SIEMENS

Excitation unit

and Starting Aids for

Fixed Speed Synchronous Motors

Device Description

Configuration Aid

Version 1
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Contents

- **Overview**

- **Field of application**

Excitation unit for fixed speed synchronous motors supply the excitation winding of the motor with the necessary excitation current. The excitation unit controls the ramp-up of the synchronous motor and synchronization to the supply network. It regulates the reactive power or power factor of the motor to a given value. The excitation unit also provides protective functions for the motor.

The functionality of the excitation unit also allows excess energy to be fed back to the supply network. However, for this to happen, the motor protection feature must be suitably set out.

- **Drive system**

The excitation unit supports three possible ways of ramping up the synchronous motor:

- asynchronous ramp-up, ramp-up on line
- synchronous ramp-up, ramp-up with a starting converter
- assisted ramp-up via a pony motor

Diagram of typical asynchronous ramp-up

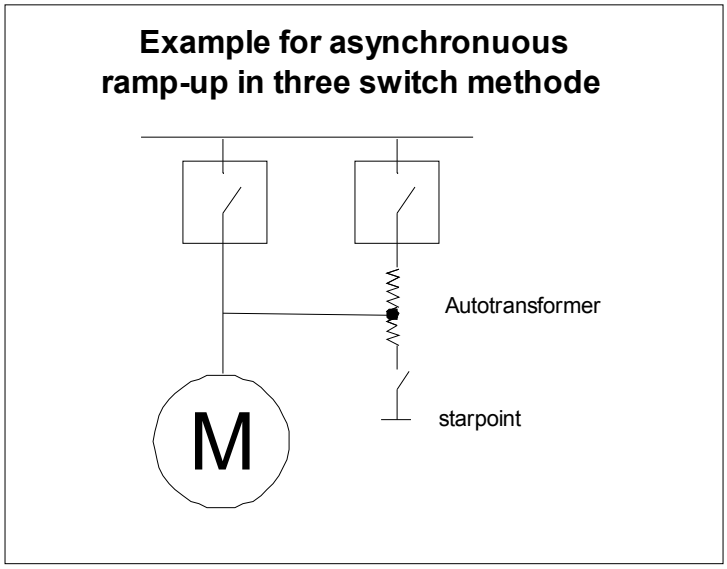


Diagram of typical synchronous ramp-up

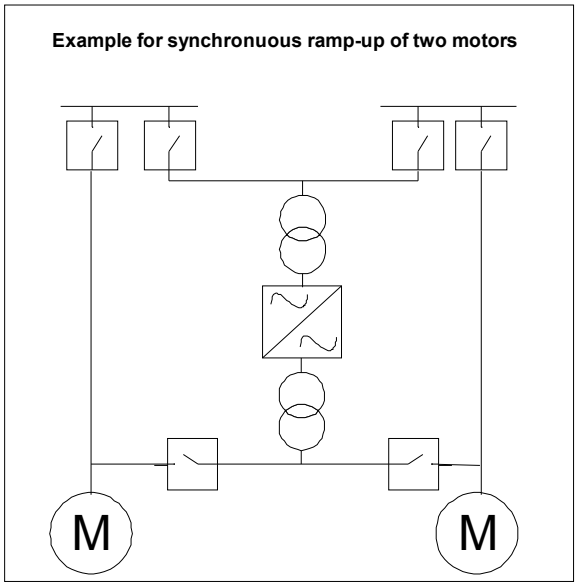
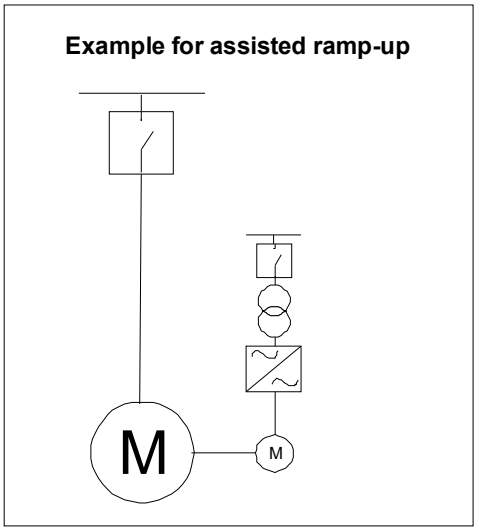


Diagram of typical assisted ramp-up



In the case of asynchronous or assisted ramp-up, the field is first excited in the course of synchronization. With synchronous ramp-up, the field is excited throughout ramp-up. The excitation unit must be set up according to the ramp-up method. There are three technical solutions available for this:

Motors with an exciter and d.c. excitation are suitable for asynchronous or assisted ramp-up.

Motors with an exciter and counter-rotating field excitation are suitable for asynchronous, synchronous and assisted ramp-up.

Motors with sliprings are suitable for asynchronous, synchronous and assisted ramp-up.

• The principle of asynchronous ramp-up

For asynchronous ramp-up, the excitation unit provides the established ramp-up procedures
– DOL (direct on line)
– reactance starting
– autotransformer in three-switch method
– autotransformer in three-switch method as per Korndörfer
– autotransformer in four-switch method

• The principle of synchronous ramp-up

For synchronous ramp-up, the excitation unit provides excitation power and control for ramp-up at a starting converter with dc-link (LCI-drive), set up on a SIMOVERT S basis. Here the excitation unit is able to coordinate the ramp-up of several motors. The starting converter can maintain parameter sets for up to four different motors.

• The principle of assisted ramp-up

For assisted ramp-up, the excitation unit provides the control for ramp-up with a pony motor. There are three distinct situations.

During ramp-up, the shaft assembly has little counter-torque and the network is relatively stiff. The pony motor is then connected directly to the network. Once maximum speed is reached, the synchronous motor is hard connected to the network and excitation is then built up. The pony motor is switched off.

During ramp-up, the shaft assembly has little counter-torque and the network is relatively soft. The pony motor is then connected directly to the network. Once maximum speed is reached, excitation is built up in the synchronous motor which is connected to the network by means of a synchronizer. The pony motor is switched off.

During ramp-up, the shaft assembly has a lot of counter-torque. The pony motor is then connected to the network via a frequency converter and run up to synchronous speed. Once synchronous speed is reached, excitation is built up in the synchronous motor which is connected to the network by means of a synchronizer. The pony motor is switched off.

• Excitation unit product overview

The excitation unit is available in the following implementations:

- D.C. power supply for synchronous motor with d.c. exciter:
  Output data:
  30ADC, 300V

- D.C. power supply for synchronous motor with sliprings:
  Output data:
  600ADC, 300V

- Three-phase power supply for synchronous motors with counter-rotating field exciter:
  Output data:
  130AAC, 400V, self ventilated
  360AAC, 400V, forced ventilated

Other ratings with lower or higher excitation currents/voltages are optionally available on request.

- **System components for excitation unit and starting aids**

Additionally Siemens offers beside the excitation unit also products to serve the entire drive system that is needed to run up to speed and operate synchronous motors. This also includes choosing a suitable starting procedure and setting up the associated system components. The system components are as follows:

Switchgear and if necessary, feeding transformer:
Siemens provides the switchgear to match the chosen ramp-up method. Should a dedicated feeding transformer be required to operate the motor, Siemens can calculate the required impedance of the transformer.

- Starting reactors and autotransformers:
  Together with the motor manufacturer Siemens can size and deliver the reactors and the transformers.

- Stator feeds for synchronous ramp-up via current-source inverters:
  Input data for the starting converter/input transformer (step-down transformer):
  2.3-13kV 6-pulse, 50/60Hz, according to network
  Output data for the starting converter/output transformer (step-up transformer):
  2.4 to 10MW, 2.3-13kV 6-pulse, 50/60Hz, according to motor

  12-pulse stator feeds for high starting outputs in air and water cooling are available on request.

- Pony motor:
  Siemens provides asynchronous motors both with and without a converter feed as pony motors.

- Special solution:
  Siemens is prepared to combine the various starting aids such as DOL and starting converter or even add field supply for continuous speed control in an excitation unit as an engineered solution.

- **Description**

- **Functions in steady-state operation**

During steady-state operation of the synchronous motor, the excitation unit regulates to a given power factor or to a given reactive power. This setpoint value can be assigned locally at the excitation unit or can be assigned decentralized. The changeover between local and decentralized or between power factor and reactive power regulation can occur at the excitation unit without a bump with the machine running. The excitation unit limits the power factor and the reactive power to the values prescribed by the motor manufactorer. The operator can also directly assign a setpoint for the excitation current locally. The excitation unit limits the excitation current to a maximum and minimum value in all modes of operation. These limits (referred to below as the motor parameters) must be assigned by the motor manufacturer.

To improve motor availability, the excitation unit provides optional overexcitation to increase the pull-out torque in the machine by briefly increasing the excitation current, should there be a loss of synchronism. Depending on the load surge or drop in line power, this increase in torque can prevent loss of synchronism.

- **Functioning of the excitation unit with asynchronous ramp-up**

During standard starting of the synchronous machine, direct on line ramp-up (DOL), the excitation unit actuates the circuit breaker and regulates the excitation current to rated current in good time before synchronous speed is reached. Once synchronous speed is reached, the excitation unit switches excitation current regulation over to steady-state operation.

Should direct starting not be allowed, the excitation unit also has the option to provide control for the alternative starting procedures with reactor or autotransformer.

- **Functioning of the starting device with synchronous ramp-up**

- **Starting converter with single motor operation**

The synchronous motor is started up with the aid of the SIMOVERT S starting converter. The excitation unit controls the circuit breaker in the switchgear and the functions of the starting converter. When the motor has reached about 95% of its synchronous speed, an automatic synchronizer takes over the synchronization of the motor with the supply network. The higher/lower commands of the automatic synchronizer to adjust the terminal voltage of the motor and the frequency (speed) to the line conditions are processed directly by the starting converter. Once the time for synchronization is reached, the automatic synchronizer, taking the delay time of the circuit breaker into account, gives the command to close the circuit breaker. After motor ramp-up and at the same time as closing the circuit breaker, the starting converter is shut down and then disconnected from the motor and from the supply network. Should the line voltage fail during the starting operation, the rotating motor can be “caught” by the starting converter once the power is restored and the starting operation can be resumed.

- **Starting converter with multiple motor operation**

The synchronous motor is started as described for single motor operation. After motor ramp-up and connecting the circuit breaker, the starting converter is shut down and disconnected from the motor and from the supply network. The starting converter can be used to ramp up another motor. The starting converter and the excitation unit in its standard version are enabled for ramping up as many as four motors. Please note that an excitation unit and the related switches as shown in the diagram are required for each motor. A changeover function is also required.

- **Functioning of the starting device with assisted ramp-up**

With assisted ramp-up with a pony motor operated asynchronously on line, the excitation unit switches on the pony motor circuit breaker. Excitation is run up to no-load excitation speed before synchronous speed is reached. The synchronous machine circuit breaker is connected via a synchronizing device. After connection, the excitation unit changes excitation current regulation to steady-state operation and shuts down the pony motor. With a very stiff network, synchronization may not be necessary and excitation will be run up once the circuit breaker has been closed.

With assisted ramp-up with a pony motor and converter, the excitation unit controls the circuit breakers in the switchgear and the functions of the converter. When the motor has reached about 95% of its synchronous speed, the automatic synchronizer takes over synchronization of the motor with the supply network. The higher/lower commands of the automatic synchronizer to adjust the terminal voltage of the motor and the frequency (speed) to the line conditions are processed directly by the converter. Once the time for synchronization is reached, the automatic synchronizer, taking the delay time of the circuit breaker into account, gives the command to close the circuit breaker. The converter is shut down and disconnected from the supply network.

- **Generative operation**

- **Requirements of the supplying network**

The excitation unit is designed to allow the machine set to feed back excess energy at the drive train to the supplying network via the motor/generator. It is necessary for the frequency and the voltage at the busbar to be maintained by the supplying network (by the power supply company) and to be kept within permissible limits in accordance with requirements.

To protect the motor/generator system both in motorized and generative operation, the appropriate protective relays must be implemented in the outgoing switching devices. For motor/generator systems of about 7 MW and above, Siemens recommends differential protection and using the SIPROTEC 7UM6 protection relay. The customer must set up the relay parameters to the supplying network.

If interruptions to the supply network cause asynchronicity between the network and the motor/generator system with regard to frequency or phase, the motor/generator system must be disconnected from the supply network. Then the motor/generator system must be run up to speed again via synchronous or asynchronous ramp-up and properly synchronized.

In special cases, it is possible to synchronize the generator to the network without a prior stoppage. For more information, refer to the “Characteristics of generative operation” section.

- **Requirements of the shaft assembly**

Normally the drive train has no speed regulation, the synchronous motor applies the network frequency to the drive train. The shaft assembly must be implemented with speed monitoring and a protective energy supply cutoff.

The concept in steady-state operation is as follows:

In accordance with the energy balance at the shaft assembly, the motor/generator system assumes motorized or generative operation. The torques that the motor/generator system can feed to the drive train or

which can be taken from the drive train are limited by the rated currents and the maximum permissible temperature of the motor windings.

The protective devices of the motor/generator system disconnect the motor/generator system from the supply network, if the limits in the motor/generator system (current, voltage, temperature rise) are exceeded.

Should the motor/generator system be disconnected from the supply network in generative operation or if the supply network fails, it is necessary to ensure that the supply of energy to the shaft assembly stops immediately. It is the task of the system integrator when setting up and specifying the components of the machine set to take this operation modes or malfunction into consideration.

More information can be found in the “Characteristics of generative operation” section.

• Protection concept

The protective functions of the drive system must be distributed among the functional units as described below:

Switchgear:
- Short-circuit protection
- Motor overcurrent protection
- Differential protection (must be possible for the excitation unit to disable this during ramp-up)
- Supply network undervoltage
- Supply network overvoltage
- Loss of synchronism protection

Excitation unit:
- Reverse power protection (not for generative operation)
- Rotor temperature monitoring (during asynchronous ramp-up only)

DCS:
- Stator winding temperature
- Bearing temperature
- Cooling air temperature
- Bearing vibration
- Transformer protection – asynchronous ramp-up starting transformer/reactor
- Transformer protection – feeding transformer
- etc., etc.

Starting converter:
- Step up transformer protection without short-circuit protection – synchronous ramp-up
- Step down transformer protection – synchronous ramp-up

• Emergency off

In an emergency off situation, the excitation unit controls the circuit breaker and if applicable, the starting converter as well. A contactor-type safety combination duplicates a central emergency off command and forwards it. A maximum of four emergency off commands can be output. In the standard implementation, the emergency off operates according to the NC principle. A solution according to the NO principle can be supplied as an option. The emergency off must be engineered by the system integrator.

- **Equipment description**

- **Incoming supply for the power and control sections**

The incoming supply for the power and control sections of the exciter cabinet is three-phase (L1, L2, L3, PE).
Voltage range: 400V AC
(state different supply voltage when ordering, option)
Frequency: 50/60Hz

The excitation unit is available in the following implementations:

- DC power supply for synchronous motor with DC exciter:
  Inputdata:
  360 to 575VAC, 50/60Hz
  Output data:
  30ADC, 300V

- DC power supply for synchronous motor with sliprings:
  Inputdata:
  360 to 575VAC, 50/60Hz
  Output data:
  600ADC, 300V

  Overvoltage protection 7VV3002-3AD20 supplied loose for on site installtion; to be purchased as a separate item.

- AC power supply for synchronous motors with counter-rotating field exciter:
  Inputdata:
  360 to 500VAC, 50/60Hz
  Output data:
  130AAC, 400V, self ventilated
  360AAC, 400V, forced ventilated

Other ratings with lower or higher excitation currents/voltages are optionally available on request.

It must be taken care that there is no possibility of any commutation short-circuits between the power converter for the excitation current supply and any other power converters connected to the low voltage distribution board. In cases like these, Siemens recommends connecting a 4% commutation inductance between the power converters or isolation transformers.

- **Control voltage**

The control voltages inside the cabinet are 230V AC and 24V DC.
The integrated control-power transformer (SIEMENS 4AM61), with an output of 1.6 or 2.0kVA, provides 230V AC in a secondary circuit, non-isolated, to the power supply for the cabinet lighting, the service socket and the electronics supply of the SIMOREG DC Master or SIMOTRAS HD.
A power pack (SIEMENS 6EP1436, 20A) provides the 24V DC supply voltage for the control (SIMATIC C7/S7 and ET200S), as well as for the contactors and the protection relays.

- **Control cabinet**

Type: Siemens TS8 (Siemens 8MFI on request)
Dimensions: 2205x906x605mm (HxWxD) for DC excitation
Dimensions: 2205x1206x605mm (HxWxD) for AC excitation

Dimensions:	2205x1206x605mm (HxWxD) for the changeover device, if additional panel is required
Degree of protection:	IP40 for DC excitation
Degree of protection:	IP42 for AC excitation
Housing/frame color:	RAL 7032, pebble gray
Doors:	Hinged on the left with ventilation slits
Side panels:	On both sides
Top plate:	Perforated for DC excitation
Top plate:	Rittal venting roof or equivivalent for AC excitation
Buttom plate:	Split with rubber section for cable entry
Cable entry:	From below

For dimensioned drawings, see the technical data section

- **Cabinet lighting/service socket**

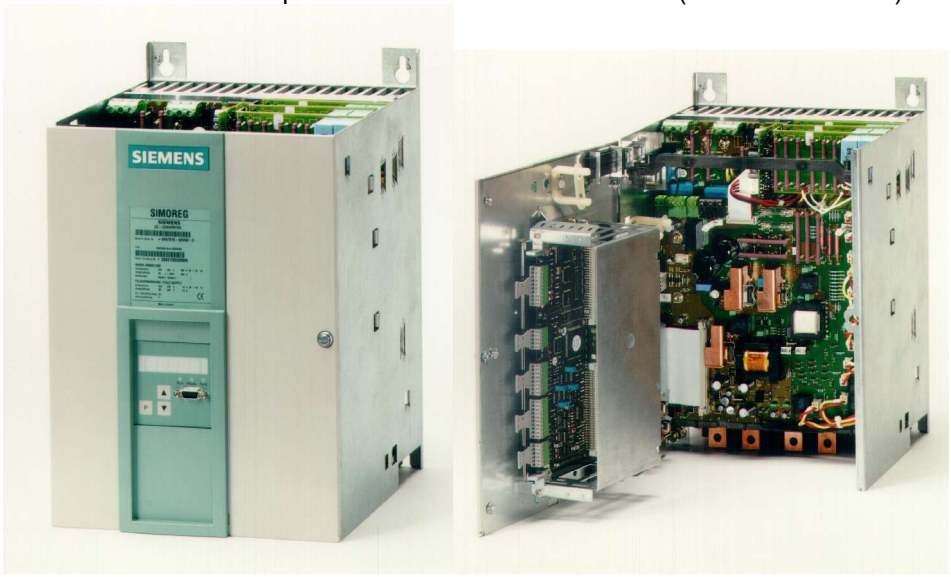
Cabinet lighting with an integrated service socket is provided in the control cabinet. The DIN-socket (230V AC, 50/60Hz, 4A) is used to supply the measuring and programming devices used during commissioning. The cabinet lighting (26W) with integrated motion sensor allows work to be done even under poor lighting conditions.

- **Emergency off**

An emergency off button with a protective shroud to prevent inadvertent operation is built into the door of the cabinet. The button drives a contactor-type safety combination (SIEMENS 3TK28), to ensure that the synchronous motor and if applicable the starting converter are safely switched off in accordance with EN 954-1. Up to four devices can be shut down with the contactor-type safety combination.

- **Rectifier for the excitation current – DC excitation**

The excitation current is output from a SIMOREG DC Master (SIEMENS 6RA70) directly to the RG exciter.



The maximum standard exciter current is 30/600A DC. Device with other ratings are available. The setpoint value is assigned by a SIMATIC C7, which transfers the setpoint directly to the SIMOREG via Profibus DP.

- **Inverter for the excitation current – AC excitation**

is output from a SIMOTRAS HD (SIEMENS 6SG70) directly to the RG exciter.

current is 130A AC for self ventilated operation of the device used (higher quest, forced ventilation required). The setpoint value is assigned by a SIMATIC setpoint directly to the SIMOTRAS HD via Profibus DP.

- **Synchronization unit (synchronuous ramp-up only)**

For synchronizing the motor to complete the ramp-up an synchronization unit type 7VE6 is used. The selection of the synchronization unit respects the harmonic distortion and commutation short circuits coming from the SIMOVERT S from the line side rectifier as well as from the motor side inverter. The operation reliability of most synchronization units as used in power plants is reduced in respect to harmonic distortion without suitable filtering.

- **Signal exchange**

- **Interface to feeding circuit breaker**

The circuit breaker is activated by a relay by means of potential free contacts, up to a contact loading of max. 220V DC at 2A. Beside the off coil and the on coil, the undervoltage coil is also activated during an emergency off, when triggering a protection relay or in the event of a failed OFF command (NO contact, 0=OFF). The off coil is activated via an NC contact until the ON command is given (1=OFF). The ON command is output as a pulse via an NO contact for a period of 2 seconds (1=ON). A total of 4 auxiliary contacts are necessary to monitor the circuit breaker.

Activations

Contact loading: *220V DC/≤ 2A*

- Circuit breaker ON (NO) 1 = Circuit breaker ON (2-second pulse)
- Circuit breaker operation OFF (NC) 1 = Circuit breaker OFF (off coil)
- Circuit breaker protection OFF (NO) 0 = Circuit breaker OFF (undervoltage coil)

The signal voltage that is made available must take into consideration the maximum contact loading of the circuit breaker.

Feedback

Contact loading: *24V DC/≤ 50mA*

- Feedback ON (NO) 1 = Circuit breaker is ON
- Feedback OFF (NO) 1 = Circuit breaker is OFF
- Feedback test position (NO) 1 = Circuit breaker is in the test position
- Feedback operating position (NO) 1 = Circuit breaker is in the operating position

All 4 signals are to be implemented at the circuit breaker as potential free NO contacts. 24V DC is supplied to the potential free contacts from the exciter cabinet and the signals are read into the control by means of the ET200S digital input module 6ES7138 or equivivalent.

- **Binary signals to the system control (DCS)**

The following binary signals are made available for system control, including the 3 activating contacts for the circuit breaker described in subsection 0.0.0, via floating contacts:

Output via the terminal strip

Contact loading: *60V DC/0.15A; 230V AC/0.5A*

- Fuse blown (NC) 0 = Fuse blown in exciter cabinet

The customer must provide the signal voltage, taking the maximum contact loading into consideration.

Output via ET200S relay output module (SIEMENS 6ES7132)

Contact loading: *120V DC/0.2A; 230V AC/0.5A*

- Emergency off activated (NC) 0 = Emergency off has been activated
- Warning (NC) 0 = Warning present
- Shut-down on faults (NC) 0 = Motor shut-down because of a fault
- Motor ready to start (NO) 1 = Motor is ready to start
- Loading enabled (NO) 1 = Loading enabled
- Motor is ON/OFF (NO) 1 = ON/0 = OFF

The customer must provide the signal voltage, taking the maximum contact loading into consideration.

• Binary signals from the system control (DCS)

The following binary signals are needed by the system control, including the 4 circuit breaker feedback signals described in subsection 0.0.0:

Read in via the ET200S digital input module (SIEMENS 6ES7138 or equivivalent)

Contact loading: *24V DC/≤ 50mA*

- Motor ON command (NO) 1 = ON command
- Motor OFF command (NC) 0 = OFF command
- Fault reported by driven machine (NC) 0 = Motor shut-down on faults
- Fault reported by MS switchgear (NC) 0 = Motor shutdown on faults

The potential free contacts at the customer end are supplied with 24V DC from the exciter cabinet and the signals are read into the control by means of the ET200S digital input module 6ES7138.

• Potential and current transformer signals from the feeding line

To measure the motor variables and to acquire the busbar variables for synchronization, the following transformer signals are required from the feeding switch gear:

Connection via transformer/terminal blocks (connecting capacity min. 2.5mm², max. 6mm²)

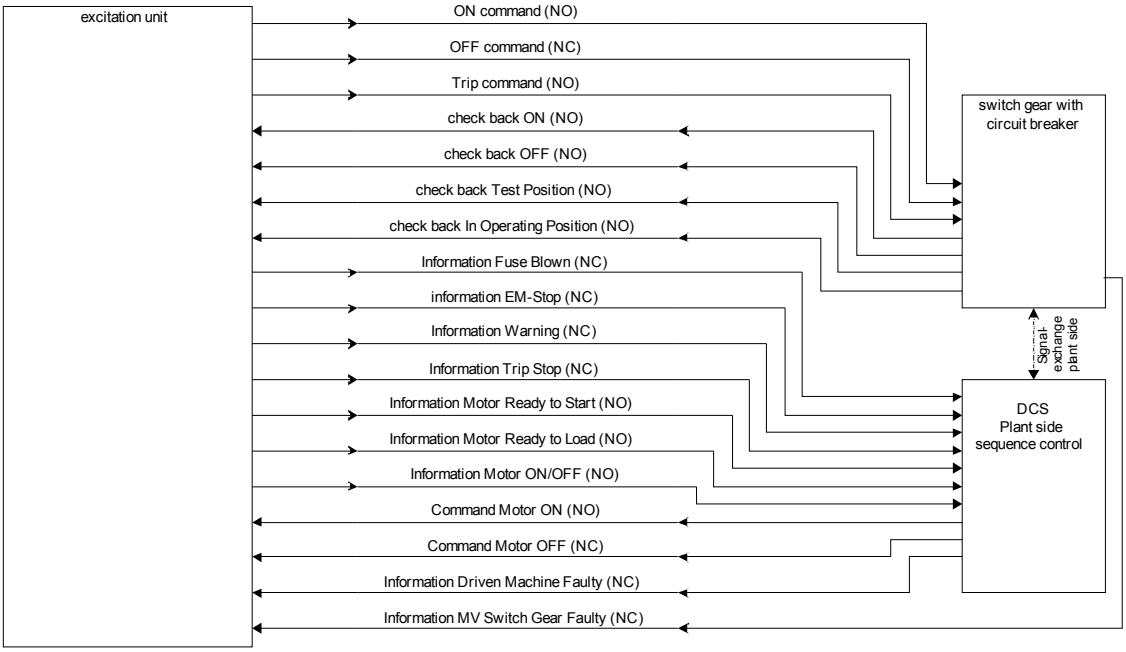
- Motor current from the current transformer measuring core (CT) in the switchgear,
  motor control unit
  Connection: 3-phase with star point
  Energy requirement: 2VA
  Secondary current: Ranging from 1mA to 6A

- Motor voltage from the potential transformer (PT) motor in the switchgear
  (for synchronous ramp-up and assisted ramp-up at the converter only)
  Connection: 3-phase
  Energy requirement: 5.5VA
  Secondary voltage: Ranging from 1V to 280V AC
  Protection and overvoltage protection provided by customer

- Line voltage from potetnial transformer (PT) busbar in the switchgear
  Connection: 3-phase
  Energy requirement: 5.5VA
  Secondary voltage: Ranging from 80V to 150V
  Protection, duplication and overvoltage protection in the switchgear

- **Signal exchange flow chart**

The signal exchange described in subsections 0.0.0 to 0.0.0 is shown in the following chart. Please note that this takes only the standard signals into consideration. Signals necessitated by additional options are not listed here.



- **Isolation monitor for the excitation circuit (AC excitation only)**

An Isolation monitor (BENDER IRDH265-422) is used to monitor the excitation circuit for an earth fault.

Principle of operation of a line isolation monitor

The isolation monitor is connected between the non-earthed supply network and the protective earth (PE).
The control keys are used to set the response values and the other function parameters. The parameters appear on the LCD display and once setting is complete, they are stored in non-volatile memory (EEPROM).
A microcontroller-driven, pulse-shaped measuring alternating voltage is superimposed over the supply network (AMP method of measurement = adaptive measuring pulse). The measuring pulse comprises positive and negative pulses of the same amplitude. The period is guided by the respective discharge capacities and the insulation resistances of the supply network being monitored.
An insulation fault between the supply network and the ground closes the measuring circuit. The evaluating circuit determines the insulation resistance, which appears on the LCD display after the measured value acquisition time.
The measured value acquisition time depends on the network discharge capacity, the insulation resistance and any interference caused by the network. The network discharge capacities do not affect measurement accuracy.
If values fall below the set response values ALARM1/ALARM2, the associated signaling relay responds, the alarm LEDs "ALARM1/2" light up and the LCD display shows the measured value (if the insulation fault is in the DC network, the faulty supply cable is indicated as well). The function of the line isolation monitor can be tested by a test button.

- **Overvoltage protection in the excitation circuit (DC excitation only)**

A varistor column (CONRADTY 820SB) protects the 30A rectifier against inadmissible overvoltages in the excitation circuit. Higher ratings use other protection devices.

- **Speed evaluation (for asynchronous and assisted start-up only)**

To detect the speed, an inductive proximity switch (2-wire, in accordance with NAMUR) must be attached to the motor. 4 pulses per rotation are required.
The evaluation is carried out by a Phoenix pulse evaluator (MCR-f/UI-DC), which converts the pulse sequence to a 4-20 mA standard signal. The speed signal is used to monitor start-up and to start the excitation power.

- **Display instruments for excitation current and machine data**

An 96x96mm analog display for the excitation current is built into the door of the cabinet.
The measuring instruments are fitted with scales:
The scale marks are approx. 30% above the rated excitation current for the motor Option, state excitation current when ordering).

To display the machine data, a 144 x 144mm SIMEAS P power meter is built into the doors of the cabinet. All the measured values formed from the current and voltage transformer set of the medium voltage switchgear, can be called up on the display of the SIMEAS P power meter. The required current and voltage transformer data is specified in subsection 0.0.0.

The following measured values are shown on the display:

- Power factor
- Reactive power
- Active power
- Phase currents
- Phase voltages
- Frequency

Other display methods, such as vector diagrams, harmonics, min-max values or an oscilloscope function can be defined in the device configuration. These display methods are not cleared at the factory.

- **Detailed description of functions**
- **SIMATIC C7/S7 control**

SIMATIC C7-634DP

SIMATIC OP17/DP12

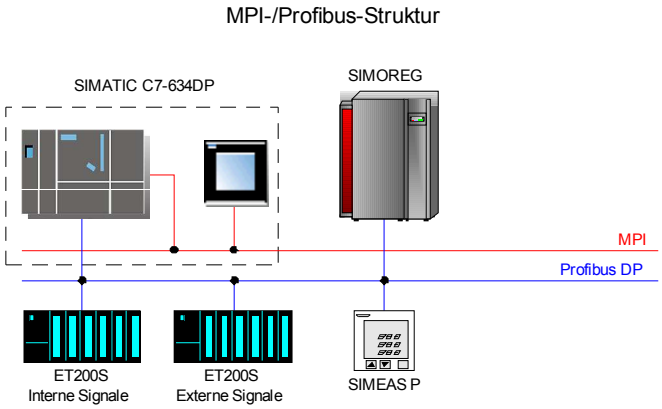
The SIMATIC S7 with OP17/DP12 is used for excitation unit with synchronous ramp-up or assisted ramp-up at the converter. For all other ramp-up types, the SIMATIC C7-634DP combination device is used.

Extract from the technical data (applies to both the devices):

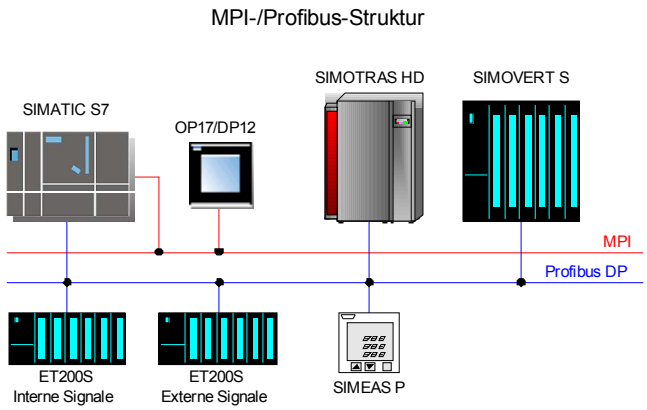
Dimensions (WxHxD):	240 x 204 x 54mm
Weight:	960g
Degree of protection:	Front/back - IP65/IP20
Ambient temperature:	0 to 50°C in operation
Supply voltage:	24V DC
Current consumption typ./max.:	340mA/390mA
EMC emitted interference:	Class B under EN55022
Display:	LC display with LED backlighting
No. of lines/characters:	8x40
User memory:	256kByte, flash
Softkeys/function keys:	16/24
Displays on the OP:	max. 99
Process/fault messages:	max. 999 messages each
Process message/alarm buffer:	max. 256 entries each

The standard display languages are English and German. Other languages are available on request (see section 0.0). The required language can be selected on the OP. Operator process communication and monitoring are then totally in the selected language. All the analog values that have been read in are viewed on the OP. The current motor status, provided this is available for the selected implementation, with start-up and running times, the heat account and all the general status information, are also displayed on the OP. Modes of operation, setpoints and control parameters can be modified. All the relevant entry fields are password-protected against unauthorized use. All process messages, such as activations and feedback, devices and signals to and from the customer, are stored in a process message buffer. All warnings and shut-downs on faults by the control, the operator or from outside, are stored in an alarm buffer. Archiving in the buffers is given a date and timestamp with a resolution of 1 second. Both buffers work as transit storage according to the FIFO principle (First In, First Out). The maximum number of messages in each buffer, both for process and fault messages, is 256 in each case. If a new message arrives and the buffer is full, it is always the oldest message that is overwritten. All messages are displayed in plain text on the OP.

Equipment configuration with the SIMATIC C7-634DP



Equipment configuration with the SIMATIC S7 and the SIMATIC OP17/DP12



• Reading, displaying and monitoring the analog values

The following analog values are recorded, transferred via Profibus DP and can be called up on the OP:

Measuring point	*Transformer in MS switchgear*	*Current controller*
Measurement via	*SIMEAS P*	*SIMOREG/SIMOTRAS*
- Line voltage for synchronous start-up	X	
- Stator voltage for asynchronous start-up	X	
- Motor current	X	
- Excitation voltage		X (SIMOREG only)
- Excitation current		X
- Active power	X	
- Reactive power	X	
- Power factor	X	
- Heat sink temperature		X

The analog values are monitored in the SIMATIC C7/S7 to ensure that the measuring range is not exceeded. Limits are formulated, which produce a warning or trip when an inadmissible range is reached. In this case, a fault message is output on the OP, in plain text. The limits used in the program are recorded in the software documentation, in the DB2 data block printout (DB_Set).

• Regulating the excitation current

The setpoint for the excitation current for the SIMOTRAS HD for AC excitation or the *SIMOREG DC Master* for DC excitation, can be regulated according to the power factor or according to the reactive power. A mode of operation cannot be selected until the start-up process is complete.

The following modes of operation can be selected via the OP:

Mode of operation	*Included as standard*	*Available as an option*
- Controller OFF	X	
- Superexcitation test	X	
- Manual mode	X	
- Local cos setpoint	X	
- External cos setpoint		X *(1)*
- Local kVAr setpoint		X
- External kVAr setpoint		X *(1)*

(1) This option includes an additional module with 2 analog inputs.
When ordering this option, both the external setpoints can be connected
(see section 0.0).

• Explanation of the controller parameters

The integrated software controller operates as a PI controller. Two sets of parameters are available for this controller and the right one is selected automatically, in keeping with the actual active power. Because the parameter sets are changed over automatically, optimum adjustment of the controller to the working point of the synchronous motor is possible at all times.

The parameter set is changed over, for example, when:

- Active power > approx. no-load power + 5% of the rated power
  A *"faster"* parameter set is used. The controller can then correct the given setpoint more quickly if the loading of the synchronous motor suddenly changes.
- Active power <= approx. no-load power + 5% of the rated power
  A *"slower"* parameter set is used. With low active power, this prevents undesirable controller vibration (oscillation).

• Explanation of controller modes

Parameters and limits for the modes of controller operation listed below are assigned in accordance with the motor parameters. The changeover between manual *(Man)* and automatic modes *(Auto)* is implemented without a bump (correcting the setpoint). This ecplanation includes some functions.

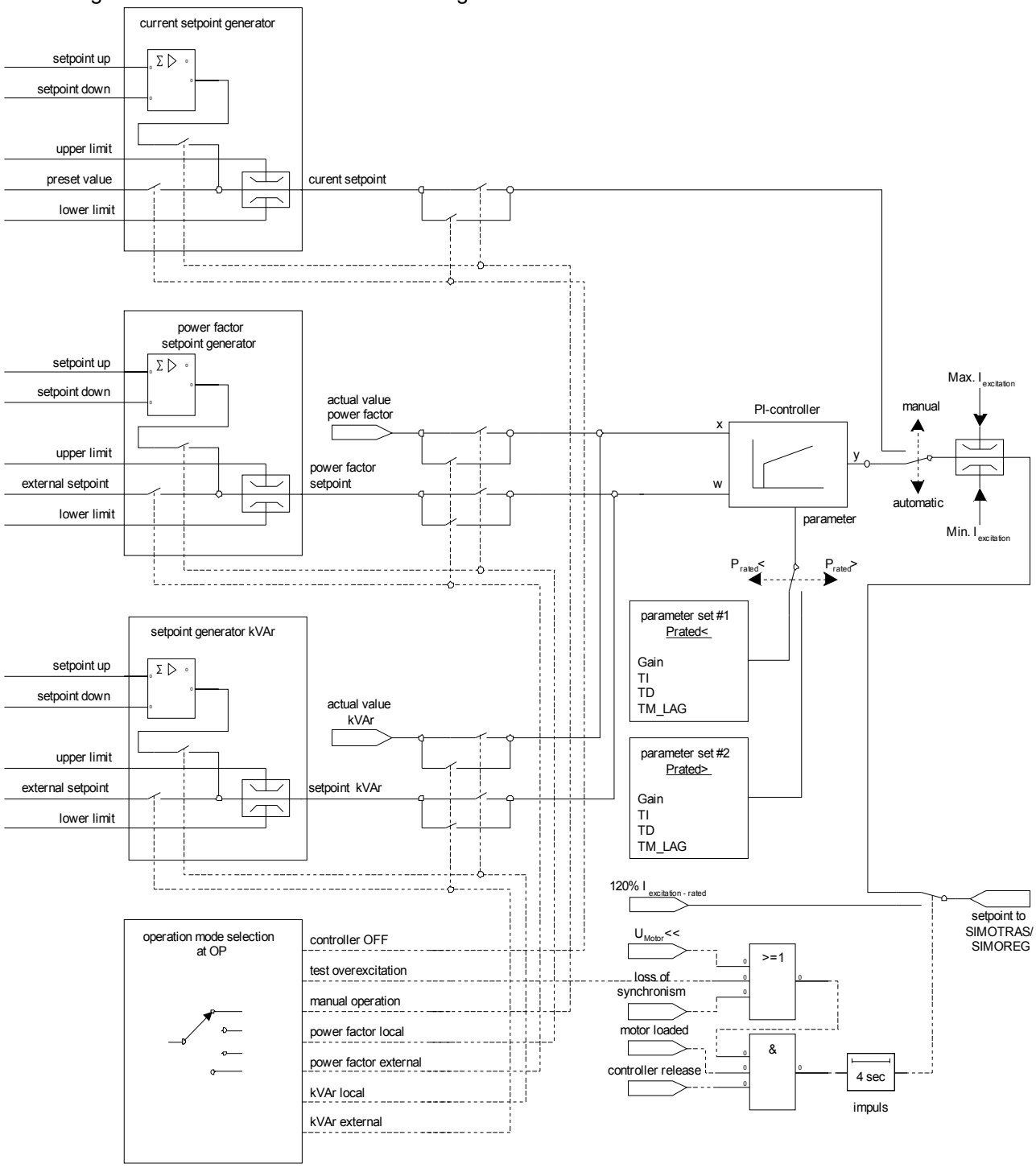
Please note:

In the standard implementation, although all modes can be selected, only those identified in section 0.0 are enabled. If a mode is chosen that is not enabled, the system switches automatically to *"Manual mode"*. The warning *"Incorrect controller mode selected"* appears on the OP.

- Controller OFF *(Man)* – *Asynchronous ramp-up*
  In this mode of operation, the control function is deactivated. A constant excitation current is output to the exciter. This excitation current is somewhat higher than the minimum excitation current and is usually about 30% to 40% of the rated excitation current.
- Controller OFF *(Man)* – *Synchronous ramp-up*
  In this mode of operation, the control function is deactivated. A constant excitation current of about 80% of the rated excitation current is output to the exciter.
- Overexcitation test *(Man)*
  An excitation current of 120% is output to the exciter for a period of 4 seconds. This mode allows the person commissioning the system to test the function and method of operation of overexcitation. Once the test function is completed, the controller returns to *"Controller OFF"* mode.
- Manual mode *(Man)*
  In manual mode, the controller acts purely as a current controller. The excitation current setpoint can be modified up or down on the OP by means of 2 keys (Up/Down). This setpoint is immediately conveyed to the SIMOTRAS HD/SIMOREG DC Master via Profibus DP and output to the exciter.
- Local power factor setpoint *(Auto)*
  This regulates the power factor of the synchronous motor. The setpoint value is assigned, as in manual mode, by using the two keys on the OP. The power factor actual value and the actual excitation current can also be read from the same display.
- External power factor setpoint *(Auto)*
  As before (local power factor setpoint), although here the setpoint value is assigned by an external 4-20mA signal from the customer.
- Local kVAr setpoint *(Auto)*
  This regulates the reactive power (kVAr) that the synchronous motor is to feed to the supply network. The setpoint value is assigned as in manual mode, by means of the two keys on the OP. The reactive power actual value and the actual excitation current can be read from the same display.
- External kVAr setpoint *(Auto)*
  As before (Local kVAr setpoint), although here the setpoint value is assigned by an external 4-20mA signal from the customer.

- **Function chart for the PI controller**

The diagram below shows the basic functioning of the PI controller.

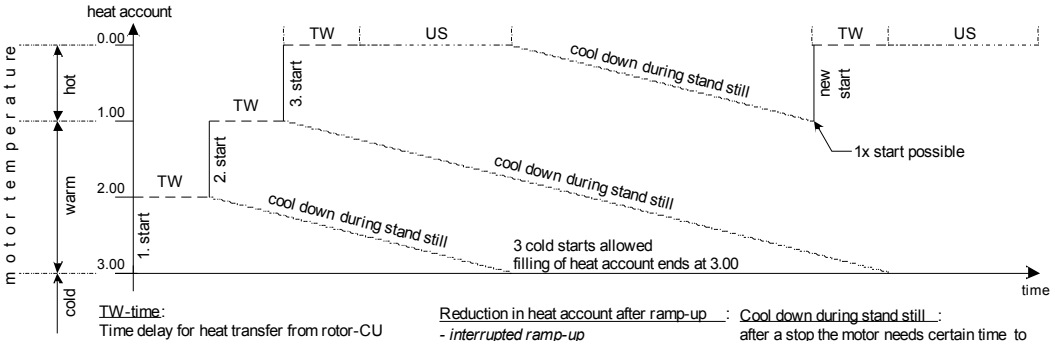


- **Integrated monitoring**

- **Monitoring the rotor temperature during asynchronous ramp-up**

The temperature response of the rotor is simulated by means of a mathematical replica in the control (=heating account). This heating account is used to restrict the start-up frequency of the motor (=restart lockout) and thus protect the rotor/motor against thermal overload. When restart lockout is activated, the time remaining until the next start is displayed on the OP.
Parameters for monitoring the rotor temperature are assigned in accordance with the motor parameters.

