the motor in nominal speed and make a speed reversal
7. Check that the excitation current reference and feedback are stable and matching
8. Increase speed reference to maximum
9. Stop the drive.

Speed reversals

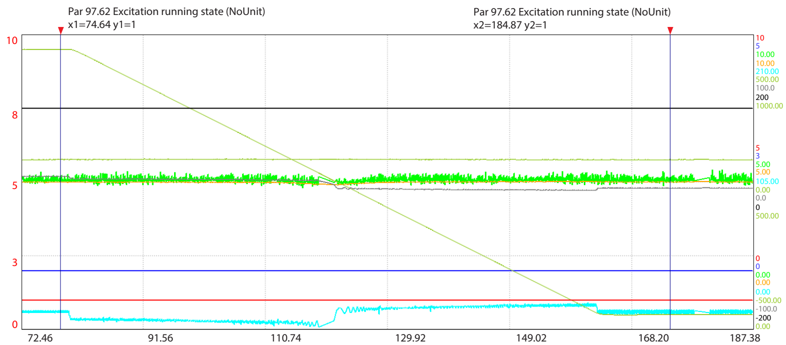
Note: Following tests are applicable for motor application.

This test is only applicable if the machine can be run uncoupled as a motor. Purpose of this test is to verify the speed range of the drive system and to verify that the motor model is functioning.

1. Prepare to monitor the following signals:
   - *01.01 Motor speed used* (rpm)
   - *01.07 Motor current* (A)
   - *01.10 Motor torque* (%)
   - *01.11 DC Voltage* (V)
   - *01.24 Flux actual* (%)
   - *97.62 Excitation running state*
   - *97.63 Excitation run command*

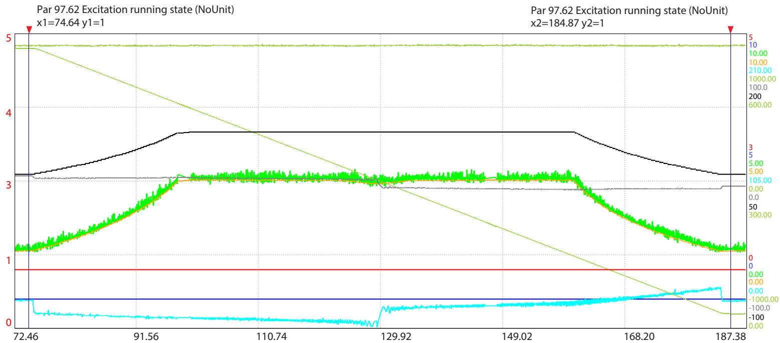
- *97.65 Excitation current reference* (A)
- *97.66 Excitation current feedback* (A)

2. Accelerate the motor to nominal speed
3. Make a speed reversal with a slow ramp, eg. 60 seconds, to keep the torque low
4. Check that the excitation current reference is stable throughout the whole constant flux area (positive speed to negative speed)



Name	Pen	Min	Max	y1	y2	y2-y1	x2-x1
{0}{1}Par 97.62 Excitation running state (NoUnit)		0	10	1	1	0	62.44
{0}{1}Par 97.63 Excitation run command (NoUnit)		0	5	1	1	0	62.44
{0}{1}Par 97.65 Excitation current feedback (A)		0.00	10.00	5.14	5.02	-0.12	62.44
{0}{1}Par 97.66 Excitation current reference (A)		0.00	10.00	5.00	5.00	0.00	62.44
{0}{1}Par 01.07 Motor current (A)		0.00	210.00	13.80	12.34	-1.46	62.44
{0}{1}Par 01.01 Motor speed used (rpm)		-500.00	500.00	450.03	-450.06	-900.09	62.44
{0}{1}Par 01.10 Motor torque (%)		-100.00	-100.00	4.1	-3.8	-7.9	62.44
{0}{1}Par 01.24 Flux actual % (%)		-200	-200	100	100	0	62.44
{0}{1}Par 01.11 DC voltage (V)		0.00	1000.00	577.23	576.23	-1.00	62.44

5. Accelerate the motor to maximum speed
6. Make a speed reversal again with a slow ramp
7. Check that the excitation current reference is decreasing as well as the flux, and that the minimum excitation current limit is working



Name	Pen	Min	Max	y1	y2	y2-y1	x2-x1
{0}{1}Par 97.62 Excitation running state (NoUnit)	red	0	5	1	1	0	110.23
{0}{1}Par 97.63 Excitation run command (NoUnit)	blue	0	10	1	1	0	110.23
{0}{1}Par 97.65 Excitation current feedback (A)	green	0.00	10.00	2.81	2.75	-0.06	110.23
{0}{1}Par 97.66 Excitation current reference (A)	orange	0.00	10.00	2.64	2.64	0.00	110.23
{0}{1}Par 01.07 Motor current (A)	cyan	0.00	210.00	20.08	20.29	0.21	110.23
{0}{1}Par 01.01 Motor speed used (rpm)	yellow-green	-1000.00	1000.00	900.17	-900.33	-1800.50	110.23
{0}{1}Par 01.10 Motor torque (%)	grey	-100.0	100.0	3.5	-3.5	-7.0	110.23
{0}{1}Par 01.24 Flux actual % (%)	black	-100	200	57	57	0	110.23
{0}{1}Par 01.11 DC voltage (V)	yellow-green	0.00	600.00	575.73	577.21	1.48	110.23

8. Stop the drive
9. Set INU back to remote mode.

Generator no-load test

Purpose of this test is to verify the speed range of the drive system and to verify that the motor model is functioning.

1. Prepare to monitor the following signals:
   - *01.01 Motor speed used* (rpm)
   - *01.07 Motor current* (A)
   - *01.10 Motor torque* (%)
   - *01.11 DC Voltage* (%)
   - *01.24 Flux actual* (%)
   - *29.02 DC voltage ref* (V)
   - *97.62 Excitation running state*
   - *97.63 Excitation run command*
   - *97.65 Excitation reference* (A)
   - *97.66 Excitation current feedback* (A)

2. Request generator to be ran in different speeds, eg. in 50% of nominal speed and in nominal speed
3. Check that the excitation current reference, excitation current feedback and DC voltage looks stable
4. Run no-load curve as instructed in section *Model tuning (page 63)*.

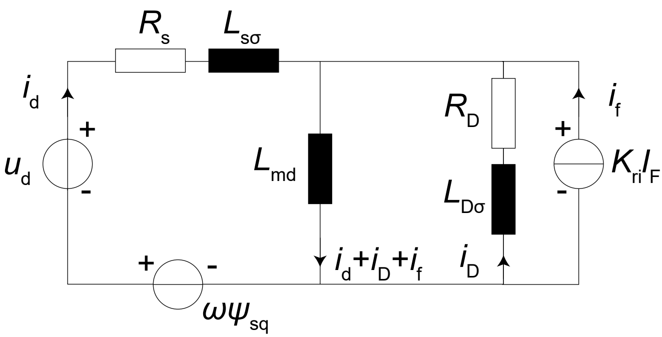
Load tests

Record INU signals in different loading points if applicable. For example record the following signals in different loading points:

- *01.01 Motor speed used*
- *01.07 Motor current* (A)
- *01.10 Motor torque* (%)
- *01.11 DC voltage* (V)
- *01.24 Flux actual* (%)
- *01.25 INU momentary cos phi*
- *29.01 Torque ref DC voltage control*
- *97.65 Excitation current feedback*
- *97.66 Excitation current reference*

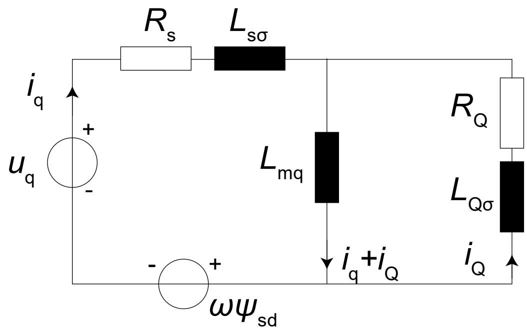
Model tuning

d-axis equivalent circuit of a salient pole synchronous machine



Motor parameter	Parameter	Declaration
R_s	-	Stator resistance. Includes also resistive losses in inverter unit and cabling. Measured by id run.
$L_{s\sigma}$	98.72 Lssigma user	Leakage inductance of stator winding
L_{md}	-	D-axis magnetizing inductance. Automatically defined from no-load curve by drive software.
$L_{D\sigma}$	98.73 LDsigma user	Damper winding d-axis leakage inductance
R_D	98.75 RD user	Resistance of damper winding
K_{ri}	98.77 Rotor to stator reduction factor	Coefficient to convert rotor current usable in machine model

q-axis equivalent circuit of a salient pole synchronous machine



Motor parameter	Parameter	Declaration
R_S	-	Stator resistance. Includes also resistive losses in inverter unit and cabling. Measured by id run.
$L_{S\sigma}$	98.72 Lssigma user	Leakage inductance of stator winding
L_{mq}	98.71 Lmq user	Q-axis magnetizing inductance. Automatically defined from L_{mq} parameter and no-load curve by drive control software.
$L_{Q\sigma}$	98.74 LQsigma user	Damper winding q-axis leakage inductance
R_Q	98.75 RQ user	Resistance of damper winding

Tuning principle

Fine tuning of machine model can be done using model error parameters, which can be made visible by inserting service level password.

In tuning the model error (flux error) parameters are minimized. When machine is loaded the currents flow both in d-direction and in q-direction. In no-load state the current exists only in d-direction and thus it is easier to tune the model in no-load condition.

For no-load testing the machine should be decoupled from load. Later for load tests the coupling needs to be connected.

Tuning should be done at rated speed, because voltage model is inaccurate at low speeds. Excitation current shall be set manually during no-load tuning.

Preparations

Parameters to monitor

- *227.01 ModErr* indicates the error in airgap flux vector length calculated using voltage model vs. current model.
- *227.02 ModErr2* shows the angular error between flux vector lengths calculated using voltage model and current model.
- *01.07 Motor current*
- *01.10 Motor torque %*

No-load tuning

Parameters to operate

- *97.60 Excitation mode*
- *97.66 Excitation current reference*

Start tuning by setting torque limit parameters *30.19 Minimum torque* > -10% and *30.20 Maximum torque* <10%. In fine tuning of machine model excitation current should be controlled manually. Manual excitation control can be selected by setting parameter *97.60 Excitation mode* = 0 (Constant excitation). It is recommended to start tuning from rated no-load current value to avoid trip for low excitation current supervision. In case the no-load current is not known, 60 % of rated excitation current can be used as a starting point.

No-load tuning of the motor model is required before it is used for operation.

No-load curve

After rotor to stator reduction factor K_{ri} is estimated, verify/fix the no-load curve according to the following procedure.

1. Set the no-load currents to parameters *98.78* to *98.83*

2. Set the no-load voltages to parameters *98.84* to *98.89*
3. Set the parameter *97.60 Excitation mode* to Controlled excitation
4. Set the operation mode to the speed control mode
5. Set the first no-load voltage value, i.e. *98.84 US no-load 1*, multiplied by 100 to the parameter *97.07 User flux reference*
6. Set the speed reference to 50-70% of the field weakening point, i.e. motor nominal speed, and start the drive and wait until speed is reached
7. Make sure that *97.66 Excitation current reference* has not been limited to *97.69 Minimum excitation current*
8. Make sure that there is no significant torque, i.e. *01.10 Motor torque %* < 5 %
   - if significant torque exists try if lowering the speed reference helps
   - if significant torque still exists try to redo the autophasing
9. Make sure that there is no significant current flowing in the stator winding, i.e. *01.07 Motor current* < 0.1 * *99.06 Motor nominal current*
   - if significant stator current exists double check the no-load parameters, i.e. *98.78* to *98.89*, and reduction factor *98.77*
10. Read *97.66 Excitation current reference* and compare it to *98.78 IF no-load 1*. Change *98.78* to *97.66* if the two parameters are not equal
11. Increase parameter *97.07 User flux reference* to reach the next no-load voltage value, i.e. *98.85 US no-load 2*, multiplied by 100. This should be done smoothly, e.g. by steps of 5-10%.
12. Repeat step (10) for all the no-load points

Verification of K_{ri}

Set K_{ri} to parameter *98.77* and check the value of model error parameter *227.01 ModErr*. If it is more than ±0.1, fine tune the K_{ri} so that *227.01 ModErr* becomes <±0.1

Finalizing

Return torque limits to normal value and excitation control to INU.

Load-tuning

Due to the model based motor control there are no additional tunings to be done with loaded motor, when model parameters are carefully tuned in no-load operation.

Note: In ACS880 it is not possible to overmagnetize the machine by fooling reduction factor because excitation control is a closed loop controller. In case the reduction factor value is wrong, the control will correct the excitation to a satisfying level. This operates well in steady state. However, if the reduction factor value is wrong, the transient at load step is bigger.

Other model parameters

98.77 Rotor to stator reduction factor

Reduction factor scales rotor current to the excitation current used by machine model. This scaling is done best by using short-circuit current and no-load curves as described earlier in this document.

Note: In ACS880 it is not possible to overmagnetize the machine by fooling reduction factor, because excitation control is a closed loop controller. In case the reduction factor is wrong, the control will correct the excitation to satisfying level. This functions well in steady state. However, if reduction factor has wrong value, the transient at load step is bigger.

Damper winding parameters

Parameters *98.73 LDsigma user*, *98.74 LQsigma use*r, *98.75 RD user* and *98.76 RQ user*.

The parameters shall be set as described earlier in this document and fine tuning is necessary very seldom, if never.

Current flows in damper winding only during transients decaying approximately in 80 to 300 ms. Thus, fine tuning of the damper winding parameters is difficult. Fortunately, the control is normally not sensitive for these parameters due to the short time the damper is active.

4

ACS880 LV-Synchro supplement

Contents of this chapter

This chapter is a supplement to *ACS880 Primary control program firmware manual* (3AUA0000085967 [English]). The supplement describes the differences of the ACS880 LV-Synchro program vs. ACS880 primary control program. Most of the firmware manual content is valid also for the ACS880 LV-Synchro program.

Program features

Introduction

This section describes the operation principle of ACS880 LV-Synchro program.

Excitation current control

The ACS880 LV-Synchro program is intended for inverter units which supply externally excited synchronous machines.

The inverter unit is connected to the stator winding of the synchronous machine. The inverter controls the air gap torque and the stator flux. The inverter also calculates the current reference for the excitation winding. This reference value is equal to current that produces a unity power factor in the steady state operation of the machine. The inverter does not supply this excitation current to the machine winding, but it sends the reference value for a user-defined excitation device.

During the power up of the machine, the excitation device builds up the air gap flux first, after which the inverter starts the modulation.

Communication with the excitation device

The installation/commissioning personnel must install and configure a fast communication link between the inverter unit and the the excitation device. At the inverter end, the alternative connection interfaces are the standard I/O interface, or a fieldbus interface. The commissioning engineer configures the interface in the ACS880 LV-Synchro program according to the actual wirings by the control program parameters.

The inverter sends the run command (*97.63 Excitation run command*), and the current reference (*97.67 Constant excitation current reference*) to the excitation device. The excitation device sends the running status (*97.62 Excitation running state*) and the current feedback (*97.64 Excitation current feedback source*) to the inverter.

The control program sets the excitation device run command when the current reference is more than zero, and keeps it set always when the inverter is modulating. When the inverter receives a stop command and stops modulating, it still keeps the excitation device run command set and the current reference for 500 ms at the minimum. This protects the excitation device from overvoltages.

Inverter uses the excitation device running status and current feedback signals for the supervision (eg, fault 7100). It also uses the current feedback signal for calculating the air gap flux generated by the excitation winding current.

For communication diagram, see *Communication between INU and EXU units (page 17)*.

Parameters

Introduction

This section describes the differences between the ACS880 LV-Synchro program vs. ACS880 primary control program:

- New parameters: The contents of parameter groups 97 and 98 are completely new for ACS880 LV-Synchro. See section *Motor control group (page 71)* and *User motor parameters group (page 73)* below.
- Restricted parameters: There are parameters in the ACS880 LV-Synchro program that are also in the ACS880 primary control program, but the parameters differ. For the differences, see section *Restricted parameters (page 75)*. For the parameter descriptions, see *ACS880 Primary control program firmware manual* (3AUA0000085967 [English]).

The other parameters in the ACS880 LV-Synchro program are identical with the ACS880 primary control program. For the parameter descriptions, see *ACS880 Primary control program firmware manual* (3AUA0000085967 [English]).

In the following tables, the term FbEq 16b / 32b refers to 16-bit / 32-bit fieldbus equivalent. This is the scaling between integer used in communication and the value shown on the panel, when a 16 or 32-bit value is selected for transmission to an external system.

Note: In the following tables the term FbEq 16b/32b refers to 16-bit / 32-bit fieldbus equivalent. This is the scaling between integer used in communication and the value shown on the panel, when a 16 or 32-bit value is selected for transmission to an external system.

Motor control group

No.	Name / Range / Selection	Description	Def / Type FbEq 16b / 32b
		Motor model settings	
97.60	Excitation mode	Selects the excitation mode for externally excited synchronous machine control	Constant excitation / uint16
	Constant excitation	Excitation current is constant.	0
	Controlled excitation	Excitation current is controlled externally.	1
97.61	Excitation running state source	Selects the source for excitation running state. It uses *97.62 Excitation running state* directly by default.	Running state from an excitation device / uint32
	Not selected	0 (always off)	0
	Selected	1 (always on)	1
	DI1	Digital input DI1 (as indicated by DI delayed status bit 0).	2
	DI2	Digital input DI2 (as indicated by DI delayed status bit 1).	3
	DI3	Digital input DI3 (as indicated by DI delayed status bit 2).	4
	DI4	Digital input DI4 (as indicated by DI delayed status bit 3).	5
	DI5	Digital input DI5 (as indicated by DI delayed status bit 4).	6
	DI6	Digital input DI6 (as indicated by DI delayed status bit 5).	7
	DIO1	Digital input/output DIO1 (as indicated by DI delayed status bit 0).	10
	DIO2	Digital input/output DIO2 (as indicated by DIO delayed status bit 1).	11
	Excitation running state	Running state from an excitation device	50
	Other [bit]		
97.62	Excitation running state	Running state from an excitation device. Source for excitation running state is selected in *97.61 Excitation running state source*.	Off / uint16
	Off	Excitation device is not running.	0
	On	Excitation device is running.	1
97.63	Excitation run command	Run command to an excitation device.	Off / uint16
	Off	Stop the excitation device.	0
	On	Start the excitation device.	1
97.64	Excitation current feedback source	Selects the source for excitation current feedback. It uses *97.65 Excitation current feedback* directly by default.	Excitation current feedback / uint32
	Not selected	Excitation current feedback source not selected.	0

No.	Name / Range / Selection	Description	Def / Type FbEq 16b / 32b
	AI1 scaled	12.12 AI1 scaled value.	1
	AI2 scaled	12.22 AI2 scaled value.	2
	Excitation current feedback	Current feedback from an excitation device.	3
	Other [bit]		
97.65	Excitation current feedback	Current feedback from an excitation device. Source for excitation current feedback is selected in *97.64 Excitation current feedback source*.	0.00 A / real32
	0.00 ... 3000.00 A	Feedback current from an excitation device.	1 = 1 A / 100 = 1 A
97.66	Excitation current reference	Current reference to an excitation device	0.00 A / real32
	0.00 ... 3000.00 A	Current reference to an excitation device.	1 = 1 A / 100 = 1 A
97.67	Constant excitation current reference	Excitation current reference when *97.60 Excitation mode* is set to Constant excitation	0.00 A / real32
	0.00 ... 3000.00 A	Excitation current reference	1 = 1 A / 100 = 1 A
97.68	Nominal excitation current	Nominal value for the excitation current. This value times 0.707 is used as excitation current reference in special situations such as ID run and Autophasing.	0.00 A / real32
	0.00 ... 3000.00 A	Nominal value for the excitation current.	1 = 1 A / 100 = 1 A
97.69	Minimum excitation current	Minimum limit for the excitation current. Minimum limit can be internally forced to zero when the drive is not modulating.	0.00 A / real32
	0.00 ... 3000.00 A	Minimum limit for the excitation current.	1 = 1 A / 100 = 1 A
97.70	Maximum excitation current	Maximum limit for the excitation current. Maximum limit can be internally forced to smaller value in order to protect the drive from DC overvoltage in case of trips or coast stops.	0.00 A / real32
	0.00 ... 3000.00 A	Maximum limit for the excitation current.	1 = 1 A / 100 = 1 A
97.71	Flux reference stopped	Flux reference used in stopped state when 97.60 Excitation mode is set to Controlled excitation	0% / real32
	0...200%	Flux reference in stopped state	100 = 1% / 100 = 1%
97.72	Maximum flux deviation	Defines how much the actual flux calculated based on the excitation current feedback can deviate from the flux reference at the moment of starting. Using smaller value enables smoother starting, however, larger value may have be used if 97.65 Excitation current feedback does not follow 97.66 Excitation current reference exactly, for example, due to scaling errors. If the deviation is bigger for more than ten seconds after the run command has been given, the drive will trip to Excitation fault.	5.0% / real32
	0.0 ... 100.0%	Maximum flux deviation in start.	10 = 1% / 10 = 1%
97.73	Excitation current ramp time	Defines the ramp time from zero to 97.68 Nominal excitation current for the excitation current reference.	0.000 s / real32
	0.000 ... 1000.000 s	Ramp time from zero to nominal excitation current.	1 = 1 s / 1000 = 1 s

No.	Name / Range / Selection	Description	Def / Type FbEq 16b / 32b
97.74	Excitation current trip margin	Defines the excitation current feedback trip margin as percent of 97.69 Minimum excitation current. If the excitation current feedback is below the minimum limit minus the trip margin while the drive is modulating, the drive trips to Excitation fault.	50% / real32
	0...100%	Excitation current feedback trip margin as percentage of minimum excitation current.	1 = 1% / 1 = 1%
97.75	Excitation current safety margin	Defines the margin for the internal excitation current maximum value which is calculated based on the motor parameters and the actual motor speed in order to prevent DC overvoltage in case of trips or coast stops. A positive margin decreases the maximum excitation current and increases safety but decreases the maximum output torque at high speed. A negative margin increases the maximum excitation current and output torque at high speed. However, a negative margin should be used only when the intermediate circuit is protected from overvoltage by a sufficiently powerful braking chopper and resistor. The margin is scaled so that for example value +10 % decreases the maximum DC bus voltage by 10 % of the DC bus overvoltage trip limit.	0% / real32
	-200...100%	Safety margin of the excitation current.	1 = 1% / 1 = 1%

User motor parameters group

No.	Name / Range / Selection	Description	Def / Type FbEq 16b / 32b
98	**User motor parameters**	These parameters are useful for non-standard motors, or to just get more accurate motor control of the motor on site. A better motor model always improves the shaft performance.	
98.70	Lmd user	D-axis magnetizing inductance of externally excited synchronous machine.	0.000 pu / real32
	0.000 ... 1000.000 pu	D-axis magnetizing inductance in per unit.	1 = 1 pu / 1000 = 1 pu
98.71	Lmq user	Q-axis magnetizing inductance of externally excited synchronous machine.	0.000 pu / real32
	0.000 ... 1000.000 pu	Q-axis magnetizing inductance in per unit.	1 = 1 pu / 1000 = 1 pu
98.72	Lssigma user	Stator leakage inductance of externally excited synchronous machine.	0.000 pu / real32
	0.000 ... 1000.000 pu	Stator leakage inductance in per unit.	1 = 1 pu / 1000 = 1 pu
98.73	LDsigma user	Damper winding d-axis leakage inductance of externally excited synchronous machine.	0.000 pu / real32
	0.000 ... 1000.000 pu	Damper winding d-axis leakage inductance in per unit.	1 = 1 pu / 1000 = 1 pu
98.74	LQsigma user	Damper winding q-axis leakage inductance of externally excited synchronous machine.	0.000 pu / real32
	0.000 ... 1000.000 pu	Damper winding q-axis leakage inductance in per unit.	1 = 1 pu / 1000 = 1 pu

No.	Name / Range / Selection	Description	Def / Type FbEq 16b / 32b
98.75	RD user	Damper winding d-axis resistance of externally excited synchronous machine.	0.000 pu / real32
	0.000 ... 1000.000 pu	Damper winding d-axis resistance in per unit.	1 = 1 pu / 1000 = 1 pu
98.76	RQ user	Damper winding q-axis resistance of externally excited synchronous machine.	0.000 pu / real32
	0.000 ... 1000.000 pu	Damper winding q-axis resistance in per unit.	1 = 1 pu / 1000 = 1 pu
98.77	Rotor to stator reduction factor	This factor scales the rotor excitation winding current from the rotor DC current scale to the stator AC rms current scale. The motor model needs this value so that it can estimate the stator flux linkage created by the excitation current.	1.000 / real32
	0.000 ... 1000.000	Rotor excitation winding current scaling factor.	1 = 1 / 1000 = 1
98.78	IF no-load 1	Excitation current at the 1st point of the no-load curve.	0.0 A / real32
	0.0 ... 1000.0 A	No-load point.	1 = 1 A / 10 = 1 A
98.79	IF no-load 2	Excitation current at the 2nd point of the no-load curve.	0.0 A / real32
	0.0 ... 1000.0 A	No-load point.	1 = 1 A / 10 = 1 A
98.80	IF no-load 3	Excitation current at the 3rd point of the no-load curve.	0.0 A / real32
	0.0 ... 1000.0 A	No-load point.	1 = 1 A / 10 = 1 A
98.81	IF no-load 4	Excitation current at the 4th point of the no-load curve.	0.0 A / real32
	0.0 ... 1000.0 A	No-load point.	1 = 1 A / 10 = 1 A
98.82	IF no-load 5	Excitation current at the 5th point of the no-load curve.	0.0 A / real32
	0.0 ... 1000.0 A	No-load point.	1 = 1 A / 10 = 1 A
98.83	IF no-load 6	Excitation current at the 6th point of the no-load curve.	0.0 A / real32
	0.0 ... 1000.0 A	No-load point.	1 = 1 A / 10 = 1 A
98.84	US no-load 1	Stator voltage at the 1st point of the no-load curve.	0.000 pu / real32
	0.000 ... 10.000 pu	No-load point.	1 = 1 pu / 1000 = 1 pu
98.85	US no-load 2	Stator voltage at the 2nd point of the no-load curve.	0.000 pu / real32
	0.000 ... 10.000 pu	No-load point.	1 = 1 pu / 1000 = 1 pu
98.86	US no-load 3	Stator voltage at the 3rd point of the no-load curve.	0.000 pu / real32
	0.000 ... 10.000 pu	No-load point.	1 = 1 pu / 1000 = 1 pu
98.87	US no-load 4	Stator voltage at the 4th point of the no-load curve.	0.000 pu / real32
	0.000 ... 10.000 pu	No-load point.	1 = 1 pu / 1000 = 1 pu
98.88	US no-load 5	Stator voltage at the 5th point of the no-load curve.	0.000 pu / real32
	0.000 ... 10.000 pu	No-load point.	1 = 1 pu / 1000 = 1 pu
98.89	US no-load 6	Stator voltage at the 6th point of the no-load curve.	0.000 pu / real32
	0.000 ... 10.000 pu	No-load point.	1 = 1 pu / 1000 = 1 pu
98.90	Saturation modeling method	Saturation modeling method used with externally excited synchronous machine.	Disabled / uint16
	Disabled	Saturation modeling disabled.	0

No.	Name / Range / Selection	Description	Def / Type FbEq 16b / 32b
	Salient pole machine	Salient pole method used for saturation modeling.	1
	Non-salient pole machine	Non-salient pole method used for saturation modeling.	2

Restricted parameters

The table below lists the parameters of ACS880 LV-Synchro program that differ from the corresponding parameters in the ACS880 primary control program. The table also describes the reason for the change, and the type of the difference:

- Hidden: parameter is not supported or it is irrelevant
- Forced: parameter is forced to certain (non-user adjustable) value
- Restricted: parameter value selections, or parameter value range, is narrowed down.

For the parameter descriptions, see *ACS880 Primary control program firmware manual* (3AUA0000085967 [English]).

No.	Name/Value	Reason for restrictions	Hidden	Forced or restricted to
21.01	Start mode	Only automatic start mode is supported	Yes	2 = Automatic
21.02	Magnetization time	Only automatic start mode is supported	Yes	
21.08	DC current control	DC hold and post magnetization are not supported	Yes	0
21.09	DC hold speed	DC hold is not supported	Yes	
21.10	DC current reference	DC hold is not supported	Yes	
21.11	Post magnetization time	Post magnetization is not supported	Yes	
21.12	Continuous magnetization command	Continuous magnetization is not supported	Yes	0 = Off
21.13	Autophasing mode	Autophasing modes "Turning with Z-pulse" and "Standstill 2" are not supported	No	0 = Turning or 1 = Standstill 1
21.14	Preheating input source	Preheating is not supported	Yes	0 = Inactive (false)
21.16	Preheating current	Preheating is not supported	Yes	
21.19	Scalar start mode	Only normal scalar start mode is supported	Yes	0 = Normal
45.11	Energy optimizer	Energy optimization is not supported	Yes	0 = Disabled
90.41	Motor feedback selection	Encoderless operation is not supported	No	1 = Encoder 1

No.	Name/Value	Reason for restrictions	Hidden	Forced or restricted to
90.45	Motor feedback fault	Encoderless operation is not supported	No	0 = Fault
90.46	Force open loop	Encoderless operation is not supported	Yes	0 = No
97.03	Slip gain	Irrelevant	Yes	
97.05	Flux braking	Flux braking is not supported	Yes	
97.08	Optimizer minimum torque	Irrelevant	Yes	
97.10	Signal injection	Signal injection is not supported	Yes	
97.11	TR tuning	Irrelevant	Yes	
98.01	User motor model mode	User motor model parameters are always required	Yes	3 = Motor parameters & position offset
98.03	Rr user	Irrelevant	Yes	
98.04	Lm user	Irrelevant	Yes	
98.05	SigmaL user	Irrelevant	Yes	
98.06	Ld user	Irrelevant	Yes	
98.07	Lq user	Irrelevant	Yes	
98.08	PM flux user	Irrelevant	Yes	
98.09	Rs user SI	Irrelevant	Yes	
98.10	Rr user SI	Irrelevant	Yes	
98.11	Lm user SI	Irrelevant	Yes	
98.12	SigmaL user SI	Irrelevant	Yes	
98.13	Ld user SI	Irrelevant	Yes	
98.14	Lq user SI	Irrelevant	Yes	
99.03	Motor type	Irrelevant	Yes	

Autophasing restrictions

There are two autophasing modes available for parameter *21.13*: Turning and Standstill 1. Turning mode is the default, and Standstill 1 mode can be used if the motor can not be turned (for example when the load is connected).

An autophasing fault (3385 Autophasing) can occur in the following situations:

- Motor axis is not in standstill. Standstill 1 autophasing must be performed with a standstill motor.
- The excitation current dynamic response is too slow. This can be corrected by tuning the gains of excitation control to fasten dynamic response.

Note that Standstill 1 autophasing might rotate the axis by a very small angle resulting from motor asymmetry and initial rotor position.

Parameter *21.13* values Standstill 2 and Turning with Z-pulse are not supported. If they are selected they will also give the autophasing fault.

Fault tracing

Introduction

This section lists warning and fault messages including possible causes and corrective actions. This section contains the faults and warnings that are specific only for the ACS880 LV-Synchro program. See *ACS880 Primary control program firmware manual* (3AUA0000085967 [English]) for the other warnings and faults.

Warning messages

Code (hex)	**Warning**	**Cause**	**What to do**
64A5	Licensing fault	Running the control program is prevented either because a restrictive license exists, or because a required license is missing.	Record the auxiliary codes of all active licensing faults and contact your product vendor for further instructions.
7100	Excitation	The excitation device did not start or did not follow the current reference after the inverter was started.	Make sure that the parameters related to the communication between the inverter and the excitation device are set correspondingly in the inverter and in the excitation device.
		The excitation device stopped, or too low excitation current was detected while the inverter was running.	Make sure that parameters that define the minimum excitation current (*97.69 Minimum excitation current*) and excitation current trip margin (*97.74 Excitation current trip margin*) are set to reasonable values. Make sure that the response of the excitation device to current reference changes is optimal.

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Appendix 1

Used per unit system

Generally accepted principles of the per unit system used in a mathematical description of electrical machines are shown. Per unit (pu) system is the dimensionless relative value system defined in terms of base values. A pu quantity x_{pu} is defined as an absolute physical value X_{act} in SI-unit divided by its base value X_B.

$$x_{pu} = \frac{X_{act}}{X_B}$$

The motor nominal values are chosen to be the basic values in the pu system.

Nominal values of the test machine

Power S_n	14.5 kVA	Frequency f_n	50 Hz
Voltage U_n	400 V	Speed n_n	1500 1/min
Current I_n	21 A	Power factor $\cos(\varphi)$	0.8 cap.
Excitation current I_f	10.5 A	Reduction factor k_n	4.637

The pu system is referred to the following base quantities:

$$U_B = \sqrt{\frac{2}{3}} \cdot U_n$$ Amplitude of a nominal stator phase voltage [V]

$$I_B = \sqrt{2} \cdot I_n$$ Amplitude of a nominal stator phase current [A]

$$\omega_B = \omega_n = 2 \cdot \pi \cdot f_n$$ Stator nominal angular velocity [Hz]

$$p_B = p$$ Number of pole pairs

where U_n is a nominal RMS value of a motor main voltage
I_n is a nominal RMS value of a motor phase current
f_n is a nominal value of a motor synchronous frequency
ω_n is a nominal value of a motor angular velocity

From these so-called derivative base quantities are determined as follows:

$$t_B = \frac{1}{\omega_B}$$ Time

$$Z_B = \frac{U_n}{\sqrt{3} \cdot I_n} = \frac{U_B}{I_B}$$ Impedance

$$S_B = \sqrt{3} \cdot U_n \cdot I_n = \frac{3}{2} U_B \cdot I_B$$ Power

$$\psi_B = \frac{\sqrt{\frac{2}{3}} \cdot U_n}{\omega_n} = \frac{U_B}{\omega_B}$$ Flux linkage

$$T_B = \frac{\sqrt{3} U_n \cdot I_n}{\frac{\omega_n}{p}} = p \frac{S_B}{\omega_B} = \frac{3}{2} p \cdot \psi_B \cdot I_B$$ Torque

$$L_B = \frac{\psi_B}{I_B} = \frac{Z_B}{\omega_B}$$ Inductance

$$C_B = \frac{1}{\omega_B \cdot Z_B}$$ Capacitance

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Appendix 2

Equipment	Identification
Transformer	
Converter	
Motor 1	
Motor 2	
Motor 3	
Motor 4	
Motor 5	

The installations of motors include the installation of lubrication units and brakes when available.

Hereby I confirm that installations of equipment listed above are completed, safe and ready for operation as well as they fulfil local regulations and additional requirements set by ABB in installation instructions and product documentation.

Date and place	
Company	
Name	
Signature	

Further information

Product and service inquiries

Address any inquiries about the product to your local ABB representative, quoting the type designation and serial number of the unit in question. A listing of ABB sales, support and service contacts can be found by navigating to www.abb.com/searchchannels.

Product training

For information on ABB product training, navigate to new.abb.com/service/training.

Providing feedback on ABB manuals

Your comments on our manuals are welcome. Navigate to new.abb.com/drives/manuals-feedback-form.

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