SINAMICS DCM

DC Converter

Closed-loop control application for a Ward-Leonard block

Edition 02 - 06/2013

SINAMICS drives

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Closed-loop control application for a Ward-Leonard block

Compact User Manual

Legal information

Warning notice system

This manual contains notices you have to observe in order to ensure your personal safety, as well as to prevent damage to property. The notices referring to your personal safety are highlighted in the manual by a safety alert symbol, notices referring only to property damage have no safety alert symbol. These notices shown below are graded according to the degree of danger.

⚠ DANGER
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⚠ WARNING
indicates that death or severe personal injury **may** result if proper precautions are not taken.

⚠ CAUTION
with a safety alert symbol, indicates that minor personal injury can result if proper precautions are not taken.

CAUTION
without a safety alert symbol, indicates that property damage can result if proper precautions are not taken.

NOTICE
indicates that an unintended result or situation can occur if the corresponding information is not taken into account.

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Qualified Personnel

The product/system described in this documentation may be operated only by **personnel qualified** for the specific task in accordance with the relevant documentation for the specific task, in particular its warning notices and safety instructions. Qualified personnel are those who, based on their training and experience, are capable of identifying risks and avoiding potential hazards when working with these products/systems.

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Siemens products may only be used for the applications described in the catalog and in the relevant technical documentation. If products and components from other manufacturers are used, these must be recommended or approved by Siemens. Proper transport, storage, installation, assembly, commissioning, operation and maintenance are required to ensure that the products operate safely and without any problems. The permissible ambient conditions must be adhered to. The information in the relevant documentation must be observed.

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1 Instructions

Note

This application document does not claim to contain all details and versions of units, or to take into account all conceivable operational cases and applications.

The standard applications do not represent specific customer solutions, but are only intended to provide support in the implementation of typical applications. The operator is responsible for the correct operation of the products described.

Should you require further information or encounter specific problems which have not been handled in enough detail, please contact your local Siemens office.

The contents of this application document are not part of an earlier or existing contract, agreement or legal relationship, nor do they change such contracts, agreements or legal relationships. The contract of sale in each case outlines all the obligations of the I DT Drive Technologies Division of Siemens AG. The warranty conditions specified in the contract between the parties are the only warranty conditions accepted by the I DT Drive Technologies Division. Any statements contained herein neither create new warranties nor modify the existing warranty.

⚠ WARNING

The units listed here contain dangerous electric voltages, dangerous rotating machine parts (fans) and control rotating mechanical parts (drives). Failure to follow the relevant Operating Instructions may result in death, serious injury or extensive material damage.

Technical Support

You can also find help for technical issues through our Technical Support:
www.siemens.de/automation/support-request (German)
www.siemens.com/automation/support-request (English)

2 Introduction

Until the early 1960s, a motor generator block (the Ward-Leonard block) was used for variable-speed drives. A DC generator driven by a synchronous motor was used to supply a DC motor. The generator armature voltage was controlled by changing the field to obtain a variable armature voltage to supply the motor. The generator thus acted as a variable, high-power voltage source for the motor. The armature voltage of the generator was controlled using a low-power field supply. This enabled the motor to be driven at variable speeds.

In some cases, the system is modernized by omitting the synchronous motor and the DC generator, and feeding the motor armature via a thyristor set.

For other cases, where the motor generator block produces sufficient performance and is in good condition, a low-cost version that modernizes only the control is often requested.

For these applications, a 4Q SINAMICS DCM can be configured using the standard functions of the technology controller and of the free function blocks to provide full control for a motor generator block. The following closed-loop control functions are implemented:

- Control of the generator field
- Control of the armature current
- Control of the motor speed
- with an additional SINAMICS DCM, also control of the motor field