Example 1: Motor is stopped manually or is shut down on faults after start-up



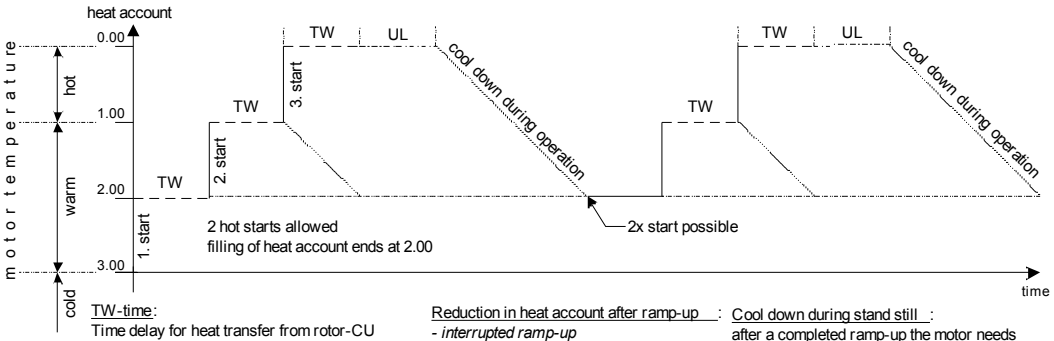
TW-time:
Time delay for heat transfer from rotor-CU to rotor core. This time will be startet after every completed or interrupted ramp-up. During this period the heat account will not be filled.

US-time:
Time delay for heat transfer during stand still from rotor core to environment. This time will be started at heat account <1.00 . During this period the heat account will not be filled.

Reduction in heat account after ramp-up:
- *interrupted ramp-up*
heat account - 1.00
- *completed ramp-up (normall intertia)*
heat account - 1.00
- *completed ramp-up (abnormal inertia)*
heat account - 1.50
- *interlock for ON command*
When the value of the heat account falls below 1.00, an ON command is ignored , until motor has cooled down (heat account >= 1.00).

Cool down during stand still:
after a stop the motor needs certain time to cool down ("cool down during stand still") before a start is possible.
The calculation of cooling will be released when no TW/US-time is active.
Heat account fills in steps of 1% within 1% of "cool down during stand still" time.

Example 2: Normal motor operation after start-up



TW-time:
Time delay for heat transfer from rotor-CU to rotor core. This time will be startet after every completed or interrupted ramp-up. During this period the heat account will not be filled.

UL-time:
Time delay for heat transfer during operation from rotor core to environment. This time will be started at heat account <1.00 . During this period the heat account will not be filled.

Reduction in heat account after ramp-up:
- *interrupted ramp-up*
heat account - 1.00
- *completed ramp-up (normall intertia)*
heat account - 1.00
- *completed ramp-up (abnormal inertia)*
heat account - 1.50
- *interlock for ON command*
When the value of the heat account falls below 1.00, an ON command is ignored , until motor has cooled down (heat account >= 1.00).

Cool down during stand still:
after a completed ramp-up the motor needs certain time to cool down ("cool down during operation") before a start is possible.
The calculation of cooling will be released when no TW/UL-time is active.
Heat account fills in steps of 1% within 1% of "cool down during stand still" time.

- **Monitoring current reduction at start-up during asynchronous ramp-up**

As soon as the medium voltage circuit breaker is on, the current increases immedialtely. As the motor approaches its synchronous speed, the start-up current slowly dies down. The period of time from the inrush peak to the reduction to approximately the rated current is monitored.

- **Monitoring for locked rotors during asynchronous ramp-up**

The speed band that is run through during the start-up process is monitored by supporting values, that is to say, the synchronous motor must reach a certain speed in a certain time, otherwise start-up will be aborted and the fault message *"Locked rotor protection triggered"* appears on the OP.

Example:

Start-up data at 100% rated voltage

Time	sec	**4**	8	12	17	20
Speed	min-1	**300**	600	900	1200	1500

Start-up data at 90% rated voltage

Time	sec	**5**	9	15	21	28
Speed	min-1	**300**	600	900	1200	1500

Stalling times for the rotor

Voltage	100%	90%
COLD stalling time	8s	10s
HOT stalling time	**6s**	**8s**

The following set values are derived from the above start-up data:

- For start-up at 100% rated voltage
  After 6s, at least 300min-1 must be reached.
- For startup at 90% rated voltage
  After 8s, at least 300min-1 must be reached.

The speed limit chosen will be somewhat lower than that specified in the start-up data for safety reasons and because of the expected program running times and measuring tolerances.

- **Monitoring for locked rotors during synchronous ramp-up**

Because of the relatively high starting torque that is available during synchronous ramp-up, it is not normally necessary to provide special start-up monitoring. We refer you to the configuration notes in the SIMOVERT S catalog for the configuration for optional start-up monitoring.

- **Start-up time monitoring**

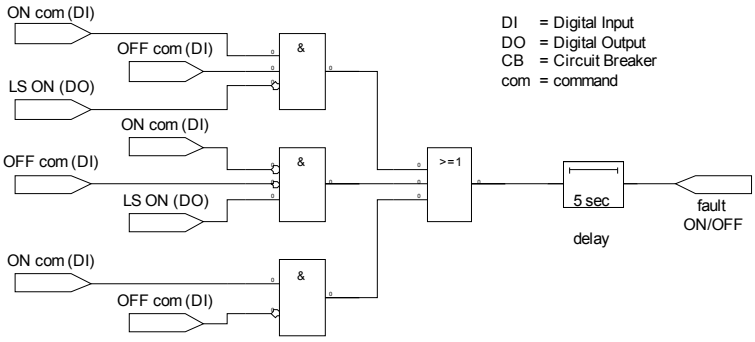
Monitoring is implemented in the same way as described in 4.4.2 *"Monitoring the current reduction at start-up"*. Here, however, the period from the inrush peak to reaching the *virtually synchronous* speed is monitored (synchronous speed minus 4%).

- **Monitoring the excitation current**

The excitation current is monitored by means of limits for overexcitation and underexcitation. The limits are set in accordance with the motor parameters and should be tested during commissioning.

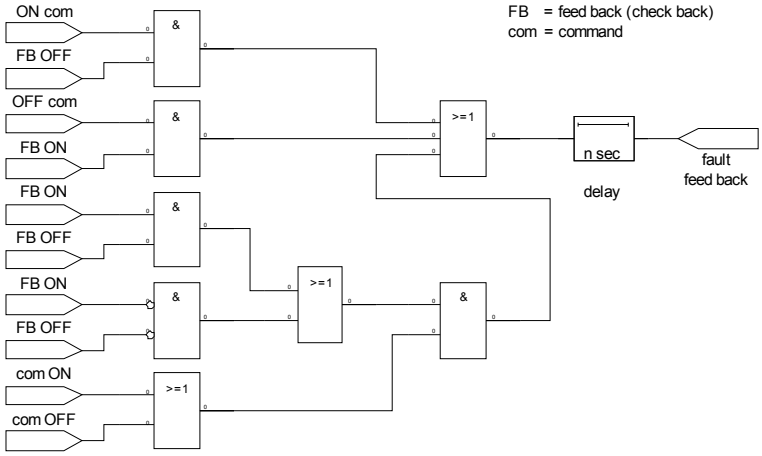
- **Monitoring the ON/OFF command for plausibility**

The plausibility of the ON and OFF command provided by the customer for the synchronous motor is monitored, as shown in the diagram below.



- **Monitoring feedback for plausibility**

Feedback read in from the switching devices is monitored for plausibility. If there is a fault condition, a warning or a shut-down on faults is triggered once the monitoring time expires (depending on the priority of the switching device) and a fault message is output at the OP. The diagram below shows the monitoring principle.



- **Operating/stand still times and statistics**

The following data is shown on the OP in the *Statistics* display (the values are fictitious):

- Control:

Minimum cycle time	*42 ms*
Last cycle time	*54 ms*
Maximum cycle time	*83 ms*

- Motor:

Last start-up time	*0m 25s (for synchronous ramp-up only)*
Last coasting time	*0m 0s (for asynchronous ramp-up only)*
Current time at rest	*0h 0m 0s*
Current operating time	*3h 20m 11s*
Total operating time	*1452h 36m 28s*
Total no. of starts	*96*

- Energy consumption:

(100 kWh display unit)	
Since last start-up	*330*
Total	*116160*

• Sequence of operations for synchronous ramp-up

The following description provides an overview of the start-up sequence and the coordination tasks of the devices involved. These are:

- the distributed control system or the operator at the excitation cabinet
- the excitation unit
- the starting converter

To implement multiple motor operation, a coordinator is also required. Depending on the overall system layout, the coordinator is implemented within the excitation units or the coordinator is an additional control cabinet, to be assigned operationally to the starting converter. The tasks of the coordinator are as follows:

- Coordinating communication between the excitation units and the starting converter
- When there are several supplying networks: coordinating which circuit breaker will be activated by the starting converter.
- Signal duplication, when required.

The coordinator does not communicate with the DCS. Motor operation can be run without a coordinator after a ramp-up operation has concluded. The communication of the excitation unit to the DCS remains available, even if the coordinator is switched off.

For further details, see the ovrview plans in the technical data section.

• Synchronous ramp-up with one motor

1) The starting converter signals “READY TO START” to the excitation unit.
2) The excitation unit signals “READY TO START” to the DCS, i.e. that there are no faults in the excitation unit or in the starting converter.
3) The “ON” command from the DCS or from the operator at the excitation panel to the excitation unit.
4) The excitation unit forwards the “ON” command to the starting converter.
5) The starting converter begins the internal starting procedure
   This means that the starting converter control starts its own auxiliaries and checks them for correct operation. After all the necessary feedback has been received, the line circuit breaker and the motor switches are closed. The motor begins to accelerate and is run up to speed in accordance with a given ramp-up characteristic.
6) The starting converter signals to the excitation unit when the motor speed reaches about 95% of the rated speed.
7) From this point onward, the automatic synchronizer in the excitation unit takes over the assignment of setpoint values for speed and motor voltage in order to synchronize the voltage and the frequency of the motor with the supply network.
8) As soon as synchronicity is reached, the excitation unit closes the circuit breaker for fixed speed operation of the motor on the supply network.
9) At the same time, the ON command to the circuit breaker is transferred by the automatic synchronizer to the starting converter. Whereupon the starting converter reduces the intermediate circuit current to zero and inhibits the inverter pulses.
10) After pulse blocking, the starting converter gives the “OFF” command to its line circuit breaker and motor switch.
11) The exciter cabinet signals “ENABLE LOADING” to the DCS.
12) The de-magnetization unit (where relevant) begins de-magnetizing the step-up transformer. This completes the run up to speed.
13) The starting converter signals “READY TO START” to the excitation unit.

- **Synchronous ramp-up with several motors**

The sequence of operations should be clear from looking at the ramp-up of motor 2 as an example.

1) The coordinator and the starting converter signal “READY TO START” to the excitation unit.
2) Excitation unit 2 signals “READY TO START” to the DCS, i.e. that there are no faults in the starting converter and coordinator and in excitation unit 2.
3) The “ON” command from the DCS to excitation unit 2 or from the operator at excitation unit 2 and if applicable, information in the message to indicate which line circuit breaker is to be used for the starting converter.
4) Exciter cabinet 2 signals the coordinator that it has received the ON command to start motor 2. The messge also indicates which line circuit breaker is to be used for the starting converter.
5) If the starting converter is already in a ramp-up phase at this time, the coordinator does not release exciter cabinet 2 to start motor 2. Exciter cabinet 2 then signals the DCS that at present, motor 2 cannot be run up to speed.
6) If the starting converter is ready to start a motor, the coordinator internally releases motor 2 for ramp-up and blocks enabling for the other motors.
7) In accordance with the assignment from the DCS, the coordinator releases a starting command from the starting converter to the desired line circuit breaker.
8) Then the coordinator releases exciter cabinet 2 for ramp-up.
9) Exciter cabinet 2 gives the “ON” command to the starting converter.
10) The rest of the ramp-up process now runs as described in single motor operation.
11) The starting converter signals the end of ramp-up and de-magnetization of the step-up transformer as feedback to the coordinator.
12) The coordinator resets enabling for starting motor 2 and cancels starting enabling for the circuit breaker. This makes the system ready to start another motor.

Note: Depending on the over system layout, the synchronizer may be installed in the coordinator panel, one unit for esach busbar.

- **Fault control when there are several motors – synchronuous ramp-up only**

Fault analysis #1: Coordinator fault
The coordinator communicates its “Coordinator WARNING” and “Coordinator FAULT” states to the excitation unit cyclically in a control word. For their part, the excitation unit communicate this status information to the DCS in their respective control words. At systems with multiple excitation units, the coordinator status messages should be linked in an OR-operation in the DCS.
If a fault occurs in the coordinator, it is not possible to start another motor until the fault is eliminated.
The fact that the coordinator has reported a fault does not affect the operation of a motor already running on line.

Fault analysis #2: Starting converter fault
The starting converter communicates its “Starting converter WARNING” and “Starting converter FAULT” states to the coordinator cyclically in the control word. The coordinator forwards these starting converter states to the DCS via the excitation unit in the same way as described in fault analysis #1.
If a fault occurs in the starting converter, it is not possible to start another motor until the fault is eliminated.
The fact that the starting converter has reported a fault does not affect the operation of a motor already running on line.

Fault analysis #3: Coordinator failure
Coordinator failure does not affect the operation of a motor already running on line.
The excitation unit signal the coordinator failure to the DCS.
It is not possible to start another motor until the fault is eliminated.

Fault analysis #4: Starting converter failure

Starting converter failure does not affect the operation of a motor already running on line.
The coordinator detects the starting converter failure and signals this to the DCS via the excitation unit, in the same way as described in fault analysis #1.

Fault analysis #5: DCS failure

If an excitation unit detects that communication to the DCS has failed, the ongoing starting processes are interrupted. The operation of motors already running continues, keeping to the last setpoint received.
After changing over to manual mode, all functions are available in manual mode.

Fault analysis #6: Several motors are to be run up to speed simultaneously.

If several excitation unit simultaneously let the coordinator know that they want to start, the excitation unit that is released for running up to speed is the one whose starting request was handled first. The other excitation unit are not released. This property is safeguarded in the software. It is not possible to predict which excitation unit will be released.

• Characteristics of generative operation

• Requirements of the supplying network

The excitation unit is designed to allow the machine set to feed back excess energy at the drive train to the supplying network via the motor/generator. It is necessary for the frequency and the voltage at the busbar to be maintained by the supplying network (by the power supply company) and to be kept within permissible limits in accordance with requirements.

If interruptions to the supply network cause asynchronicity between the network and the motor/generator system with regard to frequency or phase, the motor/generator system must be disconnected from the supply network. Then the motor/generator system must be run up to speed again via asynchronous ramp-up and properly synchronized. This request inhibits transfer switching or interruptions to the supply network when the machine set is running, particularly when generating. Should there be an interruption to the network supply, the motor/generator system must be immediately disconnected from the network. There is the risk that without the supplying network, the motor/generator system will elevate the busbar voltage to inadmissible values should there be a sudden load change. A connection with a de-excited rotor and asynchronous ramp-up shall only occur once the frequency and voltage at the busbar are safely maintained by the supplying network. Siemens requires that only the stationary machine set is connected to the supply network.

• Requirements of the shaft assembly

Normally the drive train has no speed regulation, the synchronous motor applies the network frequency to the drive train. The shaft assembly must be implemented with speed monitoring and a protective energy supply cutoff.

The concept in steady-state operation is as follows:

In accordance with the energy balance at the shaft assembly, the motor/generator system assumes motorized or generative operation. The torques that the motor/generator system can feed to the drive train or which can be taken from the drive train are limited by the rated currents and the maximum permissible temperature of the motor windings.

The protective devices of the motor/generator system disconnect the motor/generator system from the supply network, if the limits in the motor/generator system (current, voltage, temperature rise) are exceeded. It is advisable to protect the busbar against excess voltages from the motor/generator system with an overvoltage relay with trip.

Should the motor/generator system be disconnected from the supply network in generative operation or if the supply network fails, it is necessary to ensure that the supply of energy to the shaft assembly stops immediately. It is the task of the system integrator when setting up and specifying the components of the machine set to take this operational mode or malfunction into consideration.

- **Synchronizing the generator to the supply network**

Under certain special circumstances, the running generator (motor/generator system driven by the shaft assembly) can be synchronized to the supply network. This is only possible if the speed of the generator/shaft assembly can be regulated. There are two distinct situations here:
- Asynchronous ramp-up: the driven machine takes care of speed regulation
- Synchronous ramp-up: the driven machine takes care of speed regulation and alternately, the starting converter

Asynchronous ramp-up variant:
The feeding circuit breaker must be off. Speed regulation of the driven machine regulates the motor speed to 95% rated speed. Then the driven machine transfers control to the automatic synchronizer in the excitation unit of the machine. This controls the speed regulation of the driven machine in such a way that synchronicity is achieved. For this to happen, the quality of speed regulation must be adequate for the synchronization process. Once synchronicity is achieved, the circuit breaker is connected and speed regulation of the driven machine is informed of this control state. Speed regulation must be shut off.

Synchronous ramp-up variant:
The feeding circuit breaker must be off. Speed regulation of the driven machine regulates the motor speed to a speed below the rated speed. The starting converter connects to the motor and catches the motor. Once the motor is caught, the converter gives a cutoff signal to the driven machine regulator that speed regulation must be cut off. Care must also be taken to ensure that the power output and the power consumption of the driven machine are adjusted so that the rated current of the starting converter cannot be exceeded. A starting and synchronizing process begins, as described for normal synchronous ramp-up.

If the motor is generatively operated during ramp-up, please note that a motor-driven short-circuit cannot be safely detected and therefore not be switched off. It is advisable therefore to provide an additional protection relay for the starting process to quickly detect the short-circuit and shut off excitation in the event of a malfunction. Please note that with starting converter operation, differential protection is not possible.

- **Documentation**

- **CD-ROM**

One copy of the documentation for circuit diagram, terminal diagram, the software and for parameterization is provided on the CD-ROM. The language required by the end customer and the installed components will determine the file structure on the CD.

The file structure on the CD typically looks like this:

- Acrobat Reader installation file
- Schematic diagrams in PDF format
- Manuals for the devices in PDF format
- Data sheets for the motor as made available bz the motor manufacturer/customer in PDF format
- General information about the program structure and the abbreviations
- Printout of the device parameters in PDF format
- Printouts generated from STEP7 in PDF format
- Printout of the ProTool configuration for the OP17 in PDF format
- Directory for revised files after commissioning
- Parameter files for the devices in use

- **Software**

One copy of the documentation for the SIMATIC application software is provided on the CD-ROM. The documentation allows the customer and the commissioning engineers to commission and to maintain the system. The software included is all standard and application software as required for scope delivered.

- **Schematics**

The circuit diagram including the terminal diagram conform to DIN and VDE and is available in German and English. The documents are prepared in SIGRAPH ET/S Version 8. A set of documents in DIN A3 format is provided for each cabinet.

The following documentation versions are made available to the customer:

1. Approval documentation
   This set of documents is submitted to the customer for approval. Once they have been approved by the customer and returned, customer-specific entries will be included in the production document set.
2. "As shipped" document set
   Once production and testing is complete, the production documents are revised and the "As shipped" document set is prepared, ready to be enclosed with the exciter cabinet.
3. "As built" document set
   Once commissioning is complete, the documents are revised and the "As built" document set is prepared.
   N.B.:
   The commissioning revision is included in the scope and includes – as made available from job site - details of cable types, cable numbers and wire colors as specified in the terminal diagrams, the identification and connections of external equipment as specified in the terminal diagrams, the identification of the first external connection point in the schematic diagrams, as well as index modification in the header.
   Not included are customer-specific entries and entries other than those mentioned above.

Each documentation version includes the following documents:

- Cover
- Document index
- Layout diagram for the cabinet
- Schematic diagrams
- Terminal diagrams
- Cable connection diagram
- List of components (Excel format)
- List of signals (Excel format)

In addition to the paper version, the circuit and terminal diagrams are included as a PDF file on the CD-ROM described in section 0.0.0.

To enable the customer to integrate the circuit diagrams into the documentation of the overall installation, the schematics are also available as a DXF file, as an option (see section 0.0).

Documents that go beyond the scope of documentation described above, such as function descriptions, sequence charts, overview displays, etc., are not included in the standard scope of supply.

- **Product manual**

When the excitation unit is delivered, the documentation is put together in a product manual (folder, DIN A4). For multiple motor application one product manual is delivered for the total system.

The product manual includes the following documents:

- Schematics
- S7 program printouts
- Device descriptions
- Cabinet installation instructions
- Quick reference guide VSI/maintenance
- Test and inspection record

In addition to the paper version, the product manual is included in PDF format on the CD-ROM described in section 0.0.0.

Documents that go beyond the scope of the documentation described above, such as function descriptions, sequence charts, overview displays, etc., are available on request.

- **Options**

- **Degree of protection IP54**

The control cabinet is designed to provide IP54 protection and is cooled up to an ambient temperature of 30° C by means of a combined filter and fan (RITTAL SK3326.100, 230V AC) with an outlet filter activated by a thermostat (SEIFERT ST-4980).
In ambient temperatures higher than 30°C, the cabinet is cooled by a cooling unit (RITTAL SK 3255; 230V AC). The cooling unit is fitted in the left side panel of the cabinet and increases the overall width by 132mm. This implementation is only available for excitation currents up to 130A. Higher degrees of protection at higher excitation currents can be provided on request.

- **Cable entry from above**

If the installation demands it, cable entry can also be from above. To achieve this, the connection elements inside the cabinet (terminal blocks; ET200S for external signals) are moved up and the rubber lip for cable entry is put into the perforated top plate.
Cable entry from above for excitation currents higher than 130A is available on request.
Cable entry from above and IP54 is available on request.

- **Control cabinet heater (space heater)**

This option is required if the ambient temperature fluctuates greatly. A space heater (RITTAL SK3107 110-240V AC, 130W) is installed to prevent moisture condensation. If the humidity level in the excitation unit is too high, the space heater is switched on via a hygrostat (RITTAL SK3118, range of adjustment 50-100% r.h.). Power and protection (SIEMENS 5SX21) is provided internally.

- **Synchronous motor space heater**

Supplying and activating a space heater heater in the synchronous motor. This comes on whenever the synchronous motor is at rest. The outgoing power circuit (3-phase, voltage/frequency as for the incoming supply of the excitation unit power section) includes protection (SIEMENS 3RV10) and software-driven activation via a contactor (SIEMENS 3RT10). The outgoing power circuit is wired to a terminal block.

- **Incoming DC supply for the PLC**

In order to prevent control failure when there are large voltage dips/fluctuations, the supply voltage for the control is fed in separately. The control voltage feeder provided by the customer (110 or 220V DC, battery-backup, connected load approx. 1kVA) is converted internally to 24V DC by means of a DC/DC transformer.
Caution:
The electronics supply of the SIMOTRAS HD and SIMOREG DC Master needs 110 to 230V AC and is supplied with power from the incoming supply for the power section.

- **Leakage water detection**

When the synchronous motors are water-cooled (1 or 2 coolers, depending on the design) this option monitors the coolers for leakage. Probes made by ZIMMER are to be used in the motor to this effect. The measurement signals are evaluated in the exciter cabinet by the relevant evaluator (ZIMMER NR98 and DNR98, with 1 and 2 coolers respectively) and information is passed to the control. When the monitoring relay sends a signal, a warning is displayed on the OP and logged in the alarm buffer. Power is supplied to the evaluator (230V AC) inside the cabinet.

Caution:

When motors are used in potentially explosive atmospheres, this option must be requested separately, stating the type of protection required.

- **Loss of synchronism protection – overexcitation**

The reactive power is monitored as a criterion for the possible loss of motor synchronism. If the value falls below a reactive power limit because of vast load fluctuations, for example, a message is sent to the field current controller. The reactive power limit is assigned in accordance with the motor parameters.

If the motor is in operation (*"Enable loading"* signal to the customer), the controller is enabled and the above message is present, overexcitation is activated. The controller immediately raises the excitation current to 120% for a period of 4 seconds (=overexcitation). A warning is output at the OP and the loss of synchronism protection message is logged in the alarm buffer.
This measure usually “catches” the motor again, thus preventing loss of motor synchronism. If this has not worked after three successive attempts or after 20 seconds have elapsed, the motor is shut down and a fault message appears on the OP.
The function chart for the PI controller included in subsection 0.0.0 shows the way this works.
Loss of synchronism protection is only available for motor operation.

- **Diode monitoring (not for slipring fed motors)**

If one of the diodes in the exciter is open, the diodes that are still intact can be overloaded. If a diode short-circuits, there is a risk of thermal overload to the exciter winding. The XE2 protection relay from SEG can monitor the rotating diodes in the exciter.
With exciters that have a DC-supply, the direct current can be fed directly to the protection relay. With exciters that have an AC-supply, the excitation current is acquired via 3 current transformers, rectified by means of a B6 bridge rectifier and then fed to the protection relay.
The protection relay forms the trigger criterion for diode monitoring from the excitation current ripple measurement.
When diode monitoring cuts in, the synchronous motor and the excitation are shut off immediately, in order to avoid further damage. Furthermore, a fault message is output on the OP in plain text and the event is logged in the alarm buffer.

- **Reverse power protection**

The synchronous motor is monitored for reverse power by means of a directional power relay (SEG XP2-R or equivivalent). Siemens recommends to include reverse power monitoring into the protection relay in the circuit breaker. Revers power protection is not possible for generative operation.

- **Digital motor protection**

A multifunctional machine protection relay of type SIPROTEC 4 7UM62 (SIEMENS 7UM621x-2EB01-0AE0) is used to protect the synchronous motor.

General features:

- Powerful 32-bit microprocessor system.
- Totally digital measured-value processing and control, from sampling and digitizing the measured quantities to deciding whether or not to de-activate the circuit breaker and other switching devices.
- Full metallic and noise-proof isolation of the internal processing circuitry from the measuring, control and supply circuits of the installation via measuring transformers, binary input and output modules and d.c.-d.c. voltage converters.
- Easy to use via the integrated operator and display panel or by means of a connected PC with a DIGSI® 4 operating program.
- Constant calculation and display of measured process values.
- Storage of incident messages, as well as instantaneous values or rms values for fault recording.
- Constant monitoring of measured quantities, as well as device hardware and software.
- Communication with central control and storage equipment via serial interfaces is possible.
- Switching statistics: counting the trigger commands initiated by the device as well as logging the currents of the last shut-down initiated by the device and accumulating the cutoff short-circuit currents for each breaker pole.
- Elapsed time counter: protection object counting under load.
- Commissioning aids such as connection checking and phase-sequence testing, status display of all binary inputs and outputs and test measurement recording.

The basic implementation of the protection relay includes the following functions:

Protection function	ANSI No.
- Current differential protection	87G, 87M, 87T
- Stator earth-fault protection, non-directional, directional	59N, 64G, 67G
- Sensitive earth-fault protection	50/51GN (64R)
- Overload protection	49
- Overcurrent-time protection with low voltage stability	51
- Overcurrent-time protection, directed	50/51/67
- Dependent overcurrent-time protection	51V
- Overvoltage protection	59
- Undervoltage protection	27
- Frequency protection	81
- Reverse power protection	32R
- Overexcitation protection	24
- Fuse failure monitor (measurement voltage monitoring)	60FL
- Trigger circuit monitoring	74TC
- Forward power monitoring	32F
- Underexcitation protection	40
- Out-of-balance protection	46
- Circuit breaker failure protection	50BF
- Start-up time monitoring	48
- Rotor earth-fault protection with line-frequency voltage	64R
- Phase sequence monitoring	47
- Undercurrent via CFC	37

Protection functions listed above depend on the availability of potential and current transformers. Such transformers are not included in the scope of the excitation unit.

Other protection relays (with different order numbers to those above) on request.

N.B.:

Further information, such as detailed descriptions of the individual protection functions and what is required from current/voltage transformers, can be found in the protection relay manual.

• Digital transformer protection

A digital overcurrent-time and overload protection, of the SIPROTEC 7SJ600 type (SIEMENS 7SJ600x-2EA00-0DA0), is used to protect the step-down transformer – at the input end of the SIMOVERT S.

General features:

- Powerful 16-bit microcontroller system.

- Totally digital measured value processing and control, from sampling and digitizing the measured quantities to deciding whether or not to activate or de-activate the circuit breaker.
- Full metallic and noise-proof isolation of the internal processing circuitry from the measuring, control and supply circuits of the installation via measuring transformers, binary input and output modules and converters.
- Phase-separated overcurrent detection.
- Immune to d.c. components, starting and charging currents, as well as higher-frequency transient reactions.
- Selectable tripping characteristics.
- Each characteristic also has independent high current tripping I>> and in the phase branches, instantaneous tripping I>>>.
- Dynamic threshold switching between two sets of operating values for overcurrent-time protection by means of binary input.
- Choice of overload protection with or without memory function (thermal image of heat losses due to current).
- Start-up time monitoring to protect motors from starting operations that go on too long (locked rotor).
- Out-of-balance protection to detect phase failure or phase interruption and phase sequence reversal.
- Circuit breaker testing by probe activation/deactivation or by probe deactivation command.
- Possible trigger circuit monitoring for a circuit breaker coil including its lead wires.
- Easy to use via the integrated operator and display panel or by means of a connected PC with operator prompting.
- Storage of incident messages and instantaneous values to record faults.
- Constant monitoring of device hardware and software.

The basic implementation of the protection relay includes the following functions:

Protection function	**ANSI No.**
- Instantaneous overcurrent protection	50
- Instantaneous short-circuit-to-earth protection	50N
- Overcurrent-time protection	51
- Short-circuit to earth protection	51N
- Out-of-balance protection	46
- Overload protection	49
- Start-up time monitoring	48
- Trigger circuit monitoring	74TC

Protection functions listed above depend on the availability of potential and current transformers. Such transformers are not included in the scope of the excitation unit.

Other protection relays (with order numbers different to those above) on request.

N.B.:

Further information, such as detailed descriptions of the individual protection functions and what is required from current/voltage transformers, can be found in the protection relay manual.

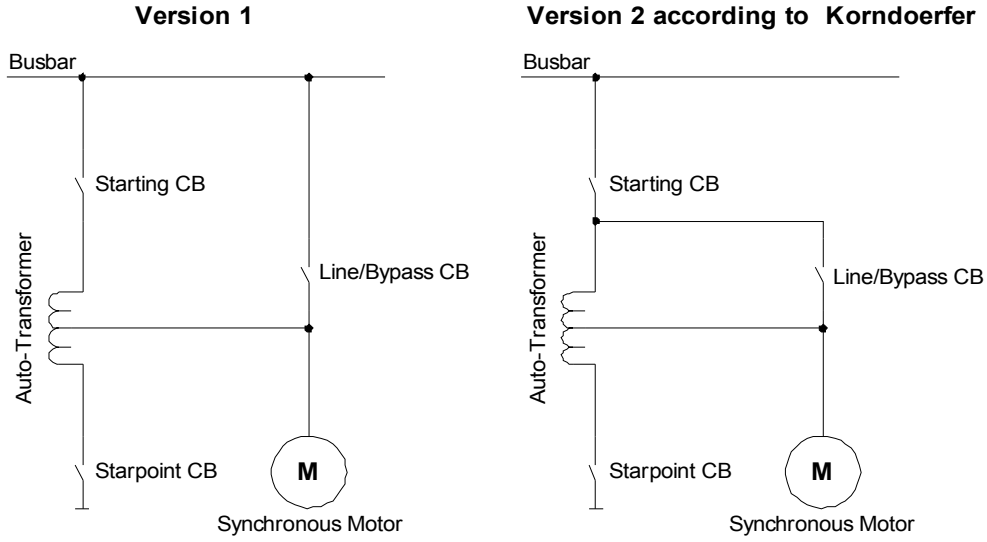
- **Excitation current supply from the earthed network**

Should the supply voltage come from an earthed network, a different earth fault protection relay make Bender is required.

- **Modified start-up method – asynchronous ramp-up**

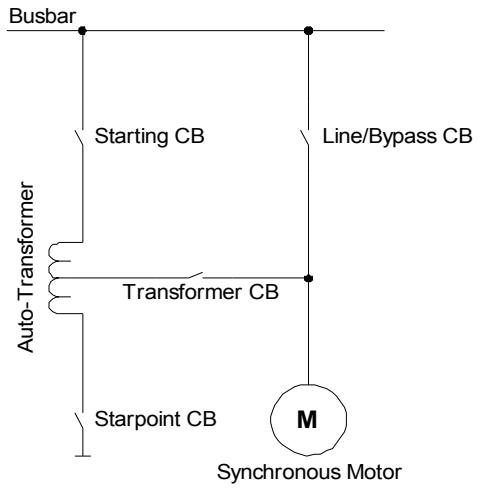
As an alternative option to direct start-up (=standard implementation), reduced voltage starting is also possible using one of the following methods:

Start-up via an autotransformer starter and the three-switch method



Starting sequence:
- Starpoint switch ON
- Starting switch ON
  Motor starts up with reduced voltage
  Wait until current has died down to approx. I_{rated} and the speed is approx. 98% of $n_{synchron}$
- Starpoint switch OFF
  Motor runs for approx. 3s at reactance setting
- Line/Bypass switch ON
  Motor runs at rated voltage

With version 1, once the line/bypass switch has been switched on, the starting switch is opened. With both versions, excitation can be turned on after opening the star point switch or after bypassing the autotransformer.



Starting sequence as for the 3-switch method, although the transformer switch and the starpoint switch are closed together. Once start-up is complete, the transformer switch is opened again and the autotransformer starter is de-energized.

• Excitation unit prepared for multiple motor operation

When operating several motors on one starting converter, it is necessary to expand the excitation installation. Two additional outputs and one additional input are required. The input is used exclusively for display purposes in the DCS.

Output via the ET200S relay output module (SIEMENS 6ES7132 or equivivalent)

Contact loading: *120V DC/0.2A; 230V AC/0.5A*

- Disconnect ON (NO) 1 = ON command
  Enable circuit breaker ON
- Disconnect OFF (NO) 1 = OFF command

The customer must provide the signal voltage, taking into account the max. contact loading.

Reading in via the ET200S digital input module (SIEMENS 6ES7138 or equivivalent)

Contact loading: *24V DC/≤ 50mA*

- Feedback Disconnect ON (NC) 1 = ON/0 = OFF

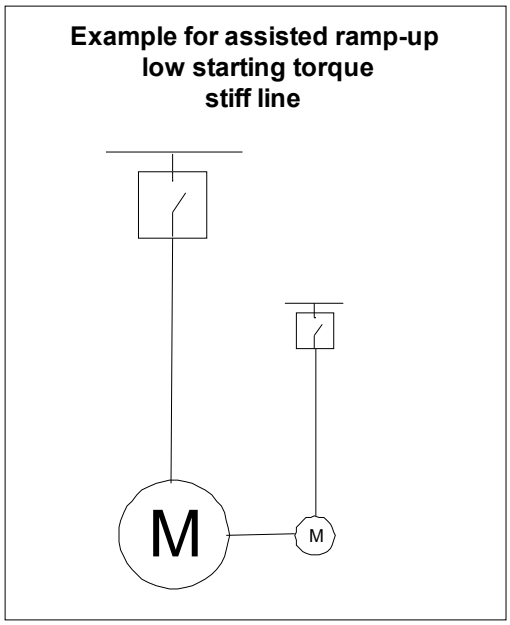
The customer must provide a potential free contact.

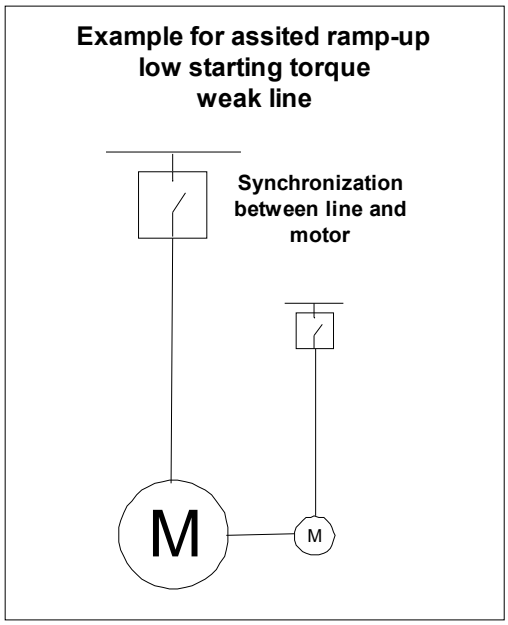
• Coordinator for ramping up several motors at the starting converter

A coordinator is required if more than one motor is to be run up to speed via a starting converter. The coordinator coordinates the functions of the excitation units and the breaker and disconnect states in the switchgear. The coordinator controls standardized interfaces to the excitation unit, to the switchgear and to the starting converter. Because of possible variance in the switchgear and during communication to the DCS/operator, the execution of the coordinator is specific to the installation. The implementations are in line with the concepts described in the “technical data” section.

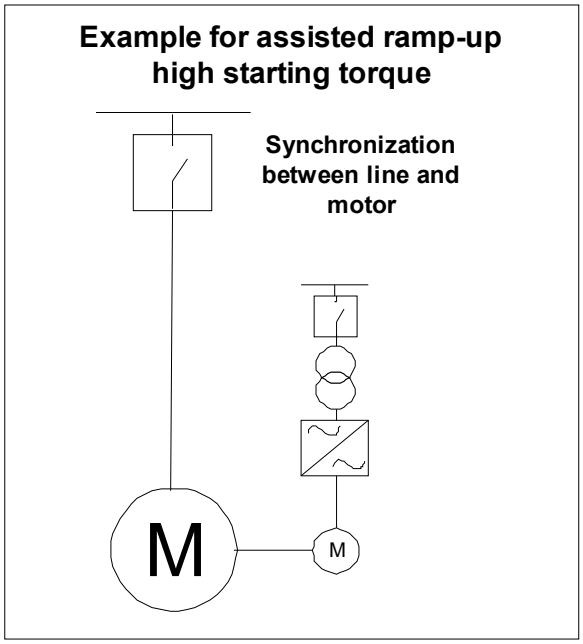
- **Assisted ramp-up**

Version 1 and Version 2: Ramp-up with asynchronous motor direct on line





Version 3: Ramp-up with asynchronous motor via converter



- **Remote display of two measured values**

By using additional ET200S or equivivalent analog output modules, various measured values, galvanically isolated, can be made available at a terminal as a 4-20mA standard signal. The measured values available are: line voltage, respectively stator voltage, motor current, excitation current (for DC excitation only), excitation current, active power, reactive power, power factor, speed (if there is a speed sensor present) and temperatures (temperatures only in conjunction with the PT100 sensors described in section 0.0).
The above option can be ordered in multiples and includes the analog output module, wiring, transfer terminals and parameterization as specified by the customer. The analog output module used has two channels, that is to say, two analog signals can be output for every purchase of that option.

- **Additional display instruments**

To display additional measured values available inside the cabinet, the option is available to incorporate additional 96x96mm display instruments in the cabinet door. The measured values available are: line voltage, motor current, excitation current, active power, reactive power and power factor.
The above option can be ordered in multiples and includes the display unit, mounting, wiring and scale as specified by the customer.

- **Extended signal exchange to the DCS**

As well as the signals provided in the standard implementation, there are additional signals in the cabinet that can be made available to the customer.
They are output, potential-free, via the ET200S relay output module (SIEMENS 6ES7132 contact loading 120V DC/0.2A; 230V AC/0.5A or equivivalent).
The above option can be ordered in multiples and includes the relay output module and mounting. The output module has two channels, that is to say, two binary signals can be output forvevery purchse of that option.

- **Communication with the external control/DCS**

It is possible to set up communication to a control provided by the customer via a bus connection in order, for example, to transfer data directly to a DCS system. An additional SIMATIC S7-300 communications processor (CP) is used for this, which prevents malfunctions at the external bus from having a negative effect on communication inside the cabinet.

- **Protocol: Profibus DP**

The option is available to communicate to an external control using a defined Profibus DP protocol. A CP342-5FO or equivivalent is the communications processor used. This CP has direct connection for plastic or PCF optical fibers. The maximum distance between stations is 50m for plastic optical fibers and 300m for PCF optical fibers. The fiber-optic cable is not included in the scope of supply. However, provided the requisite cable length is stated, a relevant, prefabricated cable can be provided on request.

The CP342-5FO is configured as a SLAVE. Both the send mailbox and the receive mailbox are 32Bytes in size. Data are exchanged consistently with the external control at the customer end via the Profibus DP protocol, by means of the functions DP_SEND and DP_RECV.

To allow the customer to monitor the connection, the send mailbox includes a toggle-bit, that can change its signal state at a frequency of 1Hz. The same signal must be generated at the customer end and placed in the receive mailbox. This ensures that should the bus system fail, both ends will be able to detect it.

Only data that are not absolutely essential for the safe operation of the synchronous motor can be exchanged via Profibus DP. This includes the binary signals listed in subsection 0.0.0, as well as the analog signals present in the control in 16-bit format (integer).

N.B.:
The existing interface on the terminal strip is retained. It is **mandatory** to place the signals described in subsections 0.0.0 and 0.0.0 on the terminal strip and the I/O-modules described.

- **Protocol: others**

If communication other than that described in subsection 0.0.0 is to be implemented, some in-depth clarification of the controls, protocol, available communications structures, transmission rates, etc., is required. (The price of the option incl. clarifications, is available on request).
With the SIMATIC S7 control, the following transmission physics can be implemented by connecting a SIMATIC S7-300 CP:

Communications interfaces through an additional SIMATIC S7-300 CP:

- Serial coupling (CP340/CP341)
  - RS 232C (V.24)
  - 20mA (TTY)
  - RS 422/RS 485 (X.27)

  Possible protocols: ASCII, RK 512, 3964 (R) and printer driver.
- Profibus (CP342-5 and 342-5 FO)
  - Profibus DP
  - SIMATIC S7 communication
  - SIMATIC S5-compatible communication
- Industrial Ethernet (CP343-1)
  - ISO or TCP/IP transport protocol
  - SIMATIC S7 communication
  - SIMATIC S5-compatible communication

- **Hardware documentation in other than EU languages**

In diviation to the German/English standard, the option is available to provide the schematics for the excitation cabinet in the national language of the particular country. The only condition is that the national language uses one of the Windows character sets.

- **Hardware documentation on data media**

Should the customer require the hardware documentation on data media, so that it can be reworked or archived, the option is available to supply the drawings in DXF format.
Other file formats are possible on request.

- **Multiple documentation implementation**

The option is also available to obtain multiple implementations of the hardware and software documentation. Prices on request.

- **Processing additional analog values**

The following analog values can also be read in/processed:

Setpoints	*Source*	*Level/Meas. principle*
- External setpoint for control	Customer	4-20mA

Temperatures	*Source*	*Level/Meas. principle*
- PT100 – Bearing AS	Motor	4-wire
- PT100 – Bearing BS	Motor	4-wire
- PT100 – Stator winding U	Motor	4-wire
- PT100 – Stator winding V	Motor	4-wire
- PT100 – Stator winding W	Motor	4-wire
- PT100 – Cold air 1	Motor	4-wire
- PT100 – Cold air 2	Motor	4-wire
- PT100 – Hot air	Motor	4-wire

The analog values are monitored to see that the measuring range is not exceeded. For temperature measurement (PT100), limits are formed which cause a warning or a trip when an inadmissible range is reached (limits specified by the motor manufacturer). In this situation, a warning or a fault message is output on the OP in plain text. The limits used in the program are recorded in the software documentation, in the printout of data block DB2 (DB_Set).

Additional analog values can be read in and processed on request. The requisite analog input modules of the have two channels, that is to say, the option includes two analog signals.

- **Customized display language on the OP**

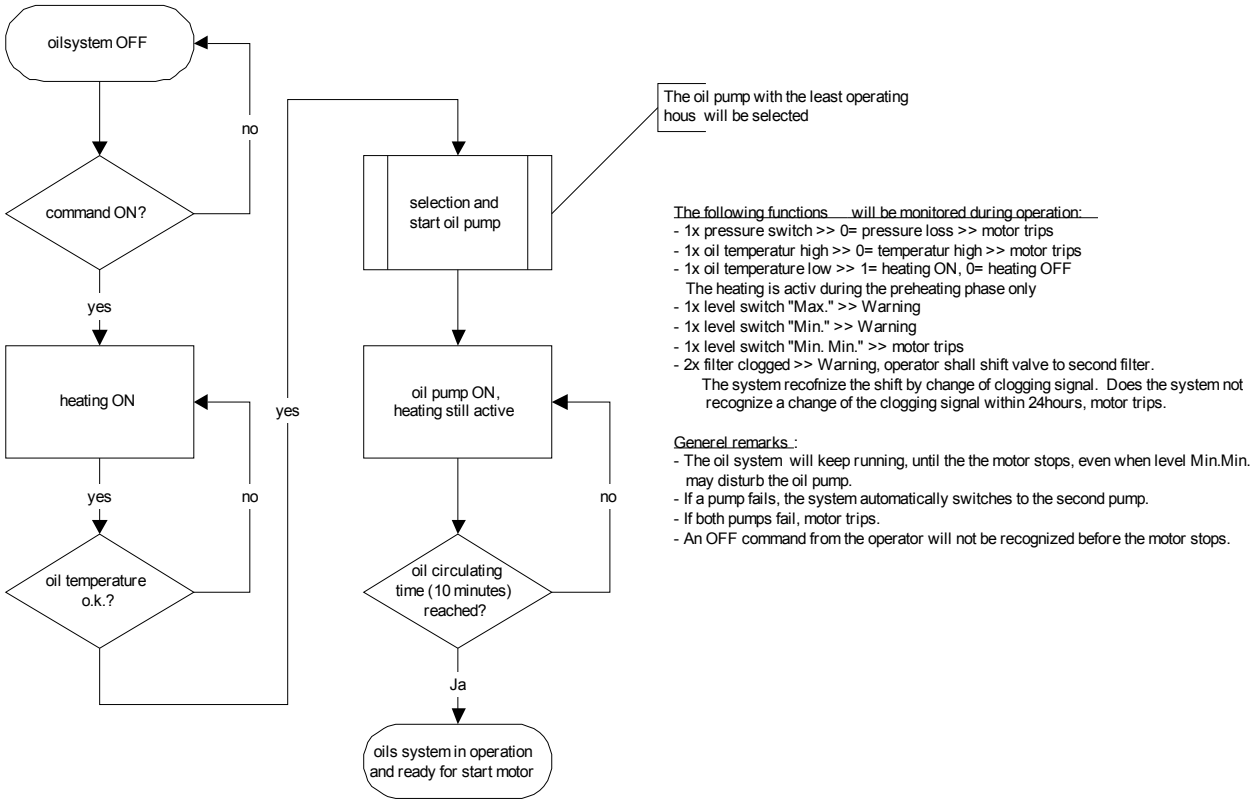
In deviation to the languages that are available as standard, German and English, the display language can also be configured in the national language of a particular country. The system messages (for definition, see below) of the OP will remain in English. Siemens makes a list of German or English texts available, which the customer can have translated with Siemens assistance into their particular national language. Siemens will then adapt the translated files and incorporate them into the program files for the OP. Then it will be possible to select the customized national language, English and German on the OP.
Please note that it is first necessary to clarify whether the relevant character set can be displayed on the OP by ProTool before this option is available for purchase.

System messages:
System messages are triggered from the OP. They are not configured. System messages give information about the operating states of the OP and about wrong operation or communication malfunctions.

- **Oil supply**

The option is available for sequence control and to monitor the oil supply for the motor from the excitation unit. The way in which this works is described below.

1. The customer provides a starting signal for the oil supply.
2. The heater is switched on and controlled by the thermostat. The oil in the oil tank is brought up to the operating temperature (pre-heating).
3. Once the oil is up to temperature, the oil pump with the least operating time is started.
4. The oil is circulated for 10 minutes. Heater activation via the thermostat is still active. At the end of the oil circulation time, the entire oil circuit should be up to temperature. Once the oil circulation time is completed and the oil is at pressure, the "oil supply in operation" signal is sent to the customer.
5. The customer can then start the motor.



6. The oil pump continuous to operate until stop command by the operator.

Signals from the DCS:

Read in via the ET200S digital input module (SIEMENS 6ES7138 or equivalent)

Contact loading: *24V DC/≤ 50mA*

- Oil supply ON command (NO) 1= ON command; 0= OFF command

Signals to the DCS:

Output via the ET200S relay output module (SIEMENS 6ES7132 or equivalent)

Contact loading: *120V DC/0.2A; 230V AC/0.5A*

- Oil supply in operation (NO) 1= Operation; 0= OFF
- Filter dirty (NO) 0= Dirty

Additional I/O for warning and fault indication as applicable.

- **Technical data**

- **Ambient conditions**

The excitation unit and the changeover device (coordinator) are designed for installation in a standard industrial environment.

Ambient conditions: Standard industrial air, without oil, corrosive gases and an abnormally high chemical and physical impurities content.

Temperature: 0°C to 40°C

Humidity: max. 90% r.h. (non-condensating)

Site altitude: < 1000m

- **Dimensioned drawing for the excitation unit for DC-supply**

- **Dimensioned drawing for the excitation unit for AC-supply**

- **Dimensioned drawing for the coordinator**

- **System description for asynchronous ramp-up**

The system configuration shown is the proposed solution for a system integration comprising switchgear, motor and transformers. This engineering standard shows the essential components and their functions. The engineering standard should form the basis for solutions to a given drive task.

System description to follow

- **System description for synchronous ramp-up**

The system configurations shown in the following sections are proposed solutions for a system integration comprising switchgear, motor, starting converter and transformers. These engineering standards show the essential components and their functions. The engineering standards should form the basis for solutions to a given drive task.

The protection shown in the single lines is e recommendation to the system engineers and shows the basic solution and some valuable options.

Siemens recommends to install an undervolatge and overvoltage protection in the switch gear.

Siemens recommends to build EM-STOP with live signals (live signal = no stop, signal low = stop).

Information to section 6.6.1 and 6.6.2:

Remark 1)

Basic functionality:

Short circuit protection	50/51	
Overload protection	49	
Differential Protection	87	

Optional functionality:

Precise earth fault monitor	51N	with split core CT
Under-/overvoltage protection, lins distortion	27/59/46	with PT
Power meter etc.	P/S/Q	with PT and CT class 0,5

Remark 2)

Basic functionality:

Short circuit protection	50/51
Overload protection	49

Remark 3)

If the circuit breakers disconnect after stop firing the SCRs, overvoltage protection is not necessary

Remark 4)

According to the options listed under Remark 1) the connections and transformers are required for the options.

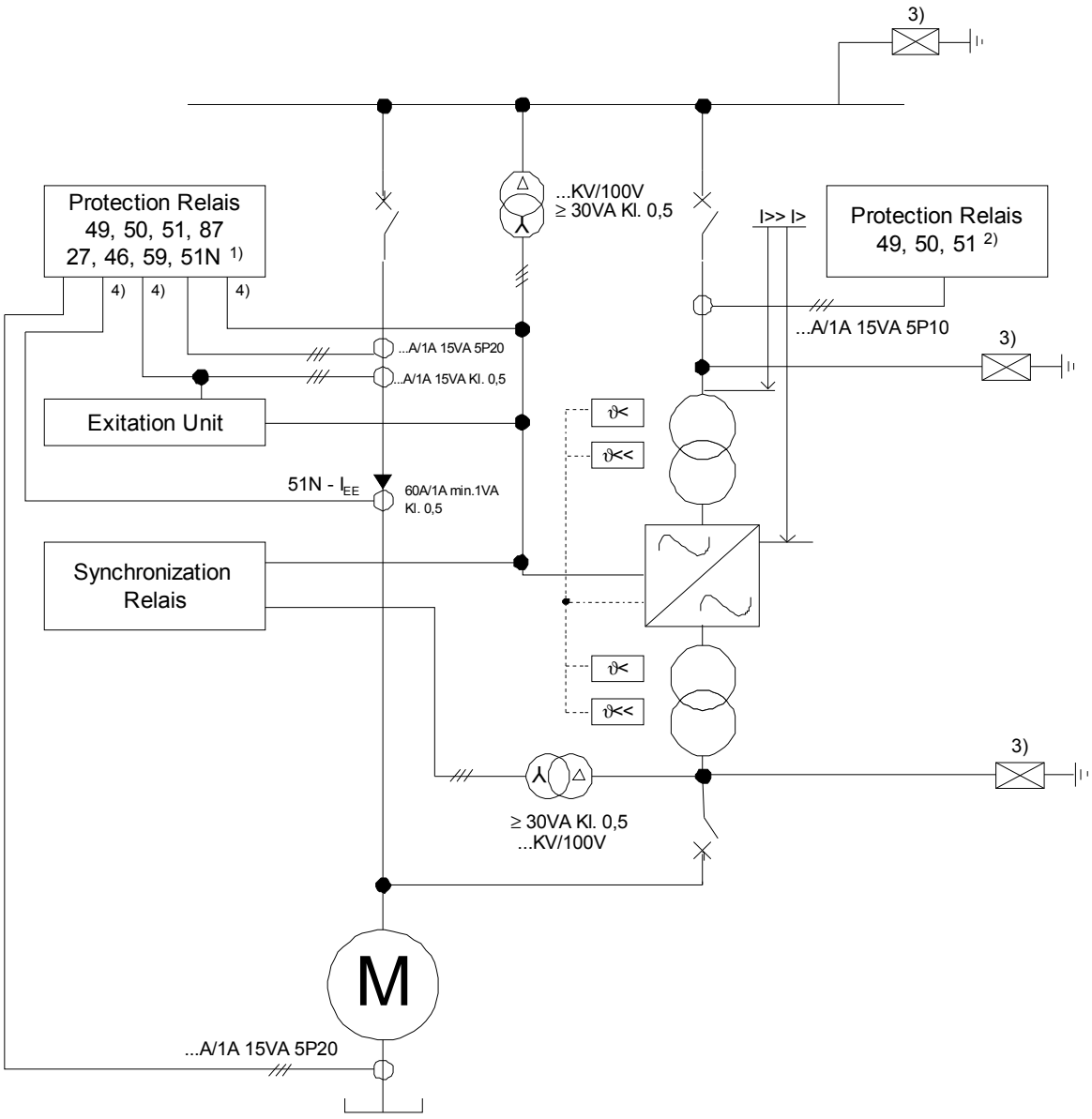
Remark 5)

Depending on the design of the excitation unit the scope includes at least one synchronizing unit for each feeding bus bar, but not more than one synchronization unit for each excitation unit. The quantity of synchronization units gets finalized during detail design.

Excitation unit and starting aids for fixed speed synchronous motors

- **Single motor ramp-up – Single Line**

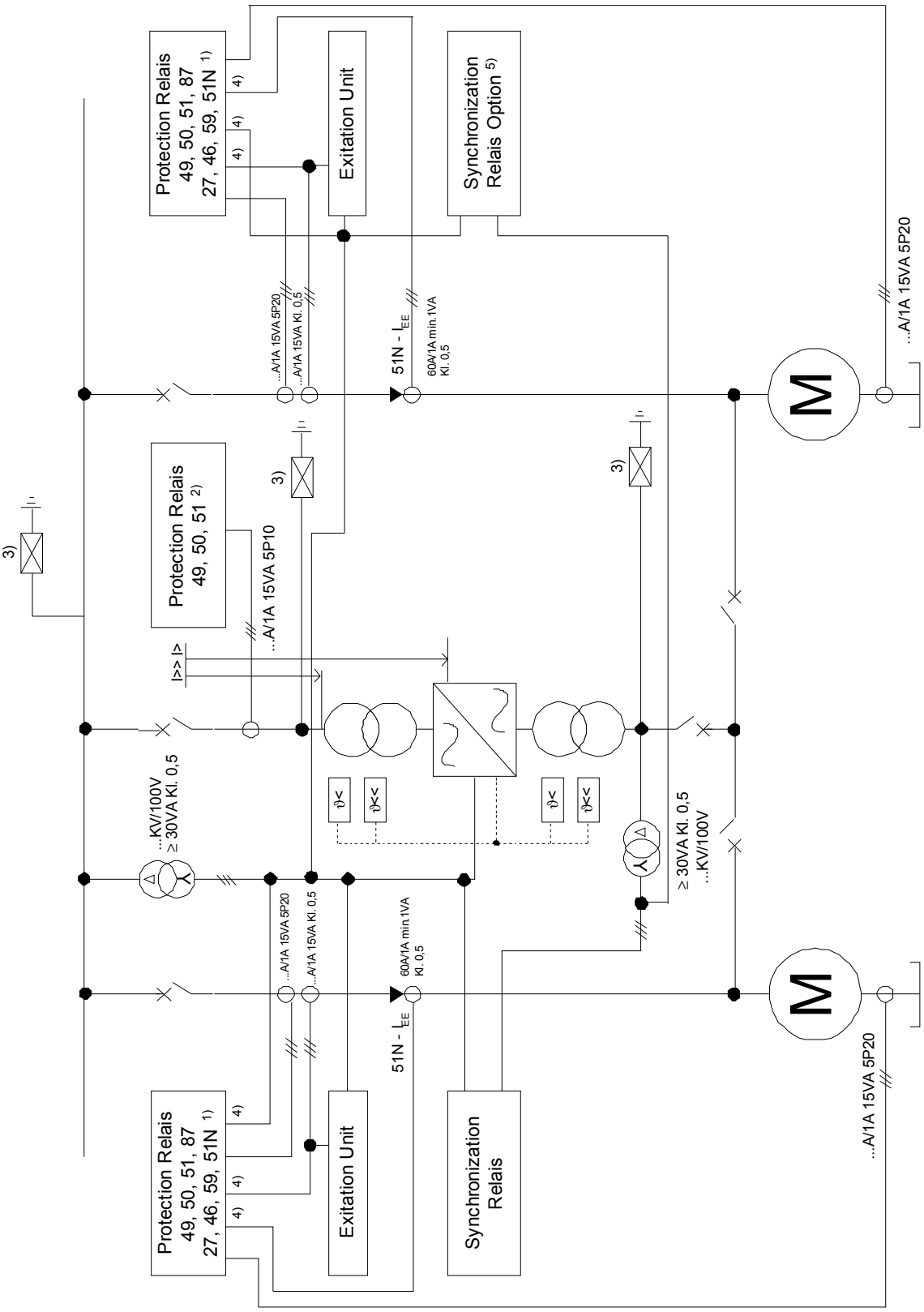
Single Line



Excitation unit and starting aids for fixed speed synchronous motors

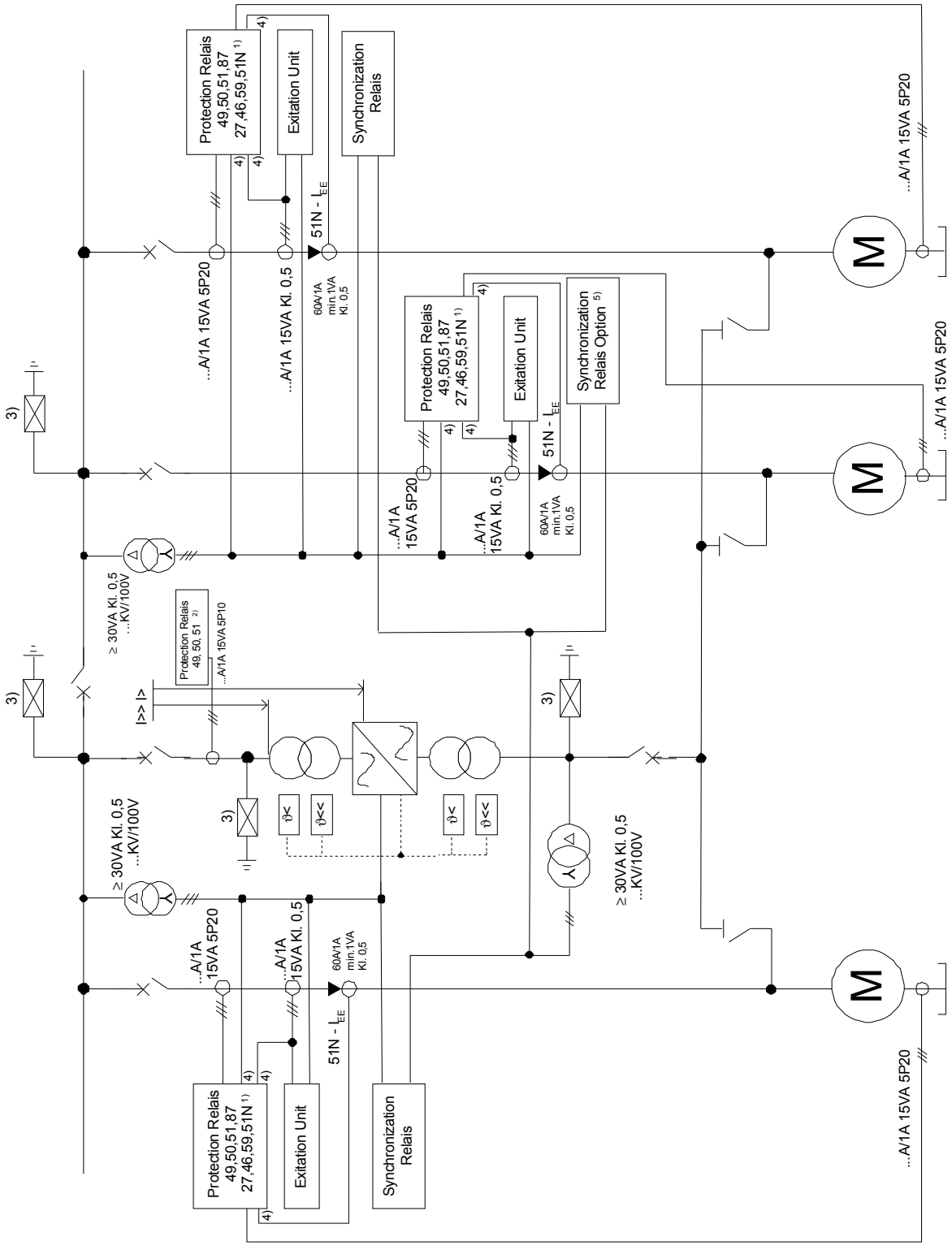
- **Multiple motor ramp-up – Single Lines**

Single line, examples for 2 motors



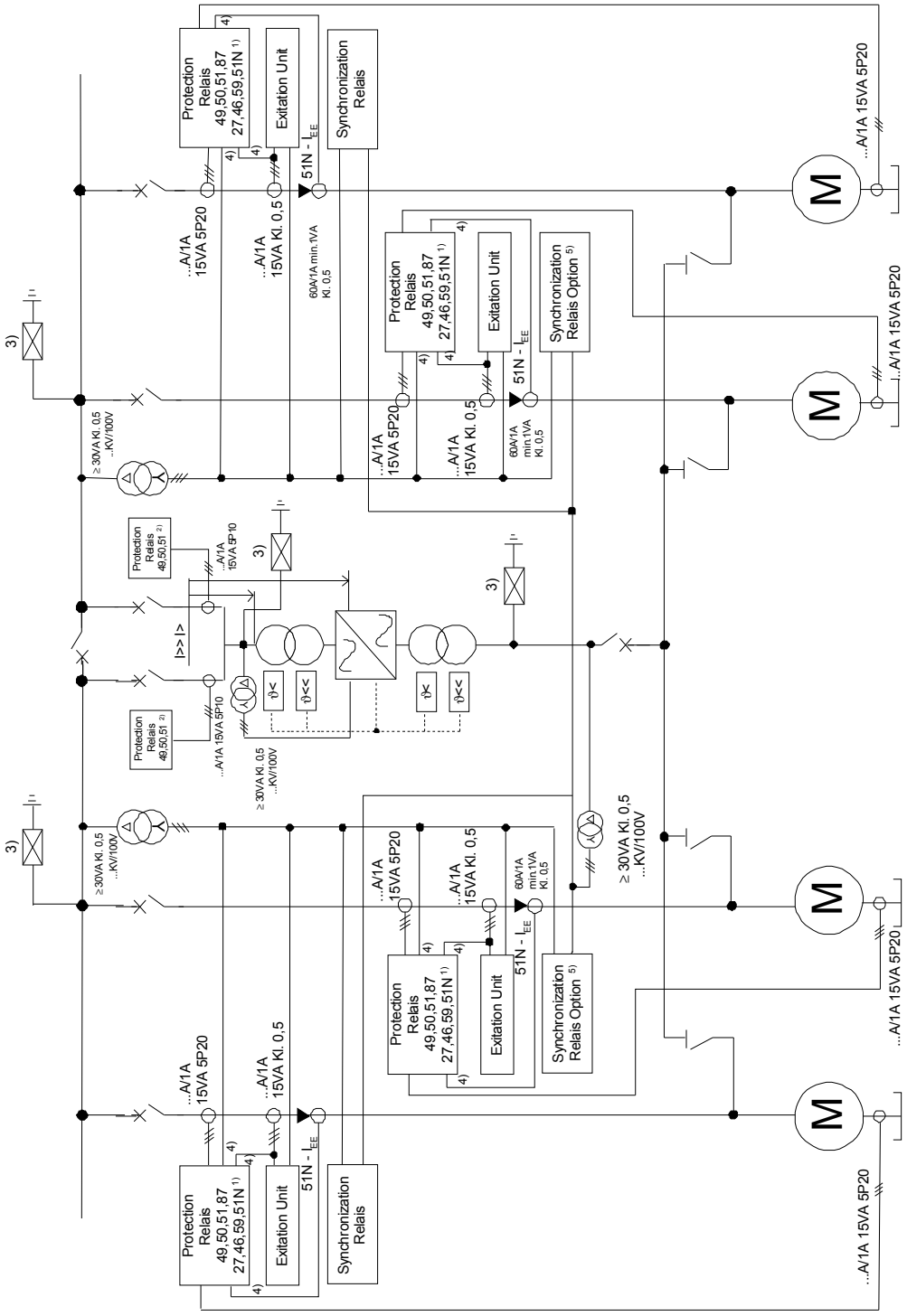
Excitation unit and starting aids for fixed speed synchronous motors

Single line, examples for 3 motors



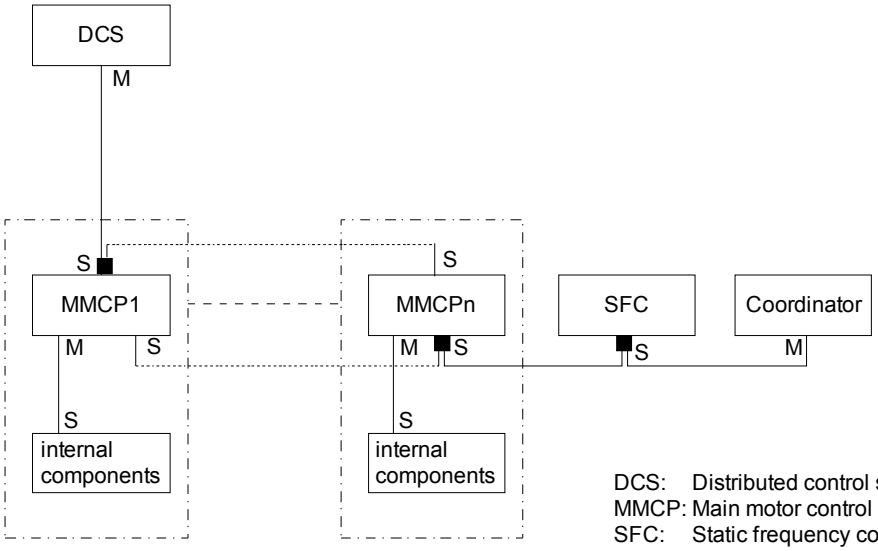
Excitation unit and starting aids for fixed speed synchronous motors

Single line, examples for 4 motors



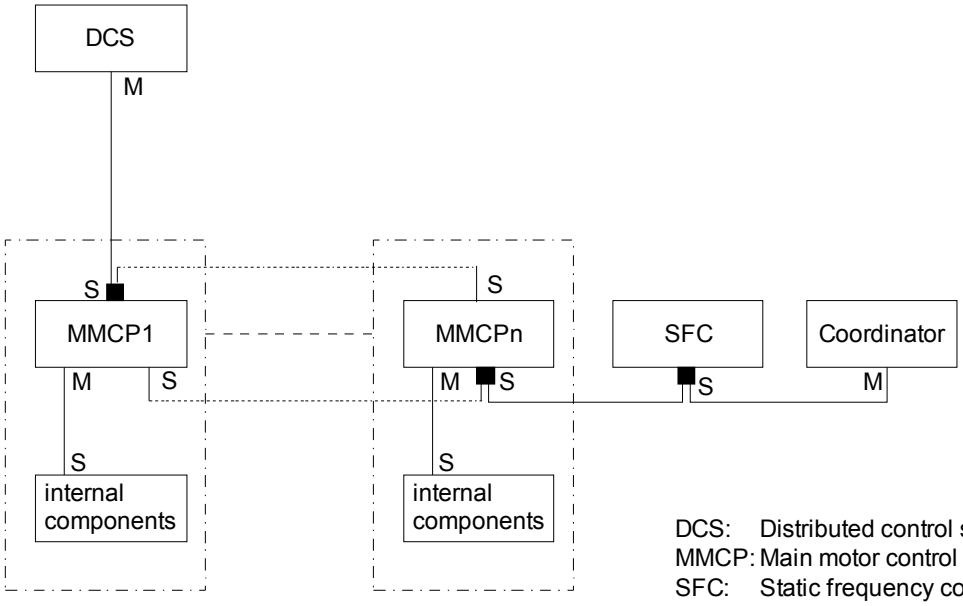
Communication concept

Multiple motor operation



DCS: Distributed control system
MMCP: Main motor control panel
SFC: Static frequency converter
M: Master of PROFIBUS DP connection
S: Slave of PROFIBUS DP connection

Multiple motor operation



DCS: Distributed control system
MMCP: Main motor control panel
SFC: Static frequency converter
M: Master of PROFIBUS DP connection
S: Slave of PROFIBUS DP connection

- **System description for assisted ramp-up**

The system configuration shown is a proposed solution for a system integration comprising switchgear, motor, converter and transformers. This engineering standard shows the essential components and their functions. The engineering standard should form the basis for solutions to a given drive task.

System description to follow

- **Ordering data**

- **Ordering data, basic units**

MLFB structure:

Excitation unit for synchronous motors on a fixed supply network	6R?	N	NNN	-	N	AA	N	-	N	A
Implementation										
DC excitation		1								
AC excitation		2								
Excitation current/A			NNN							
Ramp-up variants										
Asynchronous ramp-up					1	AA				
- DOL							1			
- 3-switch method							2			
- 3-switch method as per Korndörfer							3			
- 4-switch method							4			
Synchronous ramp-up – excitation for one motor					2	AA				
Synchronous ramp-up – coordinator					2	BB				
Assisted ramp-up					3	AA				
- Pony motor DOL without synchronization							1			
- Pony motor DOL with synchronization							2			
- Pony motor at the converter with synchronization							3			

- **Options**

Option	Identification symbol	Comments
Degree of protection IP54		
Cable entry from above		
Control cabinet heater		
Synchronous motor standstill heater		
Incoming DC supply for the PLC		
Leakage water detection		
Loss of synchronism protection – superexcitation		
Diode monitoring		
Reverse power protection		
Digital motor protection		
Digital transformer protection		
Emergency off with open-circuit principle instead of closed-circuit principle		
Modified start-up method – asynchronous ramp-up		3-switch method 3-switch method as per Korndörfer 4-switch method
Control cabinet for starting several motors at the starting converter		2 motors 3 motors 4 motors
Assisted ramp-up		Without synchronization With synchronization, without converter With synchronization, with converter
Remote display of two measured values		Specify required measured values when ordering This option can be ordered in multiples
Additional display instruments		Specify required measured value when ordering This option can be ordered in multiples
Processing additional analog values		On request, clarification required
Oil supply		
Extended signal exchange to the DCS		On request, clarification required
Communication with external control/DCS - Protocol: Profibus DP - Protocol: others		On request, clarification required
Hardware documentation in EU languages		Specify language. The customer is requested to collaborate in the translation in their own interests
Customized display language on the OP		Specify language. The customer is requested to collaborate in the translation in their own interests
Hardware documentation on data media		
Multiple documentation implementation		On request, indicate the quantity of documentation
Scala of excitation current meter according to motor data		Specify rated excitation current in order
Other supply voltage than 400V		Specify line voltage in order

- **Options ISO 9001 certificate**

IQNet

THE INTERNATIONAL CERTIFICATION NETWORK

CERTIFICATE

IQNet and **DQS** Deutsche Gesellschaft zur Zertifizierung von Managementsystemen mbH hereby certify that the organization

Siemens Aktiengesellschaft
Automation and Drives
Kombinationstechnik A&D SE

Würzburger Straße 121, D-90766 Fürth
Clemens-Winkler-Straße 3, D-09116 Chemnitz
Siemensallee 84, D-76187 Karlsruhe
Melscher Straße 7, D-04299 Leipzig
Frauenauracher Straße 80, D-91056 Erlangen

for the scope

Development, production and sales of electronic boards, units and systems for automation and drives

has implemented and maintains a

Quality Management System.

An audit, documented in a report, has verified that this quality management system fulfills the requirements of the following standard:

ISO 9001

This certificate is valid until 2002-11-14

Frankfurt am Main, Berlin 1999-11-15

Registration Number: DE-1108-02

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- **Appendix**

All statements made in the course of this description must be regarded as purely informational. Siemens reserves the right, at any time, to adapt the functionality or the described implementation to any new conditions that may pertain. No liability can be accepted for the accuracy of any statements contained herein.

Author:
Hardware configuration

Gerhard Schwab, A&D SE S3 S

Software configuration

Frank Muckenhuber, A&D SE S3 S

Product responsibility:
A&D LD

Contact person:
A&D LD M PM

Mr	Hölzel
Tel	+49-911-433 9581
Fax	xxx
e-mail	Helmut.Hoelzel@siemens.com