ABB wind turbine converters

System description and start-up guide
ACS800-67LC wind turbine converters

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List of related manuals

Standard manuals	Code (English)
ACS800-67LC wind turbine converters hardware manual	3AUA0000058400
ACS800-67LC wind turbine converters system description and start-up guide	3AUA0000059432
ACS800 grid-side control program firmware manual	3AUA0000075077
ACS800-67(LC) doubly-fed induction generator control program firmware manual	3AUA0000071689

Option manuals	
ICU800-67LC incoming units (+C108/+C109) hardware manual	3AUA0000071553
ABRU-0x DC choppers (+D150) and resistors (+D151) for ACS800-67LC/-77LC/-87LC wind turbine converters hardware manual	3AUA0000076494
Manuals for fieldbus adapters, etc.	

You can find manuals and other product documents in PDF format on the Internet. See section *Document library on the Internet* on the inside of the back cover. For manuals not available in the Document library, contact your local ABB representative.

System description and start-up guide

ACS800-67LC wind turbine converters

3AUA0000059432 Rev B
EN
EFFECTIVE: 2012-04-27

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4. Practical examples, questions and answers

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About this manual

What this chapter contains

This chapter describes the intended audience, purpose and contents of the manual. The chapter also describes the contents of other related manuals briefly, and contains information about contacting ABB.

Safety instructions

ACS800-67LC wind turbine converters hardware manual [3AUA0000058400 (English)] contains the general safety instructions that must be followed during installation, start-up, maintenance and use of the converter. For power cabinet safety instructions, see *ICU800-67LC incoming units (+C108/+C109) hardware manual* [3AUA0000071553 (English)].

Target audience

This manual is intended for people who conduct start-ups and operate with the converter. Read the manual before working on the converter. You are expected to know the fundamentals of electricity, wiring, electrical components and electrical schematic symbols.

Purpose of the manual

This manual describes the operation of the whole wind turbine converter arrangement as one system. The manual is also a start-up guide with detailed examples on how to set the program parameters to achieve the optimal system operation.

The detailed information on the converter is divided into hardware, firmware and option manuals. Subjects covered in each manual are listed in this chapter.

Applicability

This manual describes the standard ACS800-67LC wind turbine converter but it can be applied to customized units as well.

The control programs referred to in this manual are
- grid-side control program IWXR73xx
- doubly-fed induction generator control program AJXC23xx.

Contents of this manual

The chapters of this manual are briefly described below.

About this manual introduces this manual.

System description describes the ACS800-67LC wind turbine converter, its optional functions and wind turbine and converter control briefly. The chapter includes main circuit and system block diagrams.

Start-up gives instructions on how to start-up the ACS800-67LC wind turbine converter.

Practical examples, questions and answers contains examples on how to determine optimum parameter settings to the converter.

Tracing the source of warnings, limits and faults describes most typical warnings, limits and faults of the converter.

Communication details clarifies transmitted and received signals and parameters between the wind turbine controller and the converter.

Contents of other related manuals

The manuals delivered with the converter are listed on the inside of the front cover of this manual. The table below lists the main subjects in each manual.

When delivered	Manual / Contents
In all deliveries	***ACS800-67LC wind turbine converters system description and start-up guide*** **[3AUA0000059432 (English)]**
	See section *Contents of this manual* on page *10*.
In all deliveries	***ACS800-67LC wind turbine converters hardware manual*** **[3AUA0000058400 (English)]**
	This manual covers the following subjects about the converter: • safety • operation basics • hardware description • type code description • mechanical installation • planning the electrical installation • electrical installation • installation checklist • maintenance • description, instructions and technical data of the internal cooling system • technical data • dimension drawings.
In all deliveries	***Grid-side control program for ACS800 wind turbine converters firmware manual*** **[3AUA0000075077 (English)]**
	This manual describes the program controlling the grid-side converter. The following subjects apply to the grid-side converter of the ACS800-67LC as such: • signals and parameters • fault tracing.
In all deliveries	***ACS800-67(LC) doubly-fed induction generator control program firmware manual*** **[3AUA0000071689 (English)]**
	This manual describes the program controlling the rotor-side converter. The following subjects apply to the rotor-side converter of the ACS800-67LC as such: • signals and parameters • fault tracing.
With the option	***Option manuals***
	The option manuals describe the options.

DriveWindow

DriveWindow 2 user's manual [3BFE64560981 (English)] describes the use of the DriveWindow PC tool.

Further information

Address any inquiries about the product to your local ABB representative, quoting the type code and serial number of the unit. If the local ABB representative can not be contacted, address inquiries to nearest country that has support for wind turbine converters. See detailed contact information from the back cover of this manual.

In case of fault situations, ensure that the information stated below is available to get fast problem solving assistance:

- fault logger data
- data logger files (data logger 1 and data logger 2) from grid-side and rotor-side converter control programs
- parameter files from the grid-side and rotor-side converter control programs.

In DriveWindow,

- save the parameters with **File** / **Parameters** / **Save as** command to a .dwp file (for instructions, see page 110)
- copy the fault data from the **Fault logger** view and paste it to a .txt file
- copy the graphs from the **Data logger** view.

Terms and abbreviations

See also *ACS800-67LC wind turbine converters hardware manual* [3AUA0000058400 (English)].

Abbreviation	Explanation
DFIG	Doubly-fed induction generator
DTC	Direct Torque Control
MCB	Main circuit breaker
PLC	Programmable logic controller
PWM	Pulse width modulation
RUSB	USB-DDCS adapter
WTC	Wind turbine controller

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System description

What this chapter contains

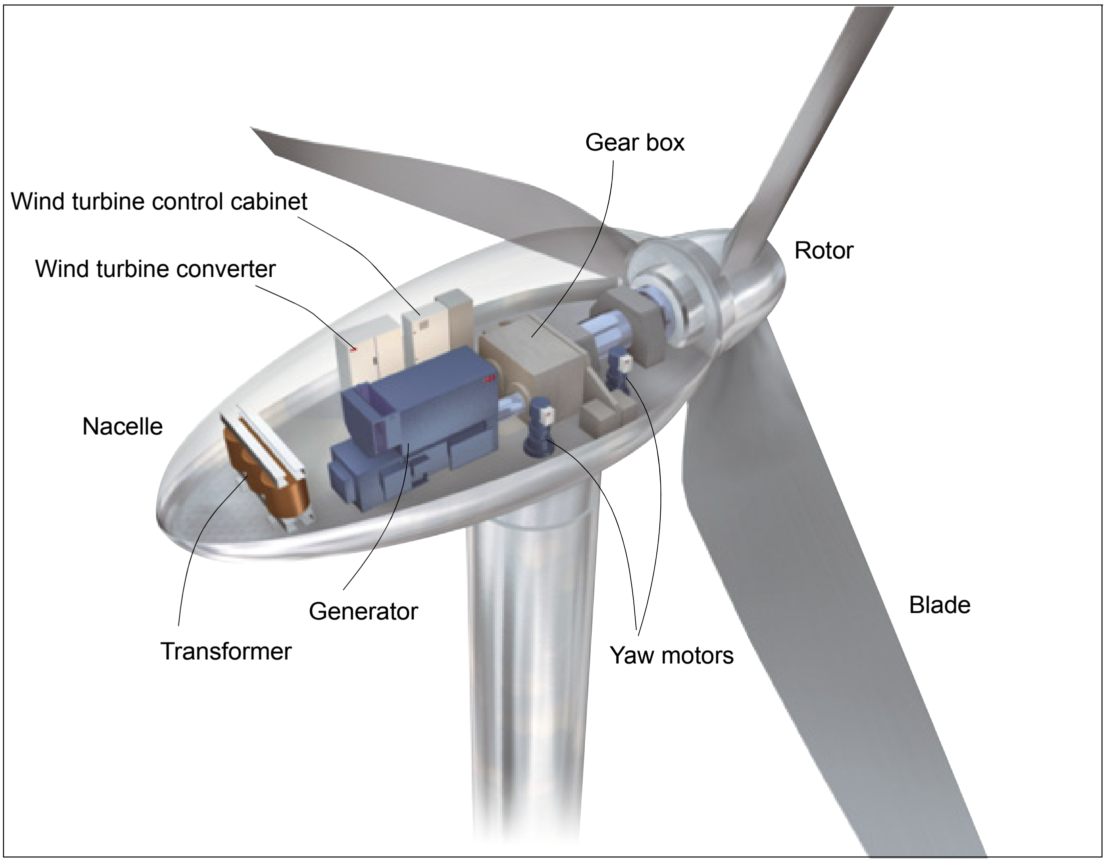
This chapter describes the main components of a wind turbine and describes the functionality of ACS800-67LC wind turbine converter as a part of a complete wind turbine system.

General

Variable-speed wind turbine concepts can be divided in two main categories, wind turbine systems equipped with a doubly-fed asynchronous generators or wind turbine systems equipped with an induction generators like squirrel-cage-, synchronous- or permanent magnet synchronous generator. Difference between these concepts is that in doubly-fed systems one-third of the rated generator power is fed through the wind turbine converter to the 3-phase power supply network while in systems equipped with eg, permanent magnet synchronous generators whole power is fed through the wind turbine converter to the power supply network.

In wind power applications the doubly-fed asynchronous generator rotor is accelerated by the wind and the mechanical speed is controlled by the pitch of the blades to stay within the operating speed range until the wind turbine converter is started. In order to stop the wind turbine converter the breaker(s) is/are opened and the rotor is braked to standstill by pitch control and mechanical brakes. Doubly-fed systems have typically a gear box for coupling the generator shaft to turbine hub, active control of turbine blade pitch for maximizing production and controlling mechanical speed, and variable speed operation depending on the rating of the wind turbine converter relative to turbine rating (eg, ±30% of the generator synchronous speed).

The main components of a wind turbine system are presented in the picture below.



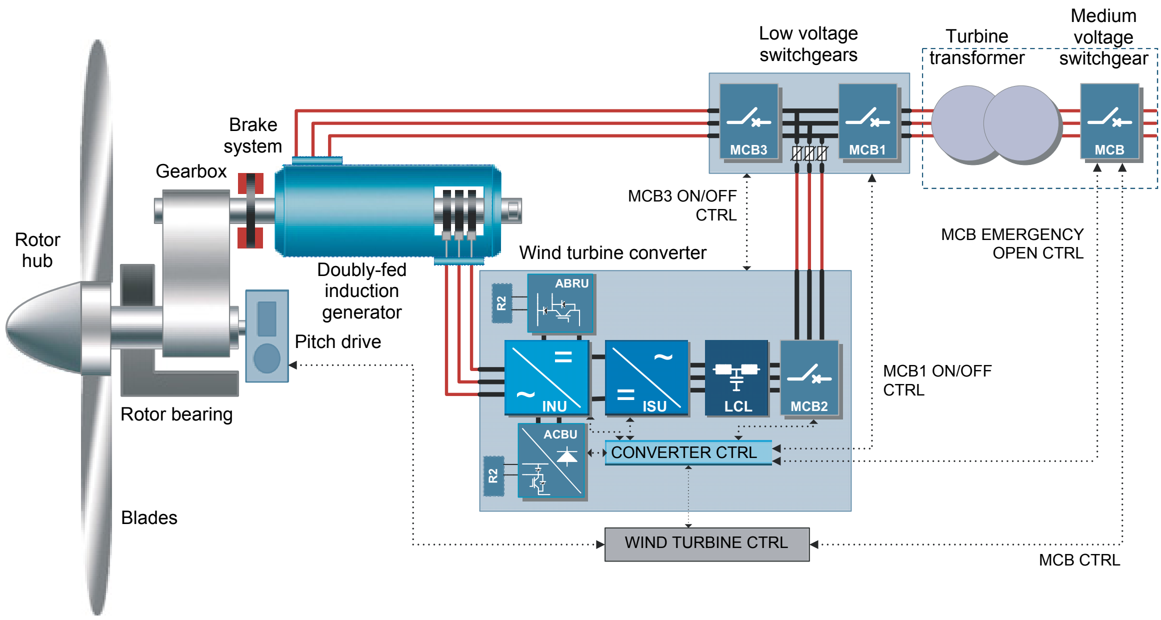
The ACS800-67LC

The ACS800-67LC is liquid-cooled four-quadrant wind turbine converter for wind turbine applications. The converter cabinet is totally enclosed, the degree of protection is IP54 as standard. The converter can be located up in the nacelle or in down tower of the wind turbine.

The ACS800-67LC allows independent control of real and reactive flow in either direction (grid to rotor), or confined to unidirectional (rotor to grid) real power flow. In doubly-fed systems the stator circuit of the doubly-fed induction generator (DFIG) is connected via stator circuit breaker to the 3-phase power supply network while the rotor circuit is connected to a wind turbine converter via slip rings.

When the rotor is accelerated by the wind and the speed is controlled by the pitch of the blades the converter can be controlled either in torque control mode or in active power control mode. If rotor mechanical speed is within acceptable area converter can be started. When the grid-side converter (ISU) has charged the intermediate DC link properly (**MCB1 and MCB2 closed**) and rotor-side converter (INU) has magnetized the generator rotor properly (correct voltage magnitude and phase sequence between the stator and grid) stator circuit breaker/contactor can be closed (**MCB3**) and converter is ready to operate and deliver power to the 3-phase power supply network.

In order to stop the converter the breakers (**MCB2 and MCB3**) are opened and the rotor is braked to standstill by pitch control and mechanical brakes. Principle of the doubly-fed induction generator with ACS800-67LC converter can be seen in diagram below.



The grid-side converter is an IGBT based module equipped with AC (optional) and DC fuses, line filter (LCL) that suppresses the line harmonics of voltage and current. The grid-side converter is controlled by RDCU-12 control unit with grid-side control program.