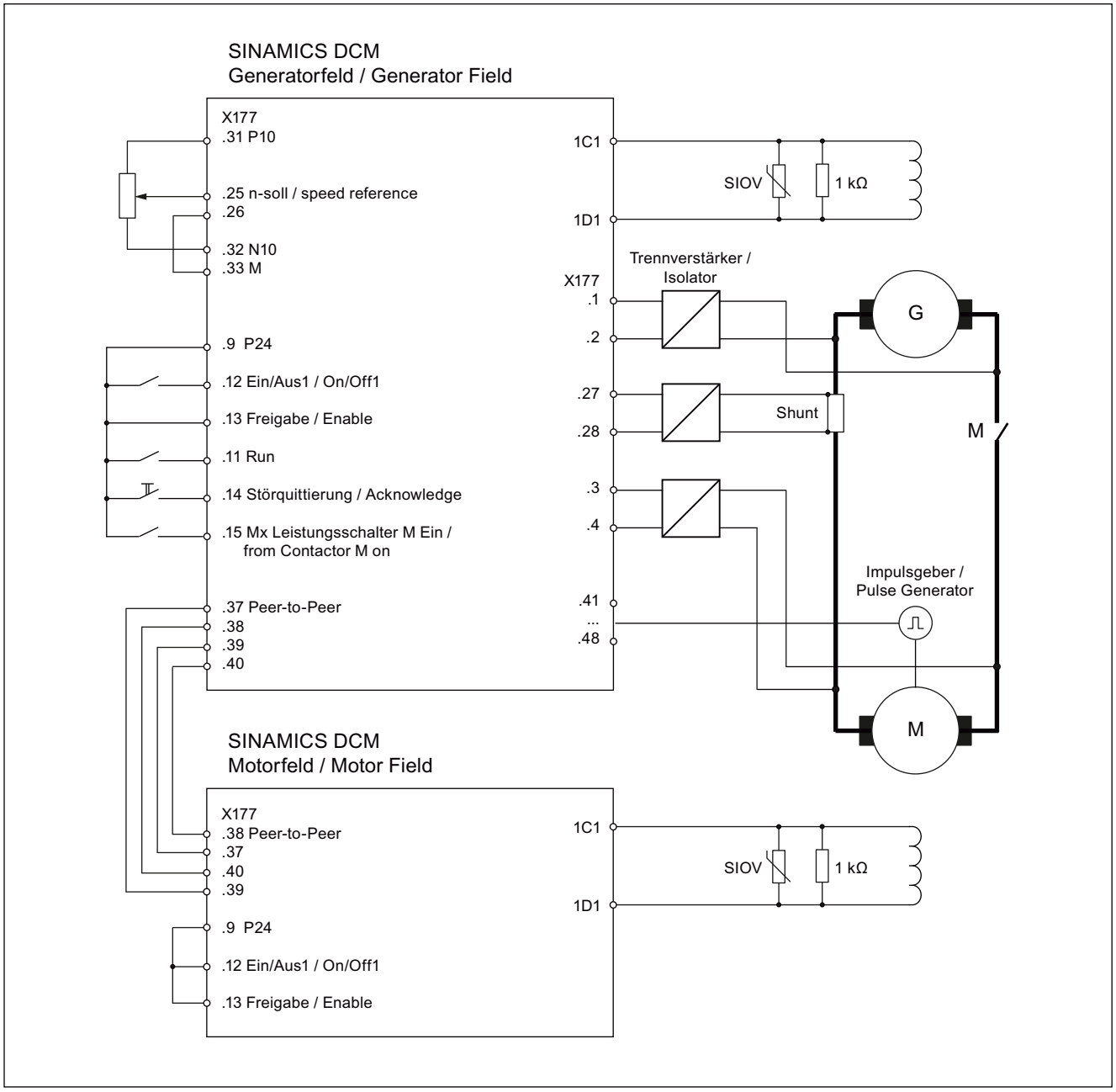
The complete control structure consists of 3 closed-loop control loops. The innermost control loop uses the normal armature current controller for controlling the generator field. The 2nd control loop uses the technology controller to control the armature current for the generator. The 3rd control loop uses the normal speed controller to control the motor speed. If, in addition, a field-weakening control is required, an additional 2Q SINAMICS DCM must be used for field control of the motor.

This application paper describes the parameter settings required to perform motor generator block control with the free function blocks and the technology controller of the SINAMICS DCM (available from firmware V1.2).
This application paper defines general guidelines to support the user with typical motor generator block control but does not describe every conceivable case of application.
Unused function blocks of the controller can be used for other functions.

Restrictions

1. The automatic optimization runs (except that of the armature-current controller for field current control) cannot be used for this application.
2. In the event of a fault in the SINAMICS DCM, monitoring should be used in the motor generator circuit. If an error occurs in the SINAMICS DCM for the generator field, its current is brought to zero. If the motor rotates, a higher armature current can occur. Under fault conditions on the converter for the generator field, this armature current from the SINAMICS DCM cannot be controlled. In this case, the current setpoint at the SINAMICS DCM for the motor field is also brought to zero when an error message occurs in the generator control.
3. The SINAMICS DCM was developed to control the armature current. Due to the versatility of the software, however, it can also be used to control a motor generator block; but this requires a certain knowledge of the customer requirements. The armature circuit of the SINAMICS DCM is used to control the field of the generator and motor.
4. Closed-loop control described in this application document for motor generator blocks should be used and commissioned by trained personnel only.

3 Typical connections



4 Selection of the components

1. SINAMICS DCM for generator field

   The SINAMICS DCM for the generator field should be a 4Q device. The 4Q version is required to obtain both polarities in the generator voltage. Operation of the motor is therefore possible in both directions of rotation. The SINAMICS DCM devices are also designed for long pulses. Long pulses enable reliable operation at high inductances. For long pulses, parameter p50079 must be set to 1. The rated current of the SINAMICS DCM should be designed for the maximum field current of the generator. Additional alpha-W pulses are required to ensure that the field current is brought to zero before a change of torque direction is carried out: P50179 = 3 to 7 (depending on the inductance of the field winding). This ensures that the current of the active torque direction is brought to zero before a torque direction changeover is carried out, and thus ensures that no circulating current occurs.
   The firmware version of the SINAMICS DCM must be Version 1.2 or higher.

2. SINAMICS DCM for motor field

   If a separate SINAMICS DCM is required for the motor field, a 2Q device is used. Since the direction of rotation of the motor is determined by a bipolar armature voltage, the field supply unit for the motor field can be a 2Q device.

3. Isolating amplifier

   Isolating amplifiers are required to match the armature current signal and the armature voltage of the motor generator block to the SINAMICS DCM. The isolating amplifiers must supply a ±10 V signal for the rated values of the drive unit.

   Isolating amplifiers for the armature current
   A faster isolating amplifier without high filtering for dynamic closed-loop armature-current control should be used for the armature current. This isolating amplifier is used together with a shunt in the armature circuit. The insulation resistance must be designed to accommodate the full armature voltage of the block. The scaling of the isolating amplifier should be ± 8 VDC for motor limiting current; this provides a certain amount of reserve for transient harmonics.

   Isolating amplifiers for motor and generator voltage
   These isolating amplifiers are designed for the maximum armature voltage of the block. The scaling should be ±8 V for rated motor and generator voltage so that a certain reserve is available for transient overvoltages.

4. Resistance parallel to field winding

   If the holding current is undershot, disable the thyristors. To prevent tripping of the overvoltage protection, it is recommended to insert a resistor ≤1 kΩ parallel to the field winding. The power of the resistor is calculated from the rated voltage of the generator or motor field. (Pv = U×U/R).

5. Protective circuit in parallel with the field circuit

   At the output of the SINAMICS DCM devices for field supply, a protective circuit must be configured to prevent overvoltage. This is active, particularly in the event of a power failure on the line side. Dimensioning is carried out according to the energy content of the field (L×I×I/2).

   For 230/400 V line voltage, we recommend the following overvoltage protection, depending on the energy content of the field winding:

up to 400 Ws:	Varistor SIOV-B32K460 (manufacturer Epcos: www.epcos.com)
up to 2000 Ws:	Varistor SIOV-B80K460
>2000 Ws:	7VV3003-6BG30 (overvoltage protection with thyristor for 4Q)

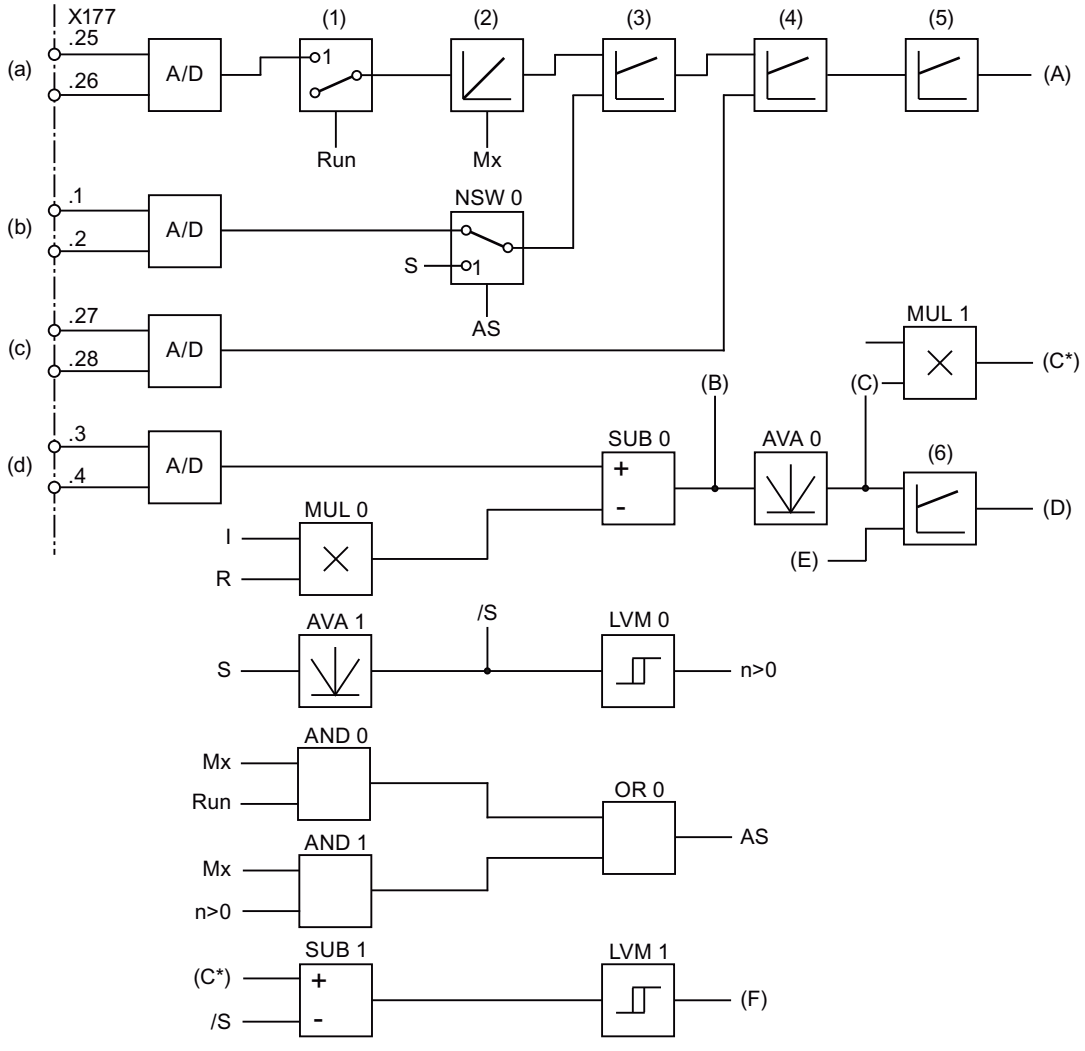
For 460/500 V line voltage, the following overvoltage protection is recommended:

up to 400 Ws:	Varistor SIOV-B32K550
up to 2000 Ws:	Varistor SIOV-B80K550
>2000 Ws:	7VV3003-6CG30 (overvoltage protection with thyristor for 4Q)

6. Semiconductor protection fuses and line reactors

The types of semiconductor fuses and line reactors are specified in catalog D23.1.

5 Block diagram for closed-loop control of the SINAMICS DCM for the generator field



(a)	Analog speed setpoint input	(b)	from the isolating amplifier generator voltage
(c)	from the isolating amplifier armature current, motor	(d)	from the isolating amplifier motor voltage
(1)	Setpoint enable from Run signal	(2)	Ramp-function generator enable from Mx signal
(3)	Speed controller	(4)	Technology controller as armature current controller for the motor current
(5)	Armature current controller as field-current controller	(6)	EMF controller for field weakening motor field
(A)	For gating unit	(B)	Actual EMF value
(C)	Actual EMF value, absolute	(C*)	Scaled absolute actual EMF value for tachometer monitoring
(D)	To generate the field current setpoint generation for the motor field	(E)	EMF setpoint
(F)	Tachometer monitoring to "External fault 3"	AS	Signal for switching over to measured speed
S	Measured motor speed	/S	Measured absolute motor speed
R	Motor resistance in %	I	Actual current value in %
n>0	of the limit monitor n>zero query	A/D	Analog-to-digital converter

6 Start/stop function and device control

1. Proposed start sequence

	Action	Comments
1	Close "ON/OFF1" contact	The field controllers for motor and generator are switched on. This starts the controller and regulates to zero volts generator voltage. For the specified setting, the actual value for the speed controller is the armature voltage of the generator and the main setpoint for the speed is zero.
2	Close the armature circuit breaker "M"	This closes the control circuit for the armature voltage while the generator voltage is regulated to zero so that no current flows.
3	Close the "RUN" contact	This enables the speed setpoint upstream of the ramp-function generator and selects the actual value for the speed controller. The motor should start to rotate via the selected ramp-function generator.
4	Change the speed setpoint to the required value	The motor will follow the speed setpoint.

2. Proposed stop function

	Action	Comments
1	Either bring the external speed setpoint to zero or open the "RUN" contact.	If the "RUN" contact is open, the speed setpoint upstream of the ramp-function generator is set to zero and the drive is decelerated to zero via the ramp-function generator. When the speed reaches zero, voltage control is selected.
2	At any time when the armature circuit switch opens, the generator control switches over to zero-volt control. This is necessary for generator safety.	Voltage feedback is selected if the "Mx" contact is open, which indicates that the armature voltage switch is open. Then the system is brought to zero generator voltage.
3	Open "ON/OFF1" contact	This switches the controllers off and inhibits the firing pulses (generator field zero). The motor field is deactivated via peer-to-peer.
4	Open the armature circuit main switch "M"	This opens the armature circuit and prevents current from flowing via the retentivity of the generator.

3. Control and monitoring functions

	Function	Comments
1	ON/OFF1	From terminal X177.12. For PROFIBUS: terminal X177.12 & bit from PROFIBUS Is forwarded peer-to-peer to the SINAMICS DCM for the motor at the same time as "ON/OFF1". "ON" simultaneously issues the controller enable. A separate controller enable should not be used for this application. Terminal X177.13 to High. "OFF1" will cause immediate current decay to zero of the SINAMICS DCM and result in a controller disable
2	OFF2	"OFF1" has same effect as "OFF2" for this application. Do not use "OFF2"
3	OFF3	"OFF3" quick stop cannot be used for this application Remedy: Cancel "Run" and switch the ramp-function generator to the desired deceleration ramp for quick stop
4	Run	From terminal X177.11, corresponds to setpoint enable upstream of the ramp-function generator

	Function	Comments
5	Fault acknowledgement	From terminal X177.14 Is forwarded peer-to-peer to the SINAMICS DCM for the motor for common acknowledgment. After acknowledging, specify OFF1 to achieve "Ready for switching on" status.
6	Mx	Feedback signal from armature circuit circuit breaker via terminal X177.15 Mx = High is circuit breaker ON Mx = Low switches to generator voltage control, blocks the ramp-function generator (RFG output becomes zero) for zero-volt generator voltage control
7	Switchover to actual speed value	Takes place when Mx=High and Run are present, or if Mx=High and n>zero are present ("AS" signal)
8	n=zero	Because of the special "OFF1" function for this application, the "n<nmin" signal may not be used (threshold for nmin boost). A separate limit monitor is used for "n>zero"
9	Error message	If there is an error message in the SINAMICS DCM for the generator, its current becomes zero and can no longer be controlled. This may result in an impermissible generator current. In this state, zero setpoint is therefore specified for the SINAMICS DCM for the motor field.
10	"Operation" signal	In "Operation", a high signal is output via terminal X177.19.
11	"Fault" signal	In the case of an error message in the SINAMICS DCM, a low signal is output via terminal X177.20. In the case of an error message in the SINAMICS DCM for the motor field, the actual current value signaled to the generator control becomes zero and the generator switches off with F60105.
12	Tachometer fault	The limit monitor LVM 1 is used to implement tachometer monitoring. When LVM 1 triggers, "External fault 3" is output
13	PROFIBUS	The 1st PZD word from the PROFIBUS must always be control word 1. Bit 10 must be set in the control word to ensure that the process data in the SINAMICS DCM are evaluated. Set p0922 = 999

7 SINAMICS DCM parameter assignment for motor field

After "Setting general parameters", the current controller optimization run p50051 = 25 should be performed. Only when this has been completed should you perform "Settings for the further parameters".

Use terminal X177.12 for "ON/OFF1" for the current controller optimization run.

Setting general parameters

Parameter	Meaning
p0003=3	Set key parameter to 3 to enable modification of all parameters
p50076[0]=	Adaptation of the rated unit armature current (excitation current motor)
p50078[0]=	Rated voltage of supply network for 1U1/1V1/1W1
p50079=1	Long pulses selected
p50082=0	Internal field not used, the armature circuit is used to supply the field
p50083[0]=4	Speed actual value can be freely connected
P50086=0	There is no automatic restart
p50100[0]=	Nominal field current
p50171[0]=100	Positive current limit 100% of p50100
p50172[0]=-100	Negative current limit -100 % of p50100
p50110[0]=	Resistance of the motor field, is set by the current controller optimization run
p50111[0]=	Inductance of the motor field, is set by the current controller optimization run
p50153[0]=3	EMF pre-control for field supply
p50155[0]=	Kp current controller, is set by the current controller optimization run
p50156[0]=	Tn current controller, is set by the current controller optimization run
p50179[0]=	Additional alpha-W pulses: 3 to 7 depending on the inductance for the motor field
p50609[0]=0	Source actual speed value
p2118[0]=60042	Select "tachometer fault" error message to be suppressed
p2118[1]=60035	Select "Motor blocked" error message to suppress
p2119[0]=3	Suppress "tachometer fault" error message
p2119[1]=3	Suppress "Motor blocked" error message

Setting the other parameters

Parameter	Meaning
p50084=2	Current-controlled operation
p50601[2]=52601	Current setpoint of the 1st receive word via peer-to-peer
p50790=5	Select peer-to-peer
p50791=2	2 words via peer-to-peer
p50793=13	Recommended baud rate 187.5 kBd
p50794[0]=52116	Absolute current actual value as the 1st send word via peer-to-peer
p50795=1	Activate bus termination
p50797=0.3	Telegram failure time peer-to-peer 0.3 s
p0840[0]=52607.0	"ON/OFF1" via peer-to Receive word 2, bit 0 & terminal X177.12
p0852[0]=52607.0	"Enable" via peer-to-peer & terminal X177.13
p02102 = 52607.1	Fault acknowledgment from peer-to-peer, word 2 bit 1 This parameter is in DO1

8 SINAMICS DCM parameter assignment for generator field

After "Setting general parameters" and parameters for "Generator field controller", perform a current controller optimization run with p50051 = 25 before entering the other parameters.

The current controller optimization run is possible only with the factory settings for the wiring of the controller structure. Do not perform the rewiring in the controller structure required for this application until after the current controller optimization run has been completed.

Setting general parameters

Parameter	Meaning
p0003=3	Set key parameter to 3 to enable modification of all parameters
p50076[0]=	Adaptation of the rated unit armature current (excitation current generator)
p50078[0]=	Rated voltage of supply network for 1U1/1V1/1W1
p50079=1	Long pulses selected
p50083[0]=4	Free actual speed value wiring
p50609[0]=0	Set only for the current controller optimization run, will be changed later to the system value
p50086=0	There is no automatic restart
p50082=21	External field supply unit for the motor field; setpoint input to the motor field after an ON command.
p50097=0	In the case of an error message, specify current setpoint 0 at motor field.
p50100[0]=	Rated current of the generator field
p50102[0]=	Rated current of the motor field
p50171[0]=100	Positive current limit 100% of p50100
p50172[0]=-100	Negative current limit -100 % of p50100
p51838=	The value of r50072[1] of the SINAMICS DCM for the motor field must be set here.
p50179[0]=	3 to 7 depending on the inductance of the generator field

Generator field controller

Parameter	Meaning
p50110[0]=	Resistance of the generator field, is set during the current controller optimization run
p50111[0]=	Inductance of the generator field, is set during the current controller optimization run
p50155[0]=	Kp current controller, is set by the current controller optimization run
p50156[0]=	Tn current controller, is set during the current controller optimization run
p50153[0]=3	EMF pre-control for field supply
p50601[2]=2294	Technology controller output as current setpoint for controller generator field (armature current controller SINAMICS DCM). Do not set the generator with p50051=5 until after the optimization run has been completed. Select a function module (next item) beforehand

Selection of technology controller and free function blocks

Parameter	Meaning
	These parameters are in DO1, can also be set with BOP20
p003=3	Expert
p009=2	Define the drive type/function module
p108[1]	Bit 16 Technology controller Bit 18 Free function blocks Bit 31 PROFINET 00050000 Hex: Bit 16 + bit 18; 80050000 Hex: Bit 16 + bit 18 + bit 31
p009=0	The device is now reinitialized

Parameter	Meaning
	The following parameters are in DO2
p20000[0] = 4	Runtime group 0 is calculated with 4 ms
P20000[1]=1002	Runtime group 1 is calculated with 16 ms

Armature current controller for generator by technology controller

Parameter	Meaning
p02280=0.1	Proportional gain for armature current controller. Should be optimized manually.
p02285=0.5	Integral time for armature current controller. Should be optimized manually.
p02291=	Positive generator field current limit Scaling 100 %=r50072[1] current p02291 = p50100 / r50072[1] × 100 %
p02292=	Negative generator field current limit. Scaling 100 %=r50072[1] current p02292 = -p50100 / r50072[1] × 100 %
p02253[0]=52134	Speed controller output selected as armature current controller setpoint generator
p02264[0]=52015	Selected as actual armature current value signal via terminal X177.27 /.28, r52015 for armature current controller input
p02200[0]=899.02	Enable technology controller for status "Enable operation", r0899.02
p02257=0.00	Set ramp-function generator ramp-up time for setpoint to zero
p02258=0.00	Set ramp-function generator ramp-down time for setpoint to zero
p02261=0.1	Filtering time for the setpoint input is 0.1 s. Set according to system condition

Speed setpoint and ramp-function generator

Parameter	Meaning
p50433[0]=	p50433 = 52011 Speed setpoint via a terminal X177.25 /.26 (factory setting)
p1140[0]=53010.08	For "Mx"=High from terminal X177.15 , r53010.08, the ramp-function generator is enabled
p1142[0]=53010.00	Setpoint enable prior to the ramp-function generator by "Run" terminal X177.11 , r53010.00
p50303[0]=20	Ramp-up time for ramp-function generator, set according to system conditions
p50304[0]=10	Ramp-down time for ramp-function generator, set according to system conditions
p50305[0]=2	Initial rounding for ramp-function generator, set according to system conditions
p50306[0]=2	Final rounding for ramp-function generator, set according to system conditions

Speed controller

Parameter	Meaning
p50083[0]=4	Selects actual speed value of the freely-wired value via p50609
p50169[0]=0	p50180 / p50181 acts as a current limit
p50180[0]=	Positive armature current limit, 100 % is positive actual rated value from shunt
p50181[0]=	Negative armature current limit, -100 % is negative actual rated value from shunt
p50200[0]=20	Filter time for actual speed value 20 ms, setting according to system conditions
p50225[0]=10	P gain for speed controller; optimize manually
p50226[0]=0.5	Integral time for speed controller, optimize manually
p50609[0]=20220	Selects actual speed value of output NSW 0 (free changeover switch)
	Free changeover switch NSW 0 for the actual speed value
p20218[0]=52019	Armature generator voltage of terminal X177.1/.2, r52019 as input X0,NSW 0

Parameter	Meaning
p20218[1]=	of measured motor speed as X1 for NSW 0 r0061[0]: For pulse encoder operation r52013: For analog tachometer r20103: For EMF control (operation without tachometer) from SUB 0
p20219=20047	From signal AS, r20047, switching to measured speed
p20221=0	NSW 0 is calculated in runtime group 0
p20222=1020	NSW 0 run sequence

EMF calculation for operation without tachometer and for monitoring tachometer failure

Parameter	Meaning
	Free subtractor SUB 0 for EMF calculation
p20102[0]=52021	Motor voltage via X177.3/.4, r52021 as input X1 at SUB 0
p20102[1]=20111	I×R drop calculated by multiplier MUL 0, r20111 as input X2 at SUB 0
p20104=0	SUB 0 is calculated in runtime group 0
p20105=1010	Run sequence for SUB 0
	Free multiplier MUL 0 for I×R calculation
p20110[0]=52015	The armature current of X177.27 /.28, r52015 is applied to input X0 of MUL 0
p20110[1]=52401	The resistance value of r52401, which can be set in p50401[0], is applied to the input X1 of MUL 0
p20110[2]=1 p20110[3]=1	Input X2 and X3 from MUL 0 = 100 %
p50401[0]=4	Typical value 4 - 6%, armature resistance factor in % of the I×R drop, set according to system conditions
p20112=0	MUL 0 is calculated in runtime group 0
p20113=1000	Run sequence of MUL 0
	Absolute value generation of the EMF by AVA 0
p20128=20103	EMF actual value r20103 as input of AVA 0
p20131=1	AVA 0 is calculated in runtime group 1
p20132=1030	Run sequence of AVA 0

Closed-loop control for field weakening of the motor

Parameter	Meaning
p50081=	**P50081=0**No EMF-dependent field weakening, the following parameters for field weakening and field weakening characteristic are irrelevant; Set **P50081=1** after manual field characteristic curve plotting, if EMF-dependent field weakening is required
p50275[0]=0.6	P gain for motor EMF controller
p50276[0]=0.2	Motor EMF controller integral time
p50616=20129	Absolute value of actual EMF value of AVA 0 output, r20129 as actual value for the EMF controller
p50615[0]=52402	Fixed value r52402 setting via p50402[0], as the setpoint for the EMF controller
p50402[0]=96	Set EMF setpoint to rated motor voltage minus I×R, typically 96 % ,100 % corresponds to rated motor voltage, setting depending on system conditions
p50693[0]=0	Disable EMF controller and perform field weakening only via the field characteristic; recommended setting, since the EMF of the motor voltage does not depend on the actual EMF value of the device.

Field weakening characteristic

Parameter	Meaning
p50117[0]=	Control word "Field characteristic included", in case of manual characteristic curve recording after setting characteristic curve p50117 to 1
p50118[0]=	Rated motor EMF. The value is not correct for this application because it is derived from p50078[0] in the device.
p50119[0]=	Rated speed in % of nmax, set value = nrated × 100 / nmax
p50120[0] to p50139[0]	Points of the field characteristic curve, include field characteristic manually

Speed zero signal, n>0

Parameter	Meaning
	Absolute value generator for the measured actual speed value with AVA 1
p20133=	From measured motor speed as input for AVA 1 r0061[0]: For pulse encoder operation r52013: For analog tachometer r20103: For EMF control (operation without tachometer) from SUB 0
p20136=1	AVA 1 calculated in runtime group 1
p20137=1040	Run sequence for AVA 1
	Limit monitor LMV 0 for the n>0 message
p20266=20134	Absolute measured speed as X input of LVM 0
p20267=0	Interval mean value M for LVM 0 = 0
p20268=0.005 – 0.03	Speed threshold as interval limit L for LVM 0, speed n>0 message for 0.5 to 3 %, for operation without tachometer at higher values.
p20269=0.003	LVM 0 hysteresis 0.3%
p20273=1	LVM 0 in runtime group 1 calculated
p20274=1050	Run sequence for LVM 0

Control: Signal AS, changeover to measured actual speed value

Parameter	Meaning
	AND element AND 0
p20030[0]=53010.08	Signal "Mx" from terminal X177.15 , r53010.08 at input I0 of AND 0
p20030[1]=53010.00	Signal "Run" from terminal X177.11 , r53010.00 at input I1 of AND 0
p20030[2]=1 p20030[3]=1	High signal at I2 and I3 of AND 0
p20032=1	Runtime group 1 for AND 0
p20033=1060	Run sequence for AND 0
	AND element AND 1
p20034[0]=53010.08	Signal "Mx" from terminal X177.15 , r53010.08 at input I0 of AND 1
p20034[1]=20270	Signal "n>0", r20270 at input I1 of AND 1
p20034[2]=1 p20034[3]=1	High signal at I2 and I3 of AND 1
p20036=1	Runtime group 1 for AND 1
p20037=1070	Run sequence for AND 1
	Or element OR 0
p20046[0]=20031	Output AND 0, r20031 at input I0 of OR 0
p20046[1]=20035	Output AND 1, r20035 at input I1 of OR 0
p20046[2]= p20046[3]=0	Low signal at I2 and I3 of OR 0

Parameter	Meaning
p20048=1	Runtime group 1 for OR 0
p20049=1080	Run sequence for OR 0

Tachometer failure monitoring: "External Fault 3", F07862

Parameter	Meaning
	Free multiplier MUL 1 for scaling the EMF for the tachometer monitoring
p20114[0]=20129	|EMF|, r20129 at input X0 of MUL 1
p20114[1]=52403	Multiplication with the field-weakening range, r52403, set in p50403[0] at input X1 of MUL 1
p20114[2]=1 p20114[3]=1	100 % as X2 and X3 from MUL 1
p20116=1	Runtime group 1 for MUL 1
P20117=1090	Run sequence of MUL 1
p50403[0]=	Enter the field-weakening range for monitoring the EMF (1/field weakening ratio × 100%); set 100 % without field weakening, e.g. for field-weakening range 3:1 = 1 / 3 × 100 = 33%
	Free subtractor SUB 1 for EMF scaled minus n-act
p20106[0]=20115	Output MUL 1, r20115 as X1 at SUB 1
p20106[1]=20134	n-act absolute, /S, r20134 as X2 at SUB 1
p20108=1	Runtime group 1 for SUB 1
p20109=2000	Run sequence for SUB 1
	Free limit monitor LVM 1 as monitoring EMF / n-act
p20275=20107	Output SUB 1, r20107 as input X for LVM 1
p20276=0.1	10 % as interval mean value M for LVM 1
p20277=0.0	0 % as interval limit L for LVM 1
p20278=0.03	3 % hysteresis for LVM 1
p20282=1	Runtime group 1 for LVM 1
p20283=2010	Run sequence for LVM 1
	Tachometer failure monitoring via "External fault 3"
p02108[0]=20281	QL LVM 1 input signal below threshold (high signal), F07862 trips above threshold LVM 1, (low signal)
p03110=100	100 ms ON delay for the error signal

Fault suppression

Parameter	Meaning
p2118[0]=60042	Selects that the error message "Tachometer fault" is suppressed. The "Tachometer fault" error message implemented in the basic unit must be hidden here
p2119[0]=3	Suppresses the error message "Tachometer fault"
p2108[0]=1	Tachometer fault of the free function blocks, F07862 does not occur (if necessary)

Scaling the analog inputs

Parameter	Meaning
p50701[0]=100 %	Scaling input, speed setpoint terminal X177.25/.26, 10 V = 100 %
p50711[0]=125 %	Scaling for AI 1 for 100% at r52015 if 8 V is present at terminal X177.27 /.28 (armature current)
p50731[0]=125 %	Scaling for AI 3 for 100% at r52019 if 8 V is present at terminal X177.1/.2 (generator voltage)
p50731[1]=125 %	Scaled AI 4 to 100% at r52021 if 8 V present at terminal X177.3/.4 (motor voltage)

Control: ON/OFF1

Parameter	Meaning
p50370[0]=200.00	Boost n<nmin message. This is required for correct functioning of "OFF1" for this application. The ON function is connected via terminal X177.12.

Control: Fault acknowledgement

Parameter	Meaning
p2102=53010.06	Terminal X177.14 , acknowledge r53010.06 as source for all faults. This parameter is in DO1

Parameters for peer-to-peer connection

Parameter	Meaning
p50790=5	Select peer-to-peer
p50791=2	Two words via peer-to-peer
p50793=13	Recommended baud rate 187.5 kBd
p50795=1	Activate bus termination
p50797=0.3	Telegram failure time peer-to-peer
p50794[0]=52268	Selects the motor field current setpoint as the 1st send word via peer-to-peer
p50612[0]=52601	Selects motor field actual current value of the 1st receive word via peer-to-peer. This applies for monitoring of the motor field. If field current for motor fails, F60105 is output.
p51117[0]=898.0	ON/OFF1 to binector/connector converter bit 0
p51117[1]=2138.07	r02138.07 fault acknowledgment to binector/connector converter bit 1
p50794[1]=52620	r52620 from binector/connector converter as 2nd send word via peer-to-peer

Parameters for the binary outputs

Parameter	Meaning
p50771=899.02	"Operation" signal via terminal X177.19; in the "Operation" state (SINAMICS DCM produces current), high signal is output
p50772=2139.03	"Fault" signal via terminal X177.20; if an error message is present, a low signal is output
p50770[1]=1	Inversion of the fault bit for output of a low signal at terminal X177.20 in the event of a fault

BICO parameters

Parameter	Meaning
r52015	Armature current generator
r52019	Generator voltage armature
r52021	Motor voltage armature
r52193	Speed setpoint before setpoint enable
r52192	Speed setpoint after setpoint enable at input for ramp-function generator
r52170	Speed setpoint at the speed controller input
r52167	Speed actual value before filtering P200
r52141	Armature current setpoint generator after limitation p50180
r02262	Armature current controller generator, setpoint
r02272	Armature current controller generator, actual value
r02294	Field current setpoint generator after setpoint limitation
r52120	Field current setpoint of generator field after limitation p50171
r20103	Actual EMF value

Parameter	Meaning
r20129	Actual EMF value, absolute
r52268	Current setpoint for the motor field
r20270	n>0
r20047	AS, signal changeover to measured speed

9 Commissioning

1. Check the old existing system

Run the old system and note the polarities and rated values:

a) Polarity and rated current of generator and motor field
b) Armature voltage
c) Armature current
d) Actual speed value
e) Speed setpoint

2. Connections

Deactivate the Ward-Leonard block.

Disconnect the existing wiring and rewire a new SINAMICS DCM according to Section 3 "Typical connections".

3. Adjusting the isolating amplifiers

The isolating amplifiers must be adjusted before use, and their polarity checked. To do this, use appropriate test voltages to simulate the actual values.

Isolating amplifiers for armature current

An mV signal that corresponds to the maximum value of the current should be applied instead of the shunt. The polarity and adjustment of the amplifier must be checked. The output value of the isolating amplifier must be positive for driving forward.

Adjust the isolating amplifiers so that 8 VDC are present when the mV of the test signal corresponds to the current limit (maximum required generator current). Terminal X177.27 must be positive against terminal X177.28.

r52015 should show 100 %. Adjust value to precisely 100% using p50711. On reversal of the test signal, r52015 should display 100 %. Remove the test voltage and connect the shunt.

Isolating amplifiers for generator voltage

Remove the cable from isolating amplifier and apply a test voltage equal to the rated generator voltage. The polarity of the test voltage must match the polarity of the generator voltage for forward rotation. Adjust the isolating amplifier to +8 VDC at the output. Terminal X177.1 must be positive against terminal X177.2.

Parameter r52019 should now show +100 %. Adjust to +100% for r52019 using p50731[0]. On reversal of polarity of the test signal, r52019 should display 100 %.

Remove the test voltage and restore the wiring to the armature voltage.

Isolating amplifiers for motor voltage

Remove the wiring between the motor armature and the isolating amplifier and apply a test voltage that is equal to the rated armature voltage. The polarity of the test voltage must match the motor armature voltage for forward rotation. Adjust the isolating amplifier to +8 VDC output. Terminal X177.3 must be positive against terminal X177.4.

r52021 should then show 100 %. Adjust p50731[1] so that r52021 displays +100 %. Reverse the polarity of the test signal; r52021 should display -100 %.

Restore the isolating amplifier wiring to the motor armature.

4. Input of parameters

After establishing the necessary wiring, enter the parameters. Enter only the general parameters and the parameters for the generator field controller initially, followed by those for the current controller for the motor field and the generator field. To optimize the armature controller for the generator and speed controller, enter all of the other parameters first. The following information provides assistance for proper commissioning.

5. Optimizing the motor and generator fields

To do this, shut down the generator and open circuit breaker "M".

Self-optimization run:

The field current controller for generator and motor must be optimized. This can be performed at standstill of generator and motor (circuit breaker for the armature voltage must be open) using the current controller optimization run with p50051 = 25. After the optimization run, the rise time of the field current should be checked; in borderline cases, re-optimize manually. The dynamics of the overall system require that the inner control loop and the field current controller exhibit good transition characteristics.

Manual adjustment:

Set p50601[4] to the desired setpoint input temporarily to obtain a basic field current value of 25% of the rated field. Supply additional 2% current steps. Then adjust p50155 and p50156 to obtain a rise time of approx. 20 - 100 ms. Typical values are p50155=10 and p50156=0.1 s.

The following test arrangement in the parameterization can be used for the step signal.
p50601[4] = 52208 from square-wave generator (see List Manual, Chapter 2, Sheet 3120) for test setpoint.
Check the step response of the current using the trace function in the STARTER.

When optimization of the field current controller has been completed, check whether the current reversal in the generator field operates correctly when the field current setpoint is reversed (set p50179 so that no circulating current occurs).

Verify the polarity of the armature current for driving forward.

Shut down the SINAMICS DCM and for the next step: Prepare the armature current control.

6. Optimizing the armature current controller

The armature current controller must be optimized manually. This can be carried out using the test generator described under field current control. In order to synchronize the armature current, the motor generator block must be running and the armature voltage switch must be closed. The field-current controller for the motor must be switched off (with p50082 = 0 in the field supply unit for the generator).. In this way, only a very low torque is produced. The motor should be braked firmly so that it does not turn above the field retentivity.

Be careful! Specify a small current setpoint of 0 to 1 %. Verify that the current does not rise to a high value. A polarity fault at the isolating amplifier can cause high generator current. Adjust the gain via p02280 and the integral time via p02285. The rise time should be approx. 50 ms. Empirical values are p2280=0.1, p2285=0.5 s.The ramp-function generator for the setpoint is thereby set to zero (p2257 = 0)

When optimization has been performed, set p50082 in the field supply unit for the generator to the correct value and activate the SINAMICS DCM for the motor field.

7. Optimizing the speed controller

Note:
Tachometer monitoring with free function blocks does not monitor the tachometer for pole faults. Therefore first set operation without tachometer and check the polarity of the actual value encoder via the connectors (r0061[0] for pulse encoder, r52013 for analog tachometer.

Optimization of the speed controller must be performed manually. This can be done using the test generator as described under field current optimization. In order to optimize the speed control loop, the armature voltage switch must be closed and the motor generator block must be in operation; the motor and generator fields must also be in operation.

Specify a low setpoint and verify that the speed is not integrated to nothing. Compare the speed setpoint and actual speed value.

Adjust the gain p50225 and the integral time p50226. The rise time for the speed control loop should be approx. 250 ms. Empirical values are: p50225=10 and p50226=0.5 s.

The function of the closed-loop control at zero volts armature voltage with armature circuit switch closed must be verified.

8. **EMF controller for the motor (field-weakening control)**

   The field characteristic must be recorded manually. The actual EMF value is the connector r20129 in this case.

   More at: FAQ (http://support.automation.siemens.com/WW/view/en/41165031)

   With field weakening, a tachometer generator or pulse encoder are always required.

9. **Closed-loop control to zero volt armature voltage when circuit breaker "M" of armature circuit is open**

   Verify that the zero volt control is working properly when the circuit breaker for the armature circuit is open.

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