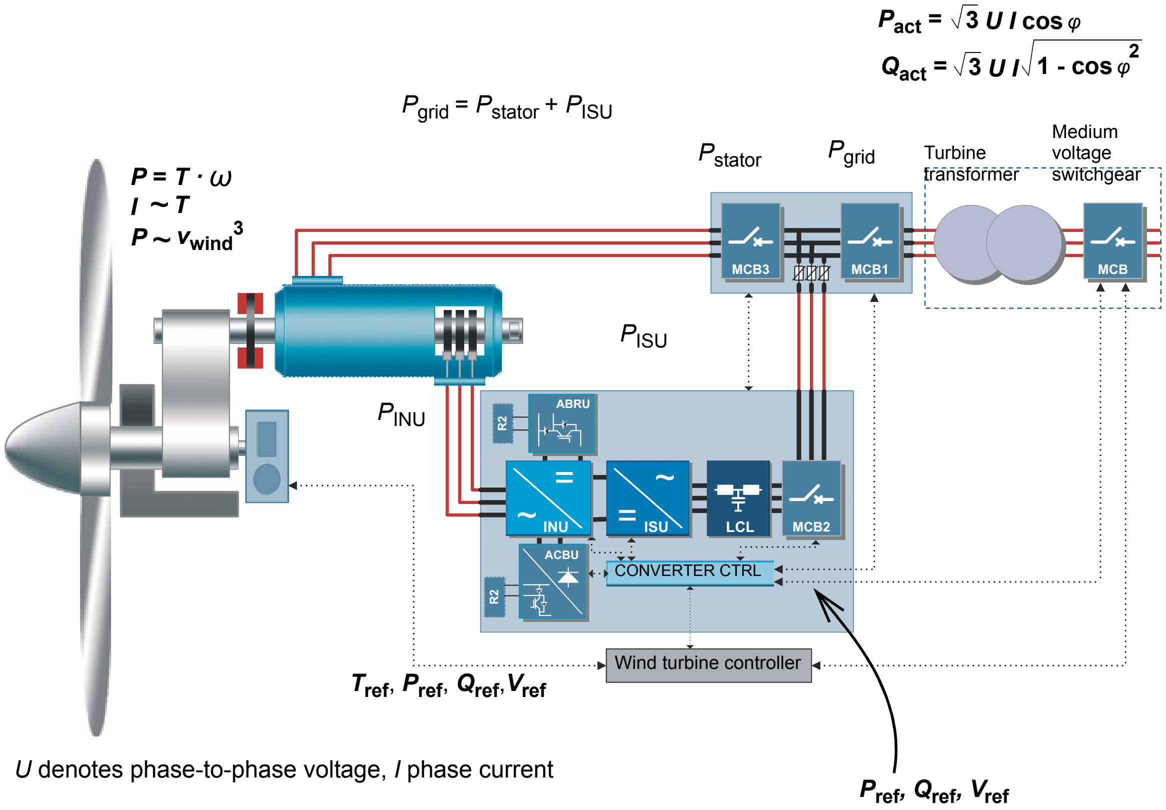
The rotor-side converter consists of IGBT based inverter modules and is controlled by NDCU-33CX control unit with doubly-fed induction generator control program. The control unit also controls the grid-side converter via a fibre optic link.

Cascade converter system

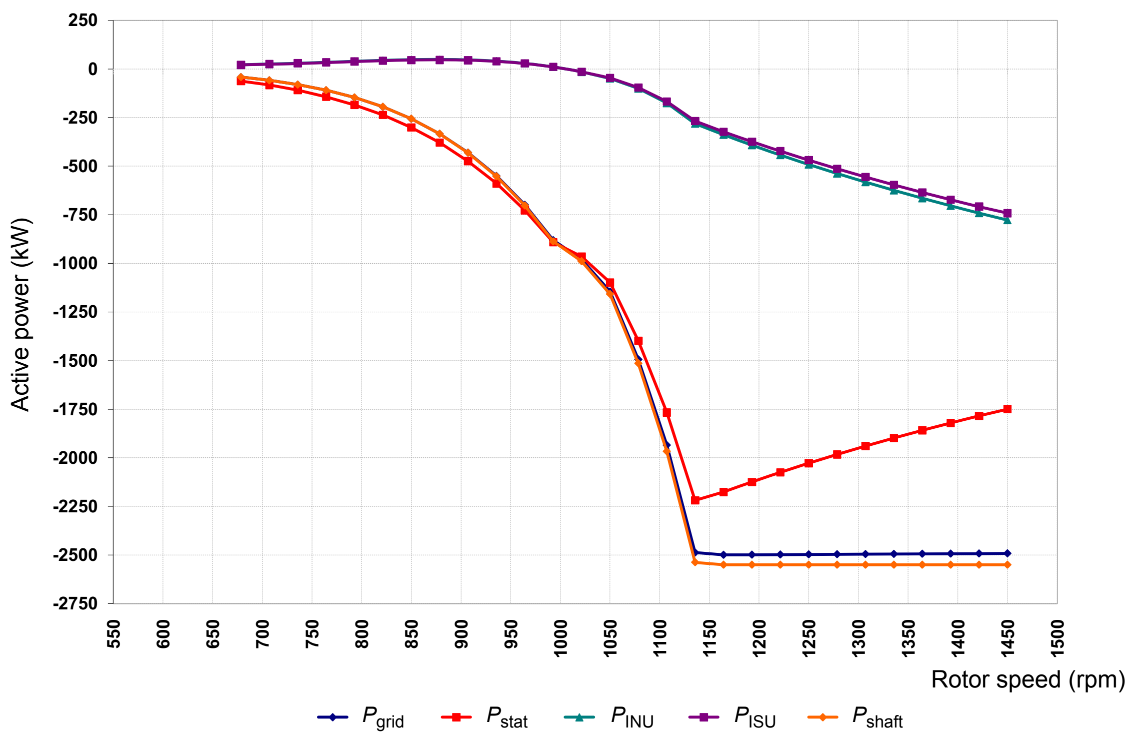
Doubly-fed asynchronous generators are essentially wound rotor induction machines with variable frequency excitation of the rotor circuit, incorporating rotor via frequency converter. Ability to convert mechanical energy into electrical energy (or vice versa) is based on electromagnetic induction. In wind power applications the doubly-fed asynchronous generator is controlled to operate as generator quadrature and thus the generator stator will always generate energy to the 3-phase power supply network.

Wind turbine converter consists of two parts, ie, rotor-side converter and grid-side converter. Between these two converters a DC link capacitor is placed as an energy storage in order to keep the voltage variations (or ripple) in the DC link small. Both converters are controlled independently by internal control firmware based on Direct Torque Control (DTC) technology.

With the rotor-side converter it is possible to control the torque or the speed of the generator and also the power factor at the stator terminals. The grid-side converter keeps the DC link voltage constant. Wind turbine systems equipped with doubly-fed asynchronous generator the stator always generates energy to the 3-phase power supply network, however the direction of the power produced by the rotor depends on the sign of the slip frequency. When the slip frequency is positive (sub-synchronous operation) the energy is taken from the 3-phase power supply network through the grid-side converter and fed by the rotor-side converter to the rotor via slip rings. In sub-synchronous operation part of the power generated by the stator is circulated back to the rotor. These power flows are shown in the picture below.



Below is a power versus speed curve example of a doubly-fed induction generator that has a synchronous speed of 1000 rpm and nominal speed of 1150 rpm.



Control of generator power

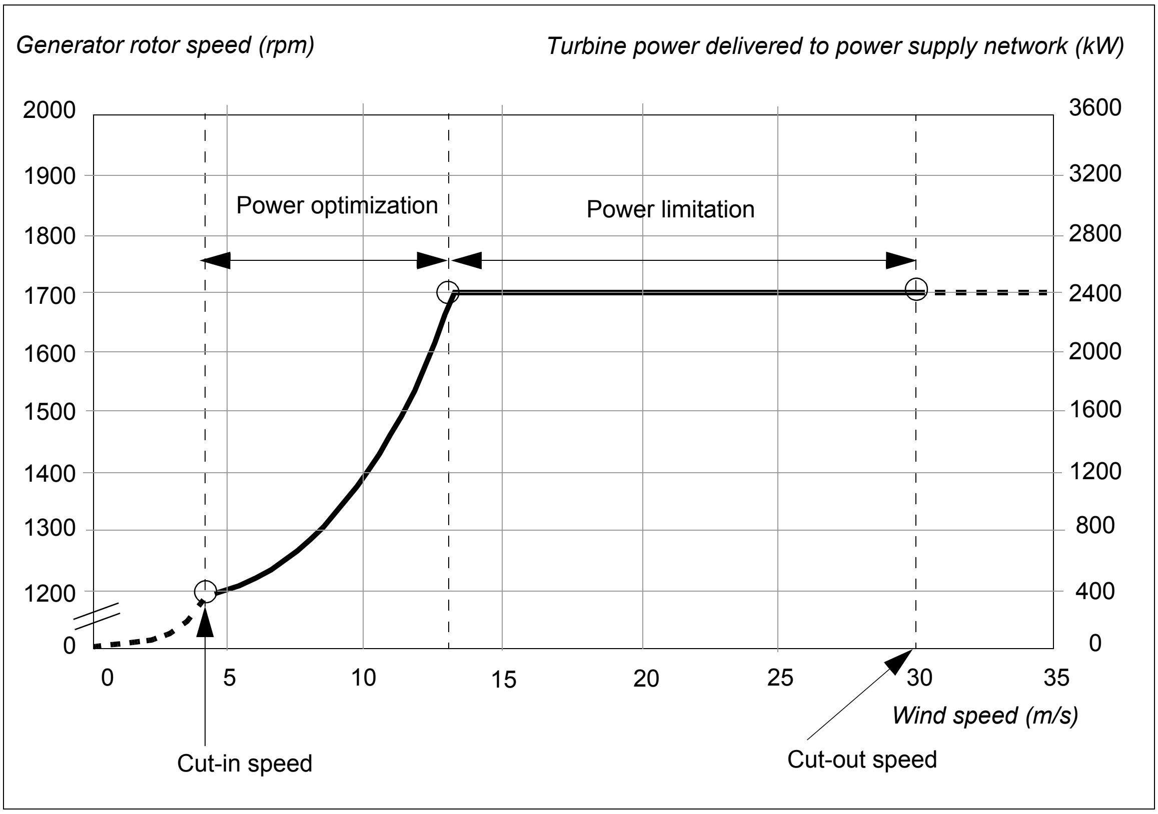
The generator power can be controlled by adjusting torque or speed:

$$P = T \cdot \omega = T \cdot \frac{2\pi \cdot n}{60}$$

where

P	≙ generator power (W)
T	≙ generator torque (N·m)
ω	≙ angular speed of the generator (rad/s)
n	≙ rotor mechanical speed (1/min ≙ rpm).

In normal operation the converter controls the generator torque. However, either torque or active power reference to the converter is supported. The overriding wind turbine controller (WTC) gives a torque reference (or active power reference) to the converter that generates a specific torque on the generator shaft. The overriding wind turbine controller defines the needed torque/power reference as a function of wind speed and turbine characteristics. A typical wind turbine power vs. speed curve is presented below. It illustrates the operational speed range of the turbine between the cut-in and cut-out speeds. Cut-in speed is the minimum wind speed at which power generation is reasonable. Cut-out speed is the maximum operating speed that the wind turbine system can tolerate. In the example below the generator is for 1700 rpm and 2400 kW.



Operational speed range of a typical wind turbine

Wind power increases cubically as wind speed increases:

$$P_w = \rho \cdot \frac{c_p(\lambda, \delta)}{2} \cdot A_r \cdot v_w^3$$

where

P_w ≙ wind power

ρ ≙ air density

c_p ≙ performance coefficient, λ tip speed ratio, δ pitch angle

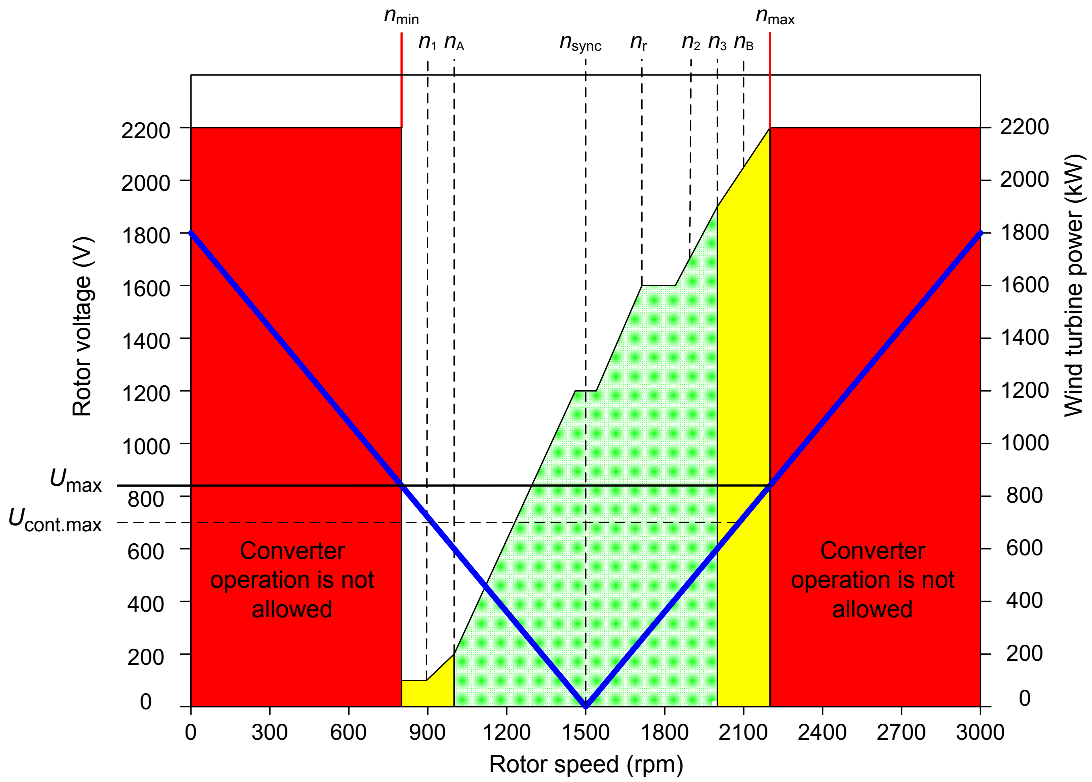
A_r ≙ rotor surface

v_w ≙ wind speed.

There is a minimum wind speed at which power generation is reasonable (cut-in speed) and a maximum speed at which the turbine can be operated safely (cut-out speed). At a certain wind speed, the turbine controller must limit the rotor speed by changing the pitch angle.

Wind turbine system operating speed area

The example below illustrates the generator speed control in different wind speed ranges.



In operating range $n_1 \ldots n_3$ the rotational speed is under normal operating conditions.

Generator rotational speeds:

n_{min} ≙ minimum rotor speed which may never be reached, not even momentarily 1)

n_{max} ≙ maximum rotor speed which may never be exceeded, not even momentarily 1)

n_1 ≙ minimum rotor speed when the converter is tripped due to underspeed (30.10 UNDERSPEED LIMIT level) ie, torque will be controlled to zero and all breaker(s)/contactor(s) are opened 2)

n_2 ≙ rotational rotor speed deviation upwards or downwards with nominal power production within standard tolerance

n_3 ≙ maximum speed when the converter is tripped due to overspeed (30.09 OVERSPEED LIMIT level) ie, torque will be controlled to zero and all breaker(s)/contactor(s) are opened 2)

n_A ≙ cut-in speed equals to the converter minimum operating speed while converter starts and generator stator synchronisation is allowed (20.21 SWITCH ON SPEED and 20.22 SWITCH OFF SPEED levels)

n_B ≙ cut-out speed ie, the speed at which the turbine control system must immediately shut down the wind turbine

n_r ≙ rated speed ie, rotational speed at rated wind speed to generate nominal power to power supply network

n_{sync} ≙ generator synchronisation speed

1) Activation speed ie, the rotational speed at which the turbine safety system must be triggered immediately (wind turbine and pitch level protection)

2) If the speed is below (n_1) or outside (n_3) the speed area, the converter may be damaged due to high rotor voltage during the shutdown procedure. Generator stator synchronisation to power supply network is not allowed in any circumstances and grid disconnection is always required.

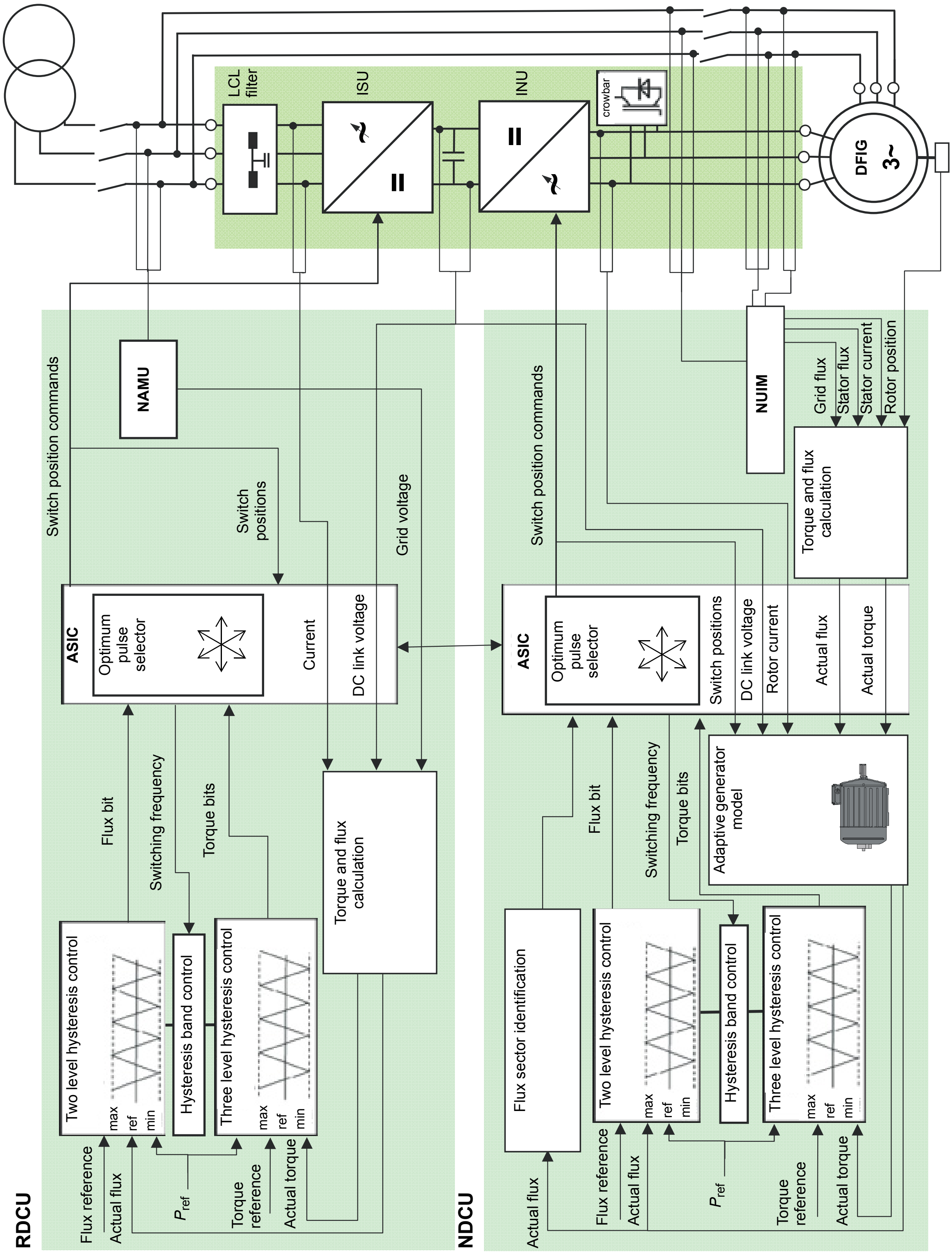
Control of torque and reactive power via rotor-side converter

With DTC technology field orientation is achieved by using advanced generator theory to calculate the accurate generator torque. The performance of DTC controlled wind turbine converter is most effective and benefits are eg, fast torque response, accurate control also at low frequencies, torque repeatability and accuracy of dynamic and static speed operations.

The main difference between DTC and conventional PWM is that the torque is controlled at the same time level as power switches (25 microseconds). There is no separate voltage and frequency controlled PWM modulator. All selections of the switches are based on the electromagnetic state of the generator and torque demand given by turbine control system.

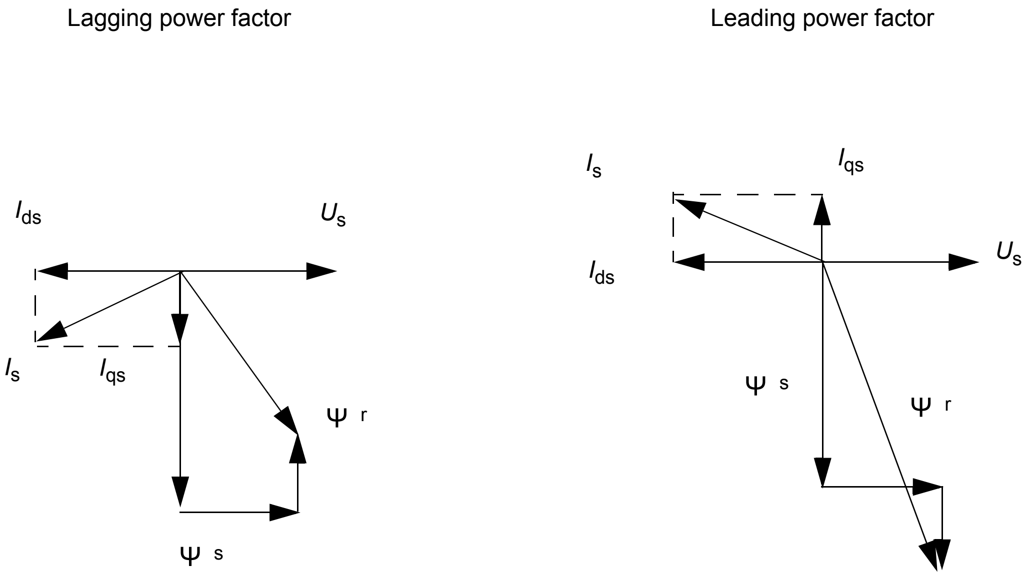
The controlling variables of the DTC are generator magnetizing flux and generator torque. In doubly-fed induction generator systems the voltage in rotor/stator windings forms the current and magnetic flux by changing the direction of the voltage in rotor windings. The direction of the flux can also be changed. By changing the voltage direction in 3-phase generator rotor windings in the correct order the magnetic flux of the generator rotor will follow this flux with a certain slip. There are eight different switching positions in the two-level converter that can affect the flux and torque of the generator. In two positions the voltage is zero, ie, when all the phases are connected to the same DC link, either negative or positive. In remaining six switching positions voltage is created in the generator rotor windings creating magnetic flux. In addition the DTC principle is used to control the power factor at the stator terminals of the doubly-fed induction generator to desired level and to synchronize the stator to the 3-phase power supply network.

The figure below shows the block diagram of the torque and power factor controller of the doubly-fed asynchronous generator fed from the rotor-side.



The basic DTC block selects the inverter switch states so that tangential motion of the flux vector is controlled by the torque error and the radial motion of the flux is controlled by the flux error. The torque reference is supplied by the WTC. The torque feedback is calculated by using stator-side quantities (at grid frequencies) ie, by a cross product of stator flux and stator current.

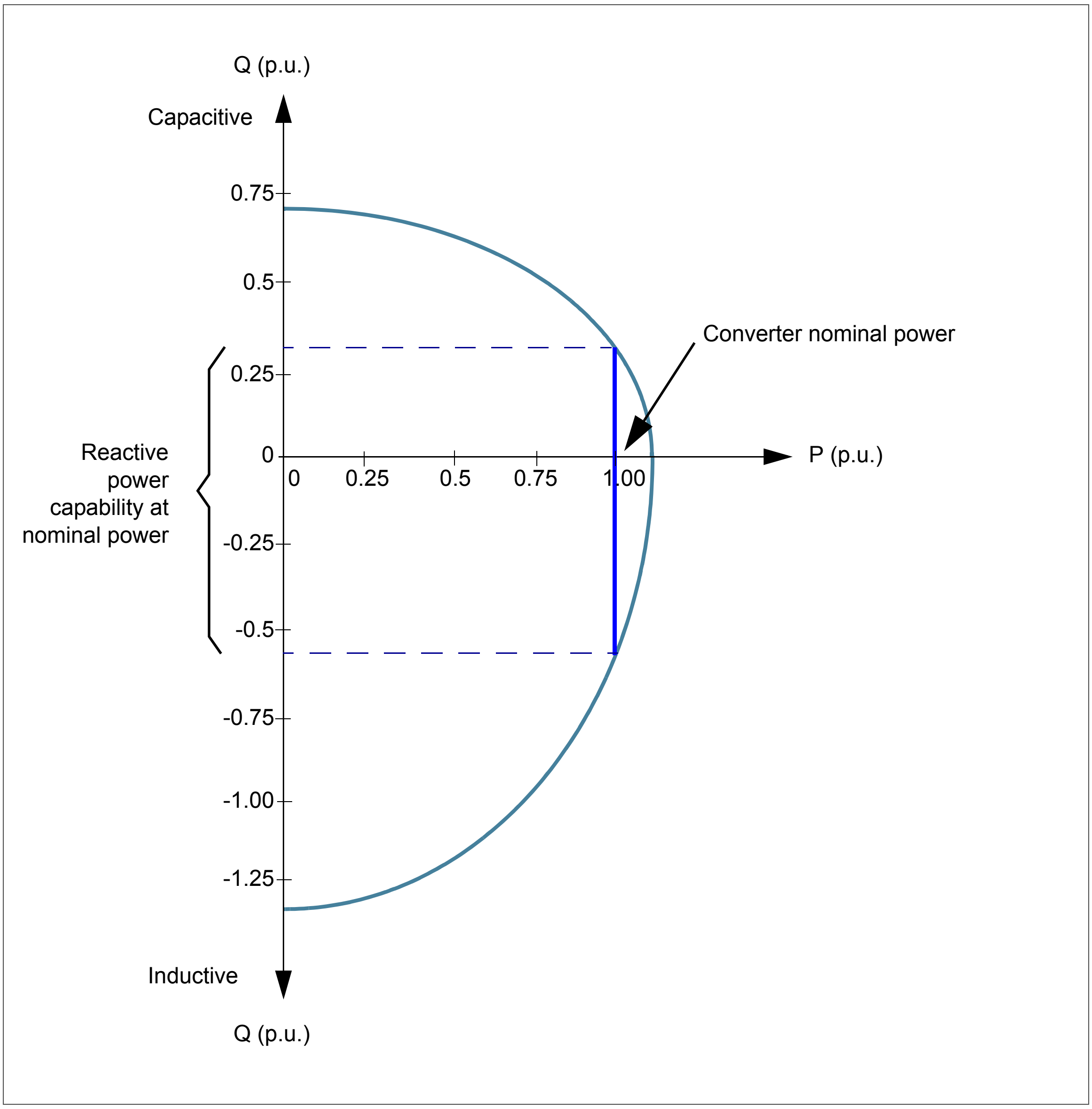
The rotor-side flux reference is chosen to achieve the desired power factor at the stator terminals. The operating flux level of the stator flux is completely dependent on the grid voltage and therefore the rotor flux reference is dependent on actual stator flux. The figure below shows the vector diagram of stator voltage, current and flux and rotor flux at leading and lagging power factors when the stator is regenerating to the power supply network.



Symbol	Description
U_s	stator voltage
Ψ_r	rotor flux
Ψ_s	stator flux
I_s	stator current
I_{ds}	d-axis current of the I_s
I_{qs}	q-axis current of the I_s

Using stator voltage (and therefore the stator flux) as reference axis, torque is proportional to the product of I_{ds} and Ψ_s. The magnitude and sign of I_{qs} determine the type of reactive (lagging or leading) power drawn by the stator.

An example curve of maximum reactive power capability as a function of the active power (power factor about 0.95 capacitive and 0.86 inductive) is shown below. Reactive power capability depends on the characteristics of the generator.

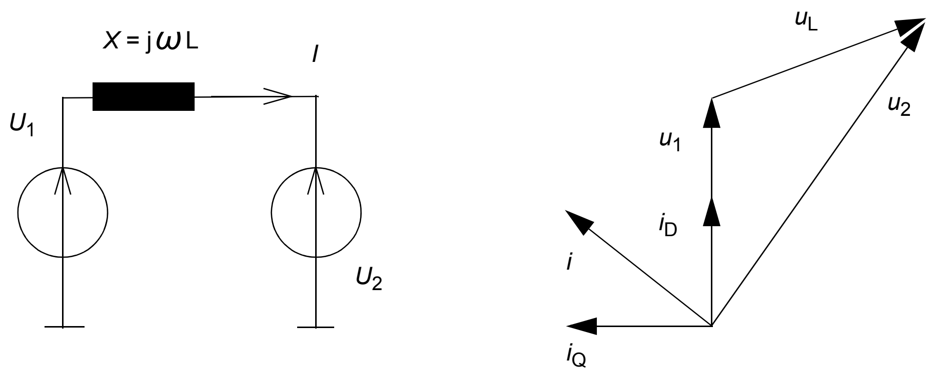


Control of torque and reactive power via grid-side converter

The fundamental theory of grid-side converter can be simplified to be analog to the synchronous generator. One voltage source is the power supply network and the other voltage source is the grid-side converter. The voltages and currents can be presented as vectors. When the reactive power is zero, the current vector is in the same direction with the grid voltage vector. In the figure below the current contains capacitive component, ie, the current is leading the grid-voltage.

The primary function of the grid-side converter is to control the power transfer between the network and the DC link. The control system can be divided into two sections:

- Flux controller and torque controller. The flux controller is controlling the length of the flux vector (flux vector is an integral of the voltage vector) that has influence on the reactive power.
- Torque controller controls the power flow from/to the power supply network (basically the power transfer angle is controlled). The DC voltage controller gives the reference to the torque controller.



Symbol	Description
U_1	grid voltage
U_2	grid-side converter voltage
ω	angular frequency of the grid
X	reactance between U_1 and U_2
P	active power
Q	reactive power
I	grid-side converter current
δ	angle between U_1 and U_2

Power transfer equation between the network and the grid-side converter is following:

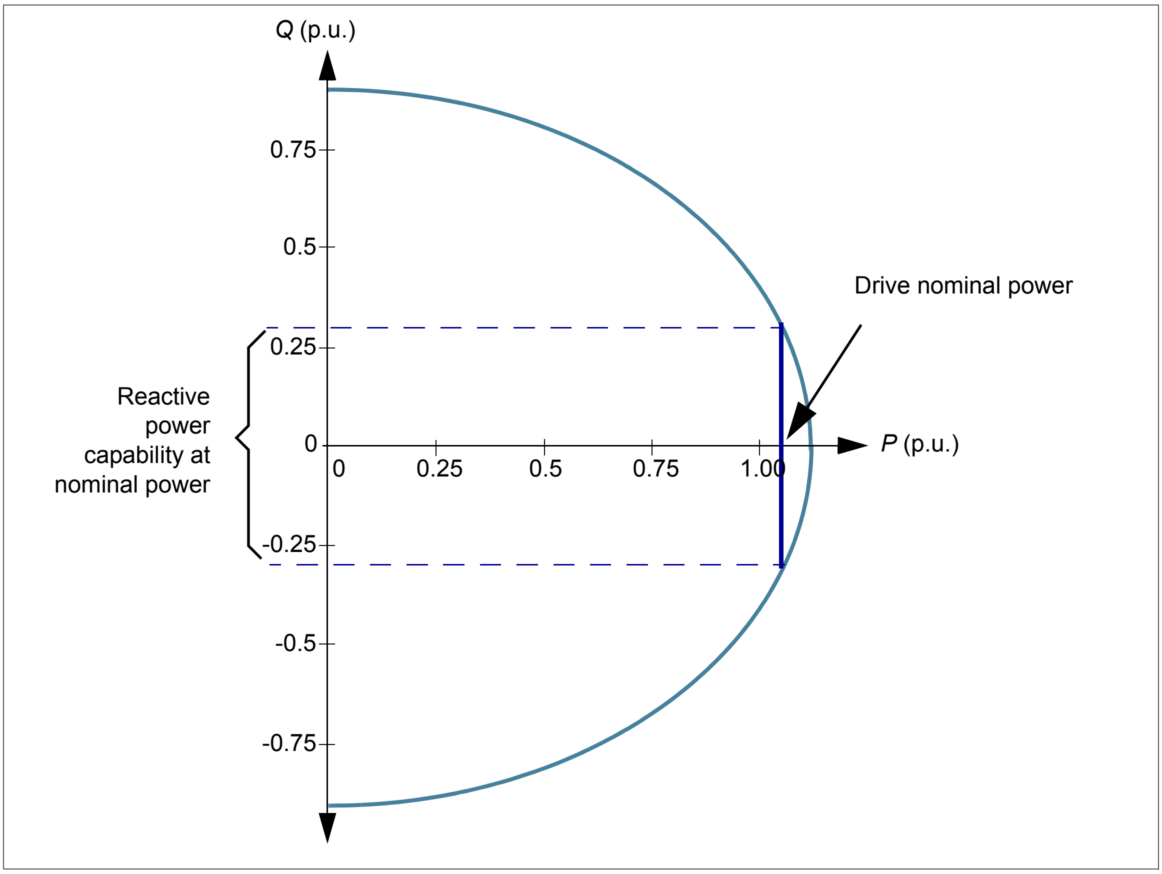
$$P = \frac{U_1 U_2}{X} \sin \delta$$

Reactive power is transferred only if there is an angle difference between the two voltage vectors. Reactive power transfer equation is following:

$$Q = \frac{U_1^2}{X} - \frac{U_1 U_2}{X} \cos\delta$$

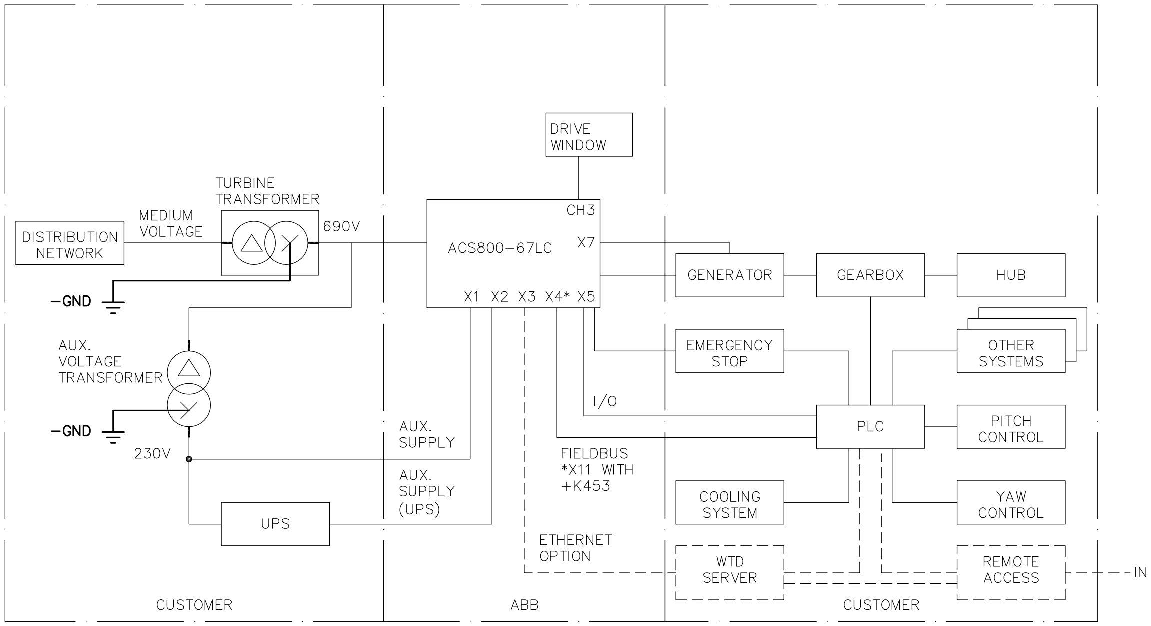
For the desirable magnitude and direction of the power and reactive power flow, the length of the converter voltage vector and its phase angle (with respect to the grid voltage vector) must be controlled. The DC voltage is controlled by keeping the power (energy) balance between the grid and grid-side converter in the DC link constant. The sign of the angle determines the direction of the power flow. The output AC voltage is controlled by setting the length of the flux reference to correspond to the desired output voltage level producing cosfii = 1.0.

The grid-side converter can control reactive power independently of speed and active power. The maximum reactive current capacity is approximately 80% of the active current capacity and depends on the rating of the grid-side converter and on the power supply network voltage. An example curve of reactive power capability as a function of the active power is shown below.



Overview of converter interfaces

An overview of the converter interfaces is shown below.



The WTC controls the converter using its main control word. For more information, refer to section *ABB Drives communication profile* on page *100*.

The start-up procedure of the converter is recommended to be proceeded with the DriveWindow PC tool. For information on using the DriveWindow, see *DriveWindow 2 user's manual* [3BFE64560981 (English)].

With optional Ethernet adapter module (NETA), the user can remotely

- monitor the converter
  - read and adjust converter parameter values
  - read status information and actual values from the converter
  - set up and monitor (numerically or graphically) the data logger and save its content to a file
  - read and clear the contents of the fault log and save it to a file
- control the converter (not recommended remotely)
  - give control commands (Start, Stop, Run enable, etc.) to the converter
  - feed a generator speed or torque reference to the converter
  - reset converter faults.

For more information, see *NETA-01 Ethernet adapter module user's manual* [3AFE64605062 (English)].

Converter control

General

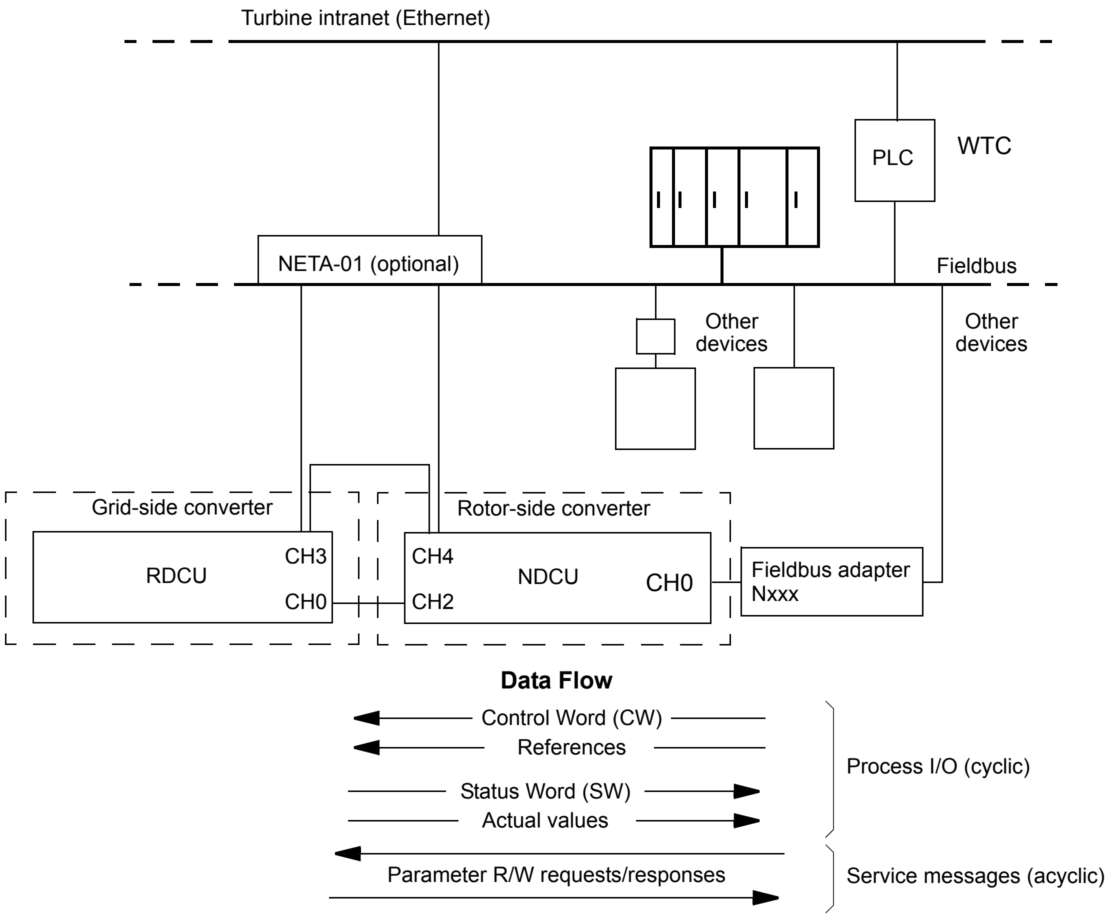
The WTC operates as the overriding controller of the converter. It is connected to the NDCU control unit of the rotor-side converter via fieldbus. The rotor-side converter control program controls the rotor-side power modules according to the references and commands sent by the overriding controller.

The transmitted and received actual signals and parameters are shown in chapter *Communication details*.

Control of ACS800-67LC

The converter can be connected to an external control system – usually a PLC controller – via a fieldbus adapter connected to channel CH0 of the NDCU control unit.

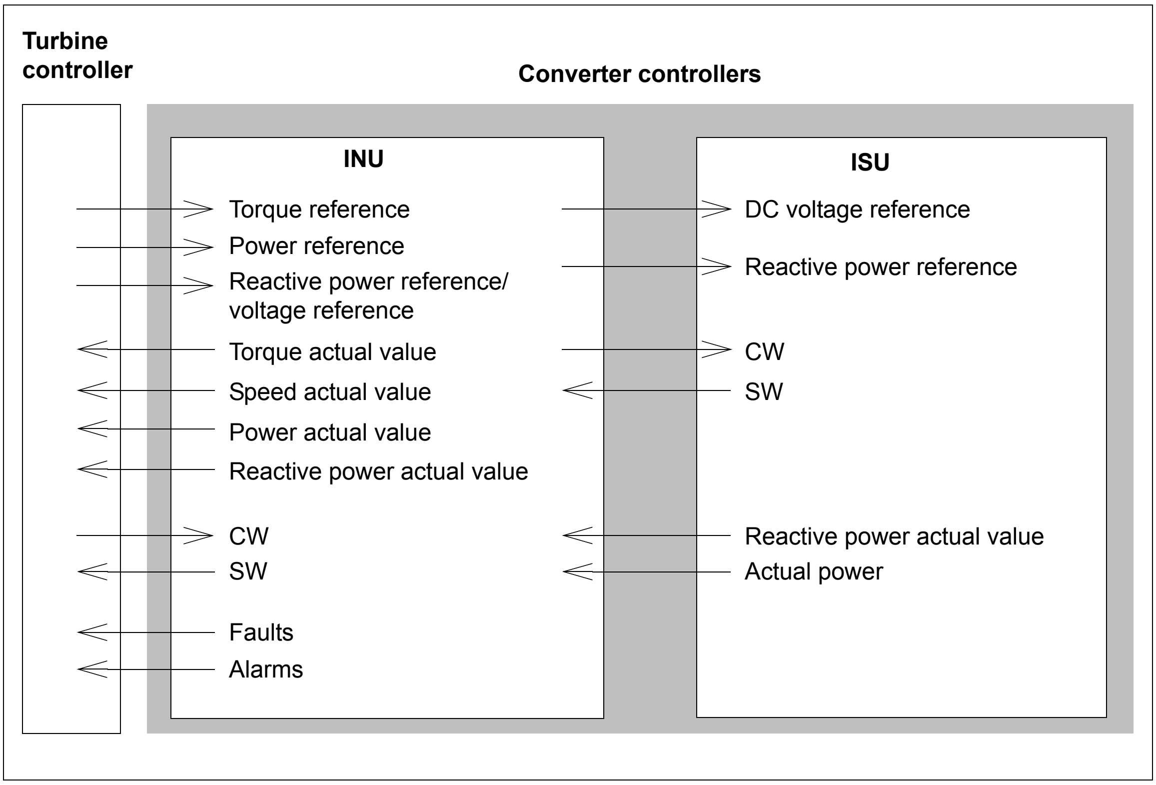
The following diagram shows the PLC interface:



The converter can be set to receive all of its control information through the fieldbus interface, or the control can be distributed between the fieldbus interface and other available sources, eg, digital and analog inputs.

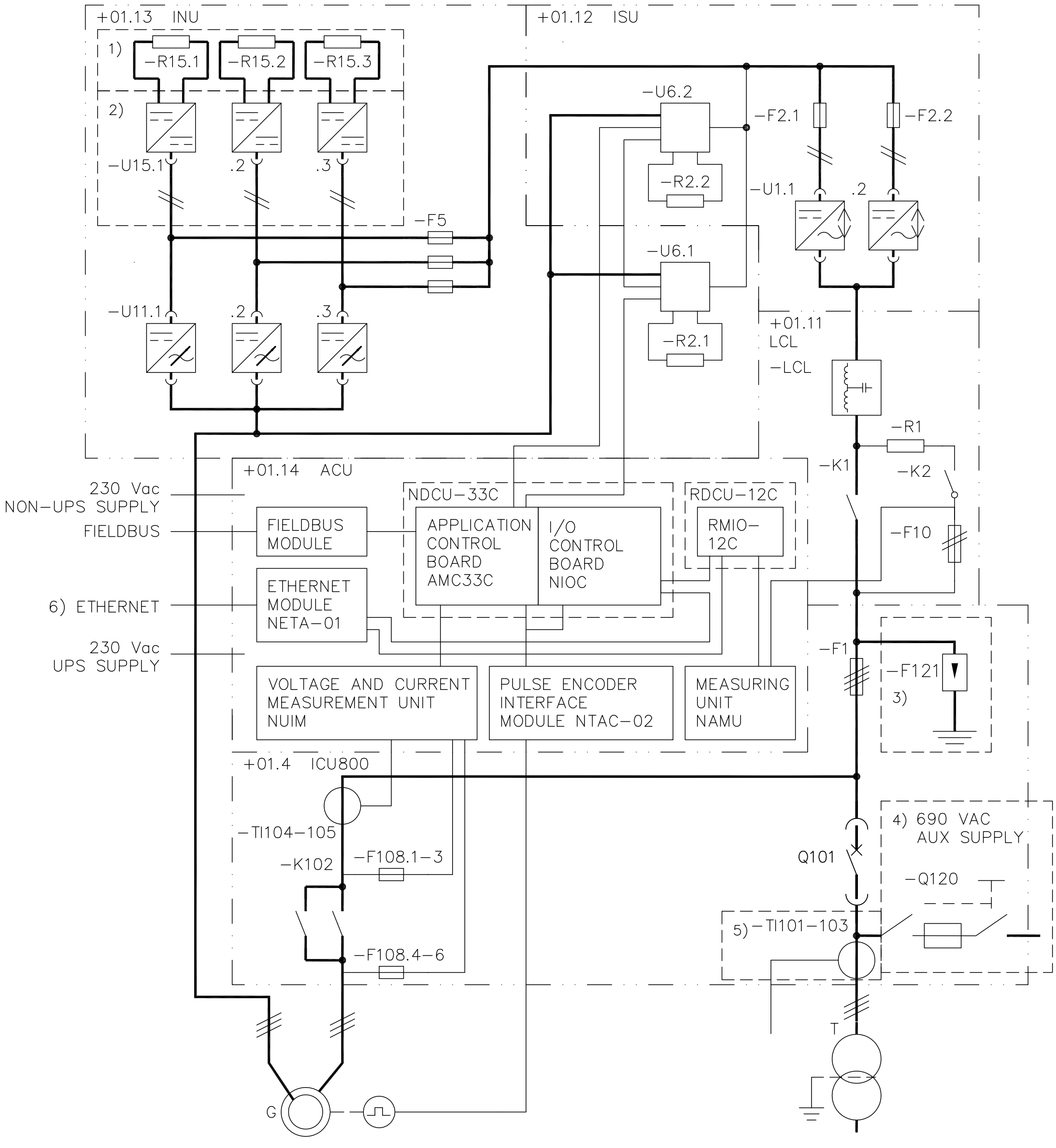
Fieldbus control

Fieldbus control of the grid-side converter is performed via the rotor-side converter NDCU control unit. The principle of reference and actual value chains in the control are shown in the diagram below. For details, see *ACS800-67(LC) doubly-fed induction generator control program firmware manual* [3AUA0000071689 (English)] and chapter *Communication details*.



Single-line diagram of the main circuit with printed circuit boards

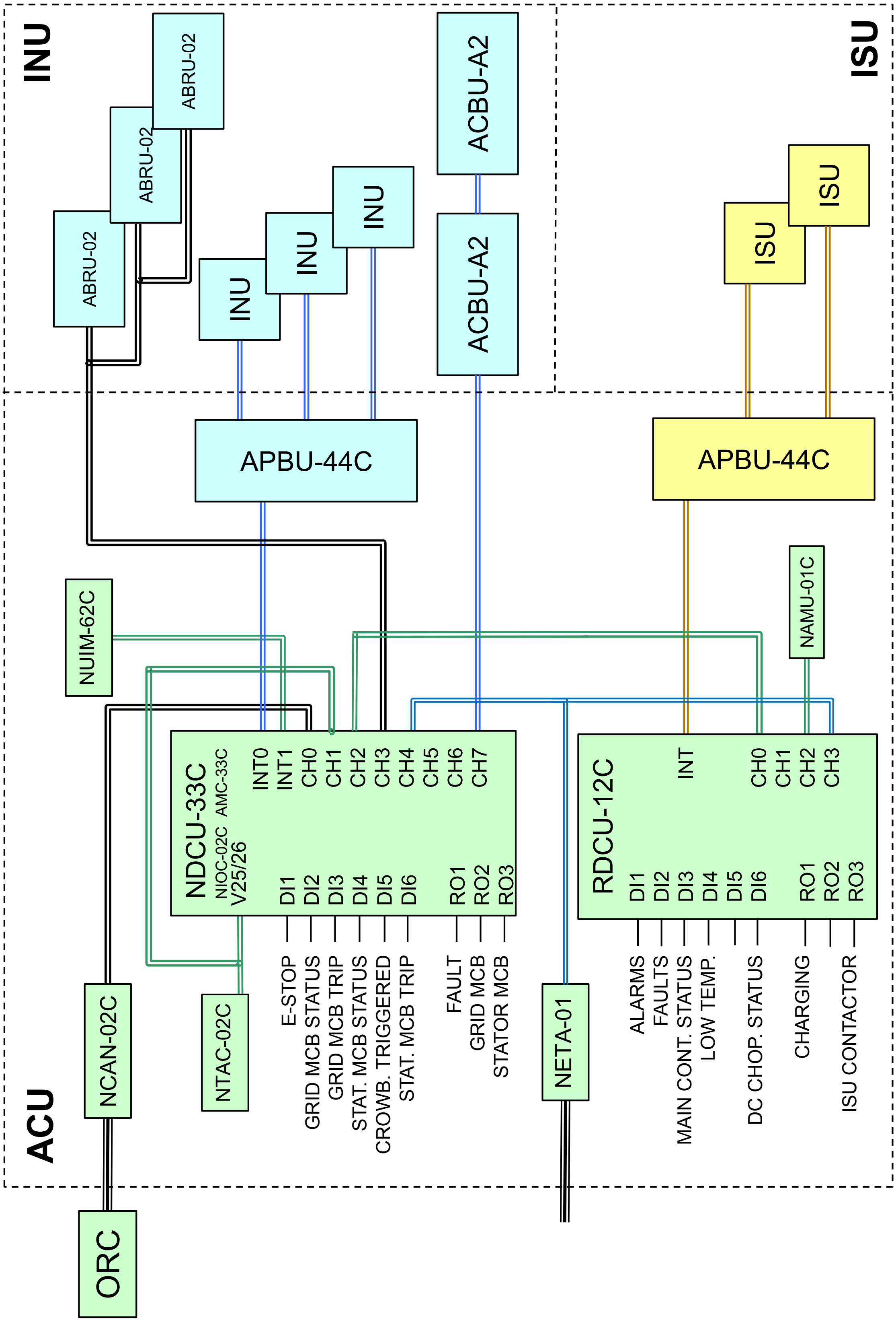
The diagram below shows the interconnections of the main circuit and printed circuit boards.



1) ONLY WITH ZERO VOLTAGE RIDE THROUGH OPTION 1 (+D150)
2) ONLY WITH ZERO VOLTAGE RIDE THROUGH OPTION 2 (+D151)
3) ONLY WITH OVERVOLTAGE PROTECTION FOR THE GRID SUPPLY (+F281)
4) ONLY WITH AUX VOLTAGE SUPPLY 690V (+G396) – (+G399), (+G409)
5) ONLY WITH GRID POWER MEASUREMENT (+G335)
6) ONLY WITH ETHERNET ADAPTER (+K464)

Interconnections between control boards

The diagram below shows the interconnections between control boards. In this diagram the converter contains two parallel-connected grid-side and three rotor-side converter modules.



Cabinet cooling

The ACS800-67LC is liquid-cooled wind turbine converter and the cooling circuit forms a closed-loop cooling system (internal circuit) together with the piping and heat exchangers in the converter cabinet. The coolant is circulated through the converter and cooled by external liquid cooling unit (LCU) equipped with a liquid-to-liquid heat exchanger.

The user must design, build and couple the cooling circuit to the LCU. The user must also balance the cooling capacity of the LCU with the converter losses in order to sustain efficient cooling.

The converter can not be isolated from the main cooling circuit. However, the converter is equipped with drain and bleed valves. For more detailed information on the cooling system, see *ACS800-67LC wind turbine converters hardware manual* [3AUA0000058400 (English)].

Cabinet heating

The ACS800-67LC is equipped with hardware-based heating control logic. The converter does not contain cabinet integrated heaters, therefore the liquid cooling unit (not part of ABB delivery) must be equipped with proper heater capable of heating the liquid and the whole converter since the heating request is activated by the converter. Temperatures in each converter cubicle are monitored separately by using thermostats (klixons) with a fixed set-point temperature (switch-off temperature +15 °C (+59 °F) and switch-on temperature +5 °C (+41 °F) with ± 5 K tolerance). The heating control logic requests starting of the pump/heating from the external cooling unit. The heating request (potential free contact) is wired to pins A2 (NO) and A1 (NC) on terminal X5 at the right-hand side of the converter cabinet.

Note: The converter does not protect in any part of the cooling unit, therefore it must always be protected independently with a proper protection device(s).

The operation of the converter temperature control logic is described below in two different circumstances: cold start and normal start.

Cold start (-30 … +15 °C, -22 … +59 °F)

The auxiliary 120 V AC power is connected to connector X1. At first, the auxiliary power is not switched on and the printed circuit boards are not energized.

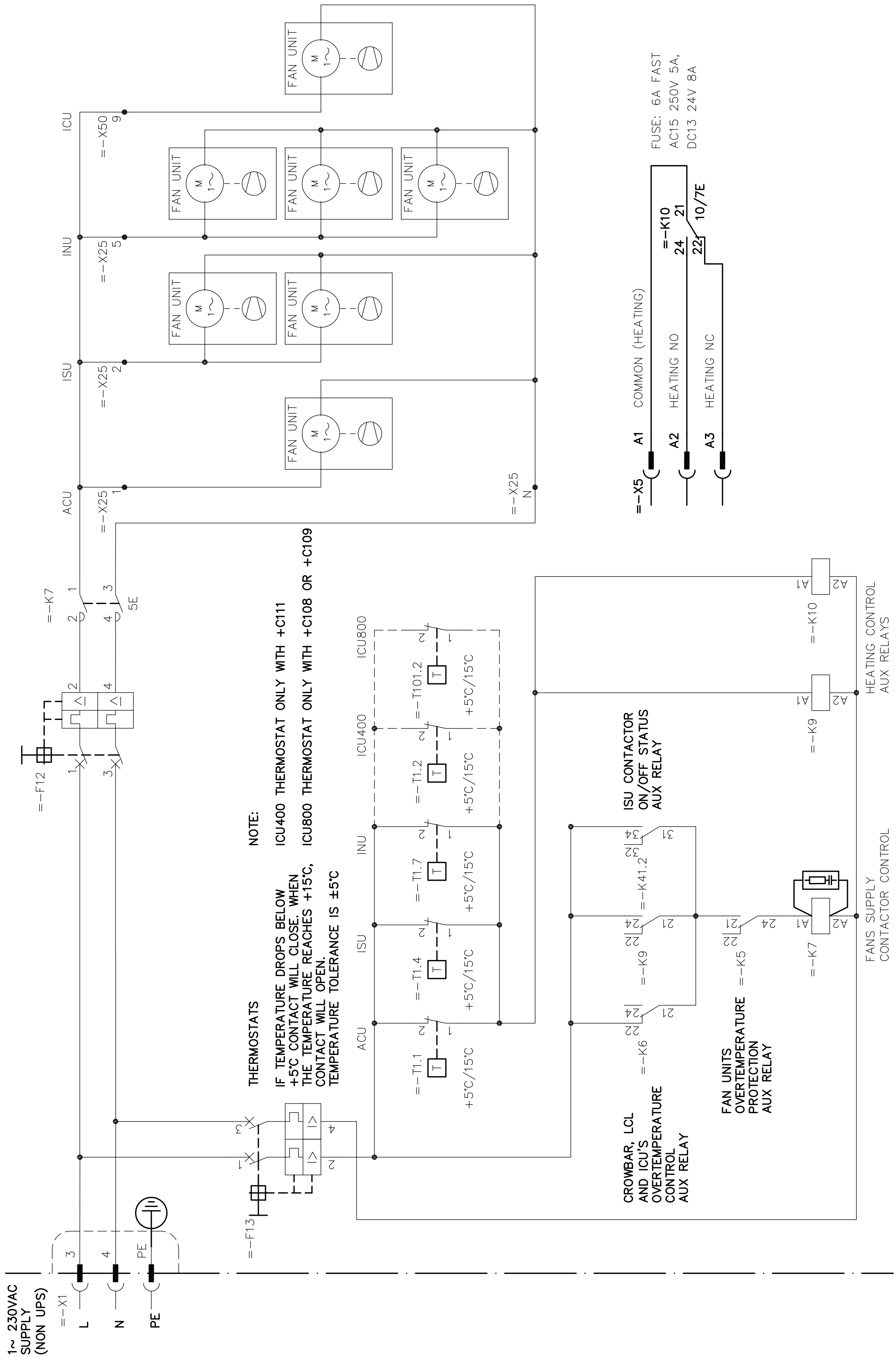
Temperature sensors control relays are K7, K9 and K10. Heating and start pump requests to the external liquid cooling unit are given if the temperature in one converter cubicle is too low. When the converter is heated up properly (switch-off temperature +15 °C (+59 °F) ± 5 K tolerance), auxiliary power to the printed circuit boards is switched on by using relay K8. The relay stays energized unless auxiliary power is switched off with circuit breaker F11 in case of a fault. The heating and start pump requests for the cooling unit change automatically from on to off when heating is not needed any more and vice versa. The cooling fans inside the converter cabinet start when heating is requested.

Normal start

When relay K8 is energized by the cold start procedure described above, the converter gives heating and start pump requests to the liquid cooling unit when the cubicle temperature decreases below switch-on temperature (+5 °C (+41 °F) ± 5 K tolerance). When the temperature rises above switch-off temperature (+15 °C (+59 °F) ± 5 K tolerance), the converter disconnects the heating request.

Circuit diagram

The diagram below shows the principle of the heating control logic of the converter.



Safety

Emergency stop of category 0

The converter is equipped with an emergency stop function of category 0 as standard.

Category 0 definition

EN 60204-1 defines category 0 emergency stop as a stop by immediate removal of power to machine actuators.

Implementation of category 0 stop in the converter

The category 0 emergency stop opens the air circuit breaker(s) and the optional contactor(s) switching off the supply power and coasting the generator to stop.

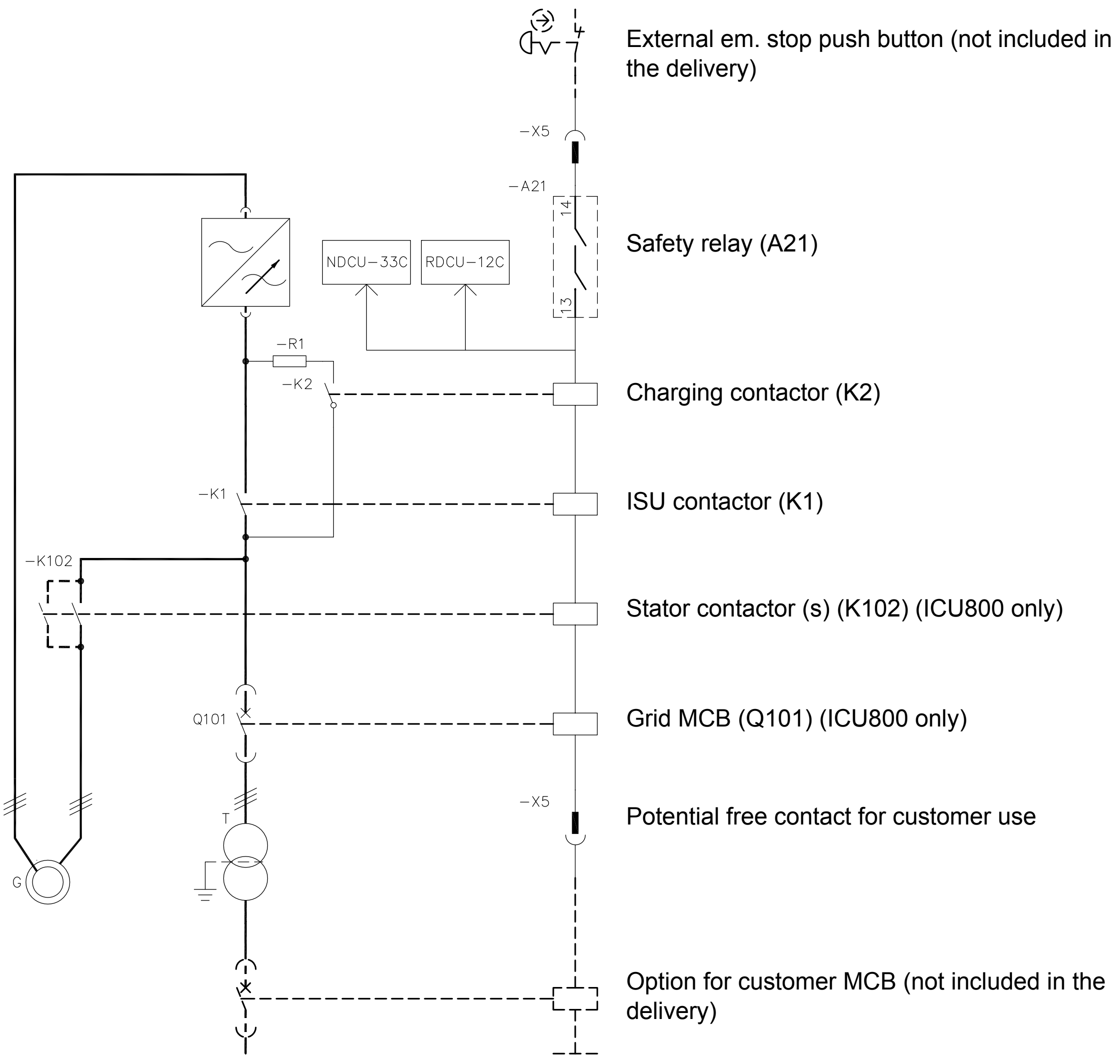
Applicable standards

The emergency stop complies with the following standards:

- EN 60204-1:2006 + A1:2009, Safety of machinery – Electrical equipment of machines – Part 1: General requirements
- EN 418:1992, Safety of machinery – Emergency stop equipment, functional aspects – Principles for design
- EN ISO 12100:2003, Safety of machinery – Basic concepts, general principles for design
- EN 954-1:1996, Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design
- EN ISO 13849-2:2003, Safety of machinery – Safety-related parts of control systems – Part 2: Validation.

Operation

The category 0 emergency stop operates as follows.



The user presses the turbine emergency stop push-button.

↓

The torque is released from the generator shaft.

↓

The air circuit breaker(s) and optional contactor(s) open.

↓

The generator coasts to stop.

Wiring

Converter does not have emergency stop button, potential free contacts for the emergency stop circuit is however supported (X5). Wire the emergency stop and reset push-buttons to connector X5 at the side of the converter cabinet. See the circuit diagram delivered with the converter.

Note: If you add or modify the wiring in the converter safety circuits, ensure that the appropriate standards (eg, IEC 61800-5-1, EN 62061, EN/ISO 13849-1 and -2) and the ABB guidelines are met. After making the changes, verify the operation of the safety function by testing it.

Use

To activate the emergency stop:

Push the emergency stop push-button.	The emergency stop activates and the button locks in the “ON” position.

To deactivate the emergency stop:

Step	What to do	What happens
1.	**WARNING!** Ensure that it is safe to apply the input voltage: • it is safe to start the generator • all cabinet doors are closed.	
2.	Turn the emergency stop push-button until the button releases.	The emergency stop deactivates.
3.	Give a reset command to connector X5 (pins C2 and C3) by pressing the reset push-button (external contact to the converter is required, reset button is not included in the converter delivery).	
4.	Give the converter a start command (rising edge) through fieldbus or DriveWindow (remote control active). **Note:** According to IEC/EN 60204-1 a reset must not initiate a restart.	Converter normal start-up sequence is executed. The grid breaker closing is enabled (MCB1). The grid-side converter charges the DC link, closes its contactor, ISU and INU start to modulate and stator breaker/contactor(s) is closed.

Safety circuit

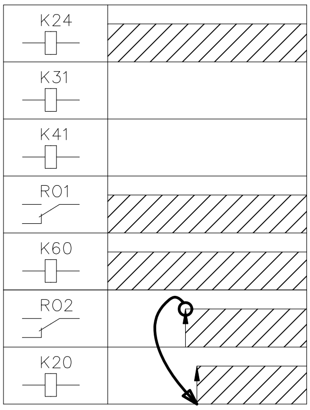
Safety circuit is described below.

In hardware level the control system has special circuits for securing the start-up conditions and monitoring the shutdown process of the converter.

Start-up order is:
1) Grid air-circuit breaker (MCB1), 2) ISU contactor (MCB2), 3) Stator air-circuit breaker/contactor (MCB3)

Shutdown order is reversed:
1) MCB3, 2) MCB2, 3) MCB1

MCB1 closing
(normal run-up)

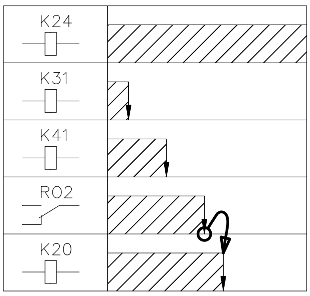


The conditions for closing MCB1 are:

- Stator air-circuit breaker/contactor is open (K31 is open)
- ISU contactor is open (K41 is open)
- No active fault in the converter (A42/X25:RO1 relay output is active)
- Additional customer MCB close control contact is closed (K60 is closed)
- No faults in the hardware monitoring circuit (K24 is closed)

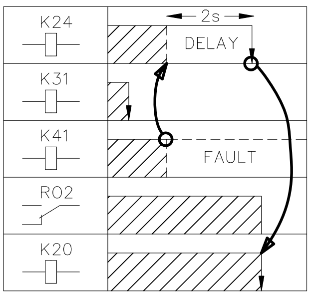
If all the conditions are fulfilled, switching on A42/X25:RO2 relay output will cause MCB1 to close.

MCB1 opening
(normal shutdown)



Normally, MCB1 opening is handled by software. When the converter is running, shutting down happens in a particular order. It starts by opening the stator air-circuit breaker/contactor (MCB3), relay K31 turns OFF. Then the converter de-energizes ISU contactor (MCB2), relay K41 turns OFF. Once both MCB2 and MCB3 are OFF, MCB1 can also be switched OFF by de-activating A42/X25:RO2 relay output.

MCB1 opening (emergency shutdown – MCB2 fault)

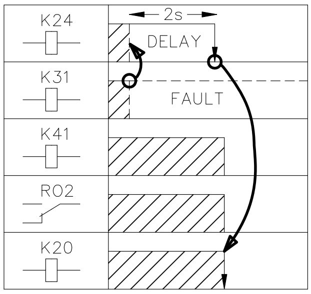


In emergency situations when the converter needs to be disconnected from the grid, the monitoring circuit of the converter shutdown process is used. Such situations happen if any of MCB devices fails during the converter shutdown:

1. MCB2 FAULT

If the monitoring circuit detects that status of ISU contactor is still closed (K41 relay is ON) after the converter tried to open the contactor and 2 sec time delay has elapsed, MCB1 will be forced to open by de-energizing K24 relay to disconnect the converter from the grid.

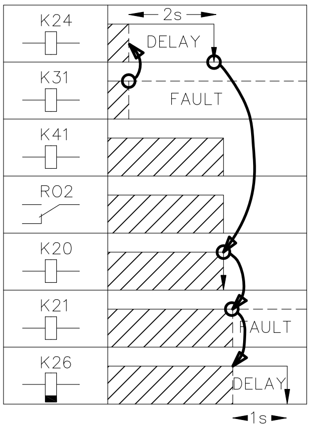
MCB1 opening (emergency shutdown – MCB3 fault)



2. MCB3 FAULT

In case the stator air-circuit breaker/contactor does not obey OPEN command from the converter, the monitoring circuit will find that MCB3 is still closed (K31 relay is ON) after time delay of 2 sec. MCB1 will then be forced to open by de-energizing K24 relay to disconnect the converter from the grid.

MCB1 opening (emergency shutdown – eg, first MCB3 fault, then MCB1 fault)



3. MCB1 FAULT

The worst case is that the grid air-circuit breaker fails to open itself. In this case the monitoring circuit will find that MCB1 is closed (K21 relay is ON) despite of OPEN command (K20 relay is OFF). After 1 sec delay K26 time relay will be de-energized. The contacts of K26 can be used to control medium-voltage grid disconnecting device (see X5 control cable connector in the hardware manual).

This example diagram describes a situation when MCB3 and MCB1 fail one after the other.

Grid codes

Grid codes specify static and dynamic requirements to be fulfilled by a wind power installation. Static requirements mainly determine the voltage control and power control during normal operation. Most of the recent grid codes include also power quality requirements such as harmonics distortion limits, flicker etc. Dynamic requirements define the dynamic behavior of a wind turbine or wind farm under grid disturbance. One of the most important dynamic requirements is grid fault ride-through capability of the wind power generator. Grid fault ride-through means that instead of disconnection, the wind generators have to stay connected to the power supply network for a certain period. Grid fault ride-through requirements define:

- how long a grid fault (eg, voltage dip/sag or swell) can last
- how to operate under a balanced (symmetrical) grid fault
- how to operate under an unbalanced (unsymmetrical) grid fault.

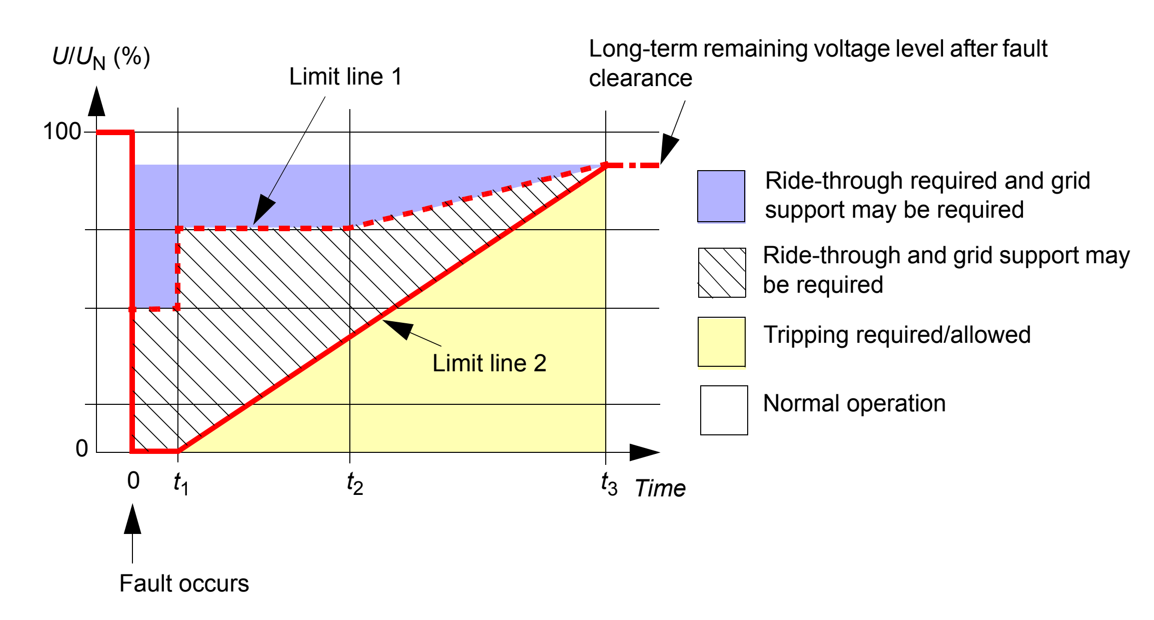
The power train concept can be used to find the optimal solution when balancing the connection requirements and costs of installation. The selection of electrical power train components (a pitch system, generator, frequency converter and transformer) has effect on the capability of an individual turbine to comply with the grid code requirements.

Although the converter has an important role in enabling the wind turbine to fulfil the grid code requirements, it is highly dependent on how the whole wind turbine system and its process is functioning (the wind turbine controller, pitch system, UPS etc.). The turbine manufacturer is responsible for fulfilling the requirements of the transmission or distribution system operator.

• REE P.O.12.3	RED ELÉCTRICA DE ESPAÑA P.O.12.3 Fault ride-through capabilities and reactive power/voltage control during faults in wind power installations
• National Grid Electricity Transmission plc	The Grid Code, Issue 4, Revision 4, 18th October 2010
• Technical regulation 3.2.5 for wind power plants with a power output greater than 11 kW	Rev. 4.1. 30.9.2010
• National Grid Code (China)	Technical Rule for Connecting Wind farm into Power Network, July 2009
• Transmissioncode 2007	Netz- und Systemregeln der deutschenÜbertragungsnetzbetreiber, August 2007
• transpower stromübertragungs gmbh	Grid Code for high and extra high voltage, 1st April 2009
• transpower stromübertragungs gmbh	Requirements for Offshore Grid Connections in the transpower Grid, 30th April 2010
• 50Hertz Transmission GmbH	Netzanschluss- und Netzzugangsregeln, May 2008
• System Service Ordinance	Ordinance on System Services by Wind Energy Plants (System Service Ordinance – SDLWindV)
• BDEW	Technische Richtlinie Erzeugungsanlagen am Mittelspannungsnetz, Richtlinie für Anschluss und Parallelbetrieb von Erzeugungsanlagen am Mittelspannungsnetz, June 2008
• TR3	Technische Richtlinienfür Erzeugungseinheiten und –anlagen Teil 3 Bestimmung der Elektrischen Eigenschaften von Erzeugungseinheiten am Mittel-, Hoch- und Höchstspannungsnetz;
• 111 FERC 61,252	United States of America, Federal Energy Regulatory Commission, 18 CFR part 35. 2005

Example limit curves

According to this example power supply network failure (eg, voltage dip/sag) may not cause instability above the limit line 1 or disconnection of the converter from the grid. The limit curves for voltage at the grid connection in case of a fault in the grid are shown below. U denotes the remaining grid voltage and U_N the converter nominal voltage.



Description of parameter settings

The parameter settings of the grid fault ride-through function are described in section *Setting the grid fault ride-through parameters* on page 42.

Grid fault ride-through capability (options +D150 and +D151)

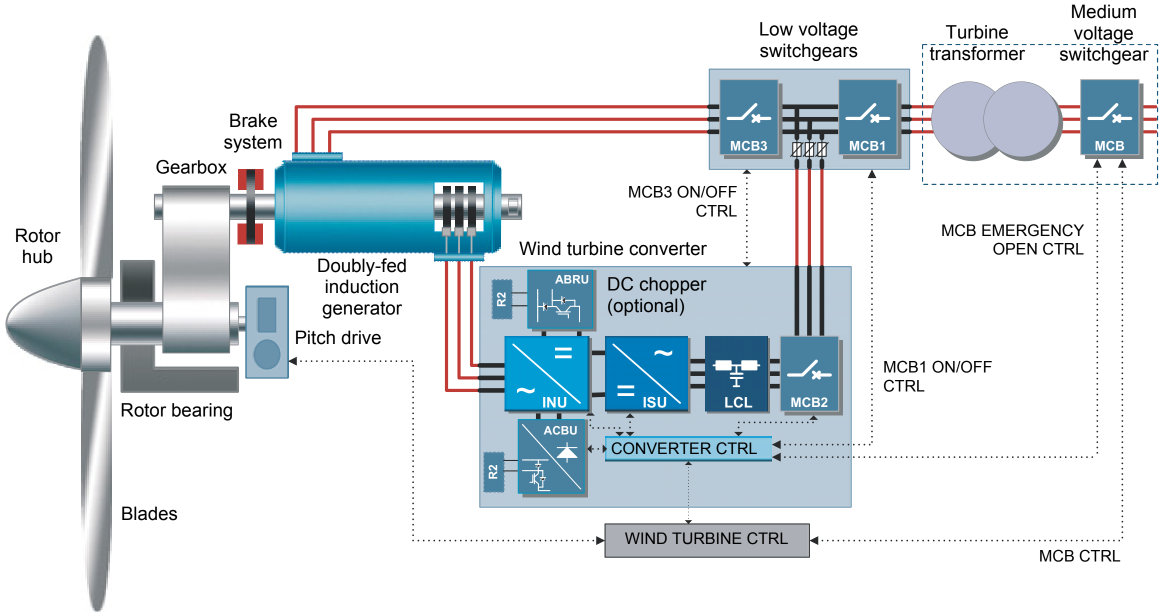
Although the advantage of doubly-fed concept is that the size of the wind turbine converter is significantly smaller than full-power converter, the drawback is that the rotor-side converter is a vulnerable part of the system. It has a restricted overcurrent limit and it needs special attention especially during faults in the grid. When faults occur and cause eg, voltage dips or sags, the magnetic flux in the generator can not change instantaneously. As a result sudden change in the stator supply voltage is followed by a large change in the generator currents. The converter responds to the change of rotor currents so that the rotor currents are maintained as required by the rotor-side converter control.

Since the output voltages and currents of the rotor-side converter are limited, the rotor-side converter may not be able to maintain the rotor currents within given limits during severe grid faults and thus it must be protected. The ACS800-67LC is always equipped with hardware-based protection device, Active Crowbar Unit (ACBU). Crowbar is connected to the 3-phase output terminal of the rotor-side converter and it is based on 6-pulse diode bridge, power semiconductor switches and brake resistor. Active crowbar is controlled by the rotor-side converter control firmware and in case of failure it can protect the converter independently. Crowbar is triggered if DC link voltage is too high or alternatively if the rotor current is too high.

Grid codes typically require that the wind turbine must remain connected to the grid under different kinds of grid failure events (eg, voltage dip/sag, short interruption, swell etc). It is very common that the wind turbine

- has to stay connected to the power system for a certain period
- may not take power from the power system
- produces capacitive reactive current.

The ACS800-67LC has two options performing grid fault ride-through function: +D150 and +D151. Both options include ABRU DC chopper unit for DC link power dissipation. Option +D151 includes also a DC resistor. The DC chopper may be needed if grid fault ride-through or high swell threshold is required. DC choppers are connected to the DC link, and they are located on top of each rotor-side converter module. DC chopper operates independently always when DC link voltage rises above its triggering level. A diagram of the wind turbine system with DC chopper is shown below.

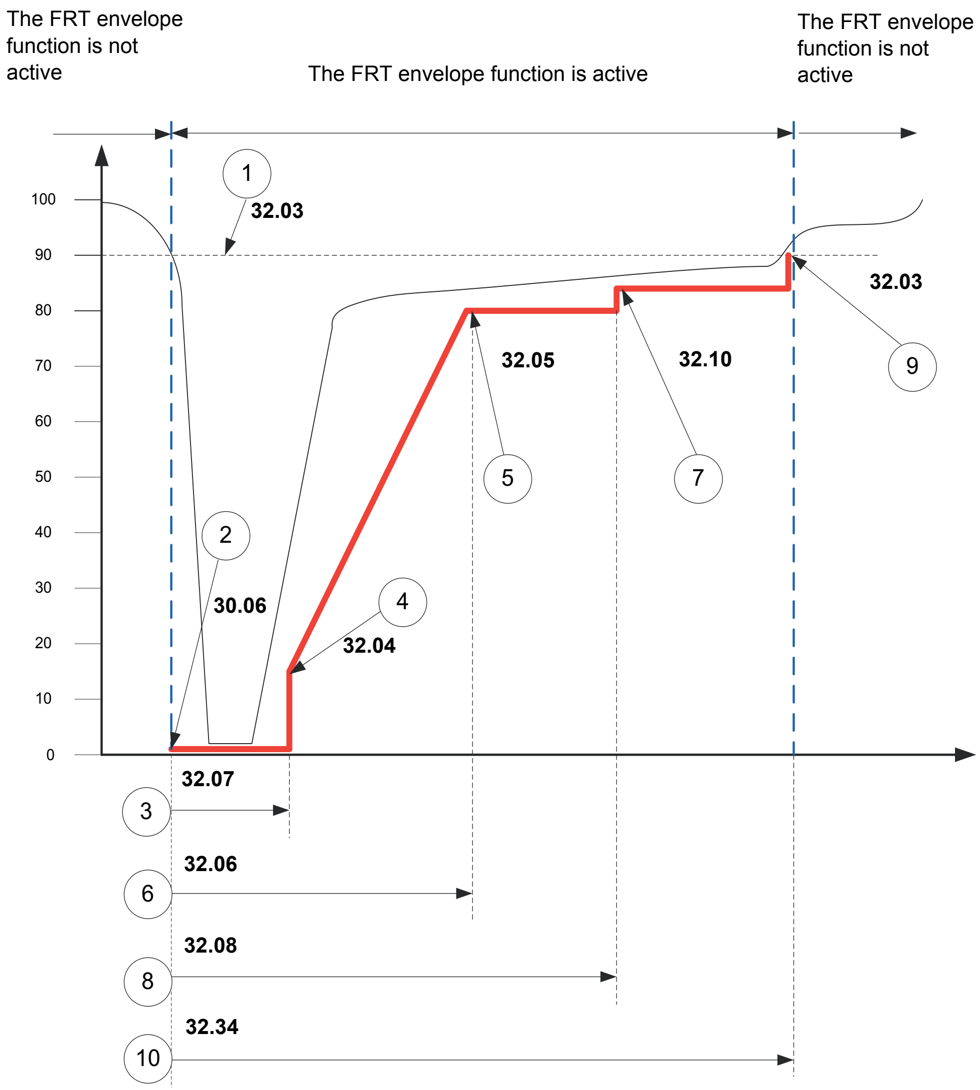


With crowbar and DC choppers the wind turbine is capable of handling fault situations like rotor overspeed, short interruptions, voltage dips/sags and swells. With these energy absorbers the ACS800-67LC is capable of meeting even the most strictest grid fault ride-through requirements in accordance with international grid codes.

Setting the grid fault ride-through parameters

The user can define when the converter must stay connected to the grid (ie, the depth and length of the grid voltage transient). The user can also define how much the converter supports the grid by feeding reactive current to the grid when the grid voltage stays below a defined area. Setting the grid fault ride-through parameters is described below. See also *ACS800-67(LC) doubly-fed induction generator control program firmware manual* [3AUA0000071689 (English)].

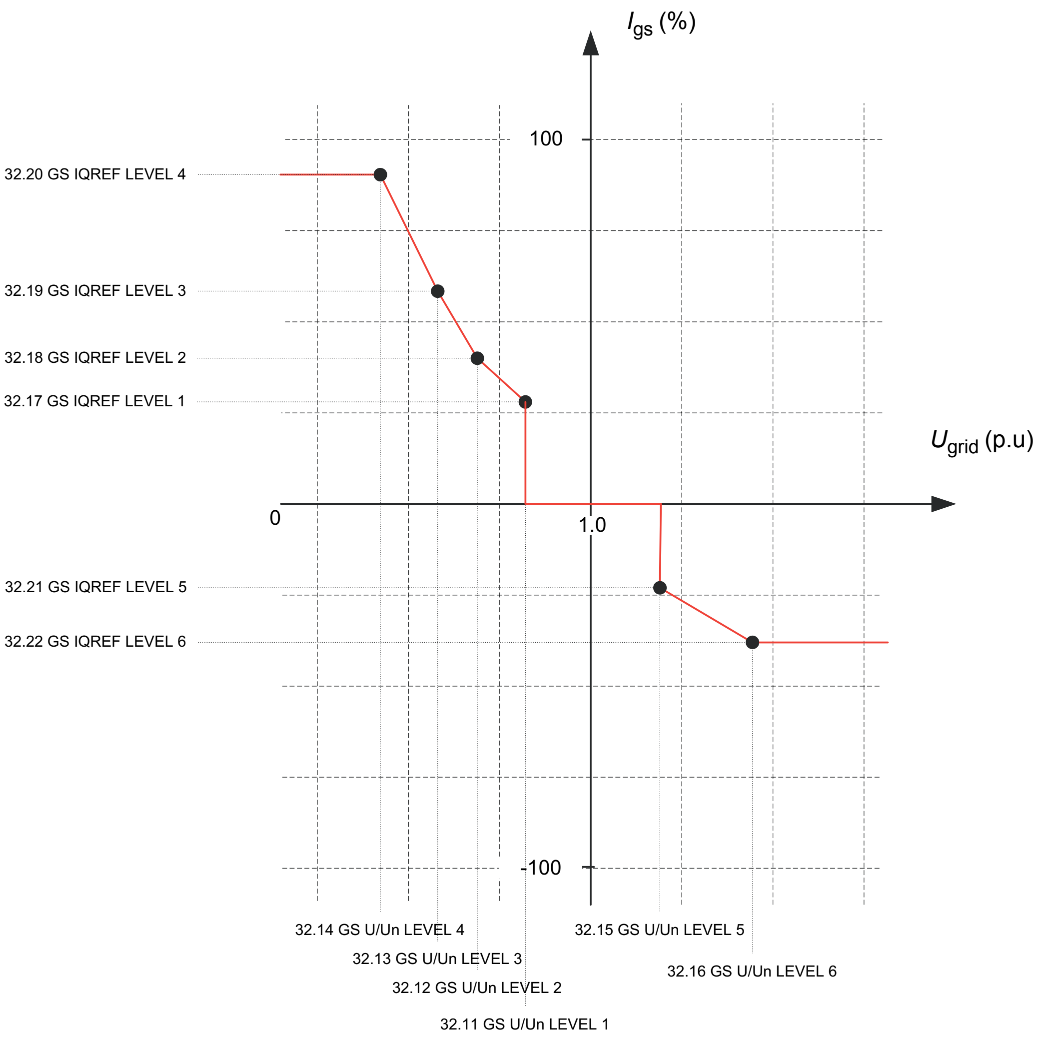
Trip areas



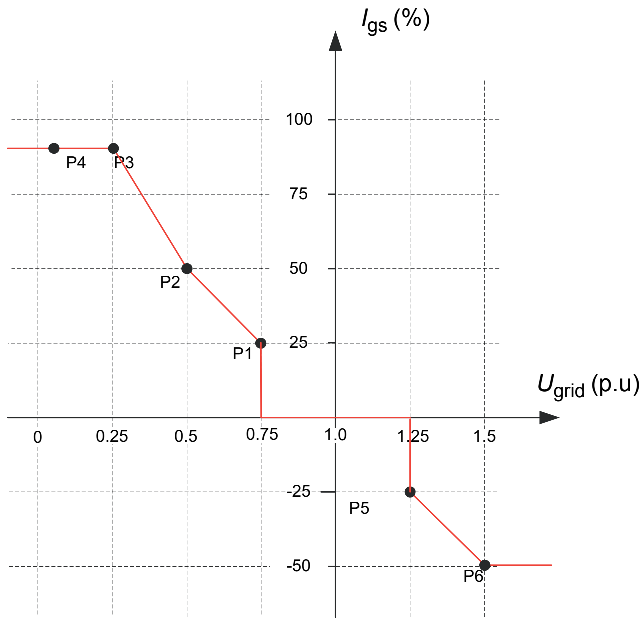
Parameter	Information
30.06 AC UNDERVOLT TRIP	Grid voltage as rms The minimum allowed grid voltage level at the start of a grid dip.
32.02 RT MONITOR SIGNAL	Enables how the grid undervoltage tripping level is defined.
32.03 RT U/Un LEVEL1	When measured grid voltage falls below level (1) a timer starts to calculate dip length.
32.04 RT U/Un LEVEL2	When time level (3) (32.07) is reached the envelope value (15%) is stepped to this point in case when the envelope value is lower (4) (32.04).

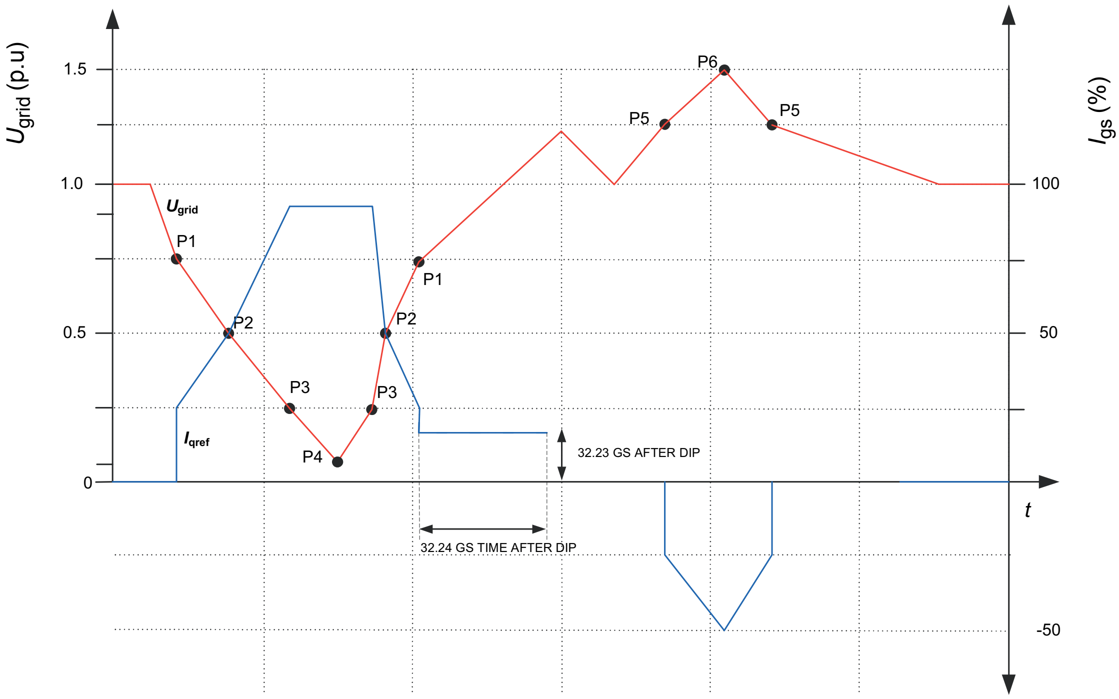
Parameter	Information
32.05 RT U/Un LEVEL3	The time when internally calculated undervoltage trip limit has reached the limit 32.05 RT U/Un LEVEL3.
32.06 RT U/Un DELTA t1	The envelope tripping value increasing time (1200 ms).
32.07 RT U/Un DELTA t2	Minimum time t_2. When the dip length timer reaches this point (3) an internally calculated undervoltage tripping limit starts to increase.
32.08 RT U/Un DELTA t3	The time how long the grid voltage can stay under the limit 32.04 RT U/Un LEVEL2. At this point the envelope tripping level is thresholdwise stepped up to value (1) 32.03 RT U/Un LEVEL1 (90%). If measured grid voltage has not exceeded 90% value at this point then the converter may trip on undervoltage.
32.10 RT U/Un LEVELHYST	The envelope tripping level is stepped up by the value (5%) of this parameter. (5%) -> 80% + 5% = 85%
32.32 U- /U+ START DIS	When the grid voltage unbalance level during grid fault ride-through rises, then the rotor current spikes also rise proportionally to the grid voltage unbalance depth. When the spikes reach a certain limit (32.32 U- /U+ START DIS), at which inverter modulation must be stopped to protect the equipment.
32.33 U (RMS) START DIS	When grid voltage is below limit, INU modulation is not started if the crowbar has been commutated.
32.34 RT U/Un DELTA t5	The envelope level (7) 32.10 RT U/Un LEVELHYST is kept constant until the time defined by this parameter is reached.
* **Note:** Consult the local ABB representative before changing the grid fault ride-through parameters.	

Grid support areas



Grid support example





Parameter setting examples according to grid code

Parameter setting examples in cases of Spanish, German, US and United Kingdom grid codes are given below.

Parameter	REE P.O.12.3	EON 2006	USA Order 661 2008	UK Grid Code
32.01 GRID SUPPORT MODE	MAX. Up-p	MAX. Up-p	OFF	MAX. Up-p
32.02 RT MONITOR SIGNAL	MIN. Up-p	MIN. Up-p	MIN. Up-p	MIN. Up-p
32.03 RT U/Un LEVEL1	80%	85%	80%	90%
32.04 RT U/Un LEVEL2	10%	0%	10%	15%
32.05 RT U/Un LEVEL 3	80%	85%	85%	80%
32.06 RT U/Un DELTA t1	3000 ms	3000 ms	3000 ms	1200 ms
32.07 RT U/Un DELTA t2	600 ms	200 ms	600 ms	140 ms
32.08 RT U/Un DELTA t3	3000 ms	3000 ms	3000 ms	2500 ms
32.09 RT U/Un DELTA t4	3000 ms	3000 ms	3000 ms	140 ms
32.10 RT U/Un LEVELHYST	0%	0%	0%	5%
32.11 GS U/Un LEVEL 1	85%	85%	85%	90%
32.12 GS U/Un LEVEL 2	50%	50%	50%	80%
32.13 GS U/Un LEVEL 3	25%	25%	25%	25%
32.14 GS U/Un LEVEL 4	15%	15%	15%	15%
32.15 GS U/Un LEVEL 5	110%	110%	110%	110%
32.16 GS U/Un LEVEL 6	120%	120%	120%	120%
32.17 GS IQREF LEVEL 1	10%	34%	10%	0%
32.18 GS IQREF LEVEL 2	100%	112%	10%	112%
32.19 GS IQREF LEVEL 3	100%	112%	10%	112%
32.20 GS IQREF LEVEL 4	100%	112%	10%	112%
32.21 GS IQREF LEVEL 5	-20%	-20%	-20%	-20%
32.22 GS IQREF LEVEL 6	-40%	-40%	-40%	-40%
32.23 GS AFTER DIP	10%	10%	10%	0%
32.24 GS TIME AFTER DIP	500 ms	500 ms	500 ms	0 ms
32.25 KVAR RISE TIME	120 ms	120 ms	120 ms	50 ms
32.26 TORQUE RISE TIME	100 ms	100 ms	100 ms	50 ms
32.27 Imax/In (LVRT)	100%	112%	100%	124%
32.28 TMIN/TN (LVRT)	3%	3%	3%	1%
32.29 Ip max/In (LVRT)	100%	112%	100%	118%
32.30 IR MAX PEAK LEVEL	2285.57	2285.57	2285.57	1777.66 A
32.31 IR MAXSLOPE SCALE	507.903 A	507.903 A	507.903 A	507.903 A
32.32 U- / U+ START DIS	80%	80%	80%	80%
32.33 U(RMS) START DIS	10%	10%	10%	10%
32.34 RT U/Un DELTA t5	3 s	3 s	3 s	180 s
32.35 PRIORITY t<t4	Iq, Ip = 0	Iq, Ip = 0	Iq, Ip = 0	Iq > Ip
32.36 PRIORITY t>t4	Iq > Power	Iq > Power	Iq > Power	Ip > Iq
32.37 P/Q UNSYM DIS	62%	62%	62%	62%
32.38 P/Q UNSYM ENA	60%	60%	60%	60%

Converter statuses

08.10 CCU STATUS WORD (status word for ABB Drives profile, Profile B and Profile C) bit statuses in rotor-side converter control program indicate the state of the converter during a grid fault ride-through event.

When a grid fault ride-through event is detected by the rotor-side converter the grid support mode is automatically enabled. During the grid support mode the torque and the active power referencies sent by PLC is neglected.

Since the power supply network voltage recovers and the grid fault ride-through event is cleared, the grid support mode is automatically disabled and the torque/active power reference is restored to its set-point value at a rate that corresponds to the parameter 32.26 TORQUE RISE TIME.

B10 LOW VOLTAGE FOR RIDE THROUGH

Set when grid voltage is below 32.03 RT U/Un LEVEL1
Reset when grid voltage is above 32.03 RT U/Un LEVEL1

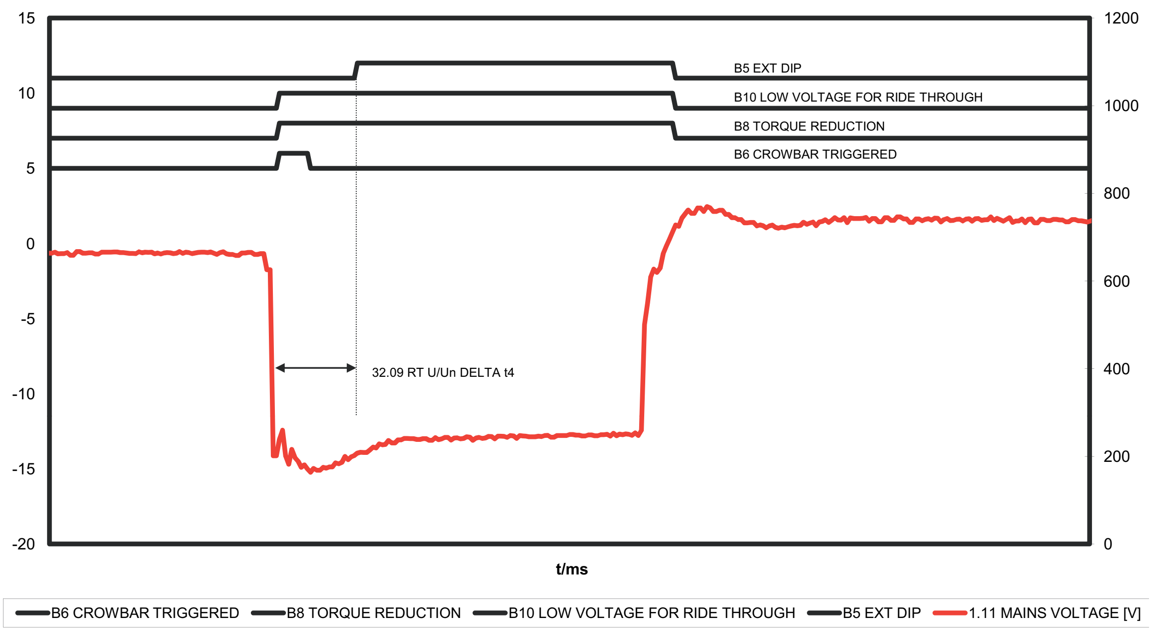
B8 TORQUE REDUCTION

Set always when final torque reference to DTC is limited so that requested torque reference cannot be produced.

B6 CROWBAR TRIGGERED

Set when active crowbar is requested to switch ON.

08.10 CCU STATUS WORD



08.10 CCU STATUS WORD	
Bit	**Name**
5	EXT DIP
6	CROWBAR TRIGGERED
8	TORQUE REDUCTION
10	LOW VOLTAGE FOR RIDE THROUGH

Torque or reactive power restoring

When the crowbar triggers both torque reference and kVAr reference is cleared. When the crowbar is commutated referencies are restored at a rate defined by parameters

32.25 KVAR RISE TIME

32.26 TORQUE RISE TIME.

Crowbar settings

Crowbar unit is used to protect the converter in case of unexpected power supply network failure. There are two types of crowbars, a passive crowbar that does not allow the grid fault ride-through function and an active crowbar that allows to operate through pre-determined power supply network failure without tripping (grid fault ride-through operation). An active crowbar is used in ACS800-67LC wind turbine converters.

The crowbar can be switched ON and OFF based on the influence of the grid voltage transient on the rotor-side converter. The rotor-side converter output is short-circuited through a resistor when the crowbar is switched ON. The active crowbar is controlled by the rotor-side converter NDCU control unit.

Parameter settings

Parameter	Setting	Additional information
31.01 CROWBAR HW TYPE	PASSIVE CB	Passive crowbar (type ACBU-P1)
	ACTIVE CB	Active crowbar (type ACBU-A2)
	ONLY GRID SU	Grid support with a passive crowbar. Software supports grid as long as the passive crowbar does not trig.
	2 ACTIVE CBs	Two active crowbars (type ACBU-A2) connected parallel
	1 REV2 CB*	One active crowbar (type ACBU-A2 with AITF-11 circuit board)
	2 REV2 CBs*	Two active crowbars (type ACBU-A2 with AITF-11 circuit board)
	3 REV2 CBs*	Three active crowbars (type ACBU-A2 with AITF-11 circuit board)
	4 REV2 CBs*	Four active crowbars (type ACBU-A2 with AITF-11 circuit board)
31.02 CB RESISTANCE	See the table below.	Crowbar resistance value as mOhm
31.04 CB MAX ENERGY	See the table below.	Maximum energy absorption capacity of the crowbar as kWs
31.05 IR TRIGG-ON LEVEL	See the table below.	Rotor current level as A when CB is triggered
31.06 UC TRIGG-ON LEVEL	1170 V**	DC voltage level when CB is switched ON
31.07 UC TRIGG-OFF LEVEL	1150 V**	DC voltage level when CB is switched OFF
31.08 CB TRIGG-OFF LEVEL	450 V**	CB bridge voltage level when CB is commutated and current is switched back to the rotor-side converter.
* April 1, 2012 onwards. ** Example setting for 690 V unit.		

Converter type	31.01 CROWBAR HW TYPE	31.02 CB RESISTANCE	31.04 CB MAX ENERGY	31.05 IR TRIGG-ON LEVEL
ACS800-67LC-1075/0575-7	ACTIVE CB or 1 REV2 CB*	400	155	2039.2
ACS800-67LC-1375/0575-7	ACTIVE CB or 1 REV2 CB*	400	155	2594.5
ACS800-67LC-1375/1125-7	2 ACTIVE CBs	200	310	2594.5
	2 REV2 CBs*	400	310	2594.5
ACS800-67LC-1595/0865-7	2 ACTIVE CBs	200	310	3028.4
	2 REV2 CBs*	400	310	3028.4
ACS800-67LC-2035/1125-7	2 ACTIVE CBs	200	310	3850.8
	2 REV2 CBs*	400	310	3850.8

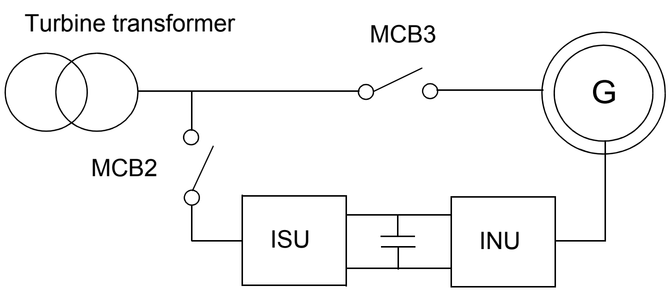
* April 1, 2012 onwards.

APBU branching unit

When the power modules are parallel connected, a branching unit is needed between the NDCU/RDCU control units and the power modules. The APBU-44C branching unit contains internal diagnostic registers for distinguishing failed power module(s) from functional ones. For information on how to download diagnostic registers, see section *How to download the diagnostics of APBU branching unit* on page *119*.

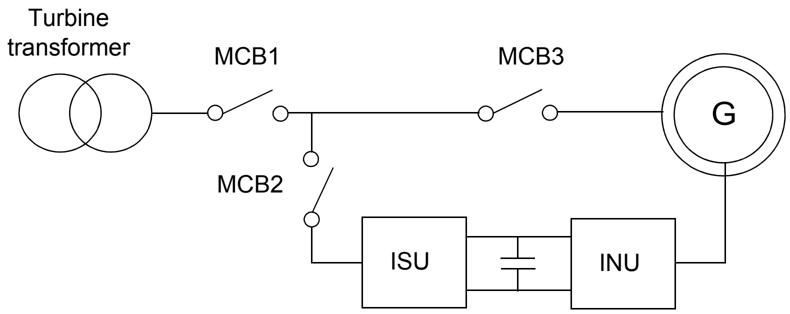
Stator circuit connection to grid

The converter can control both an air breaker and a contactor for connecting the generator stator to grid. The main difference between these two configurations is that if the stator circuit is equipped with an air breaker, it allows disconnecting the stator from grid even with a high stator current. The differences between these two configurations are presented below.



When the stator circuit is equipped with a contactor, disconnecting the stator from the grid must be handled selectively. If the stator contactor is opened under high current it may be damaged.

Selective disconnection from grid is handled so that any time the stator contactor is commanded to open, instantaneous stator current is compared to the given limit. If stator current is below the limit, the stator contactor is opened. Conversely, if stator current is above the limit, the stator contactor is kept closed and grid-side air breaker (MCB1) is opened instead; the stator contactor is opened after a certain delay.



The breaking device type for the grid connection is defined by parameter 20.27 CONT OPEN CUR.

0 A = main circuit breaker used for disconnecting stator from grid.

> 0 A = main circuit breaker and contactor are used for disconnecting stator from grid.

0 A = Medium voltage circuit breaker used for disconnecting stator from grid.

When parameter value [> 0 A] is selected, the ACS800-67LC can be disconnected from the grid in two ways depending on a parameter setting:

- If measured current 06.29 STATOR IS NO FILT is below the parameter value, the ACS800-67LC uses the stator contactor only.
- If measured current 06.29 STATOR IS NO FILT is above the parameter value, the ACS800-67LC first opens air breaker and, after a short time, the stator contactor.

The parameter value is compared to unfiltered stator rms value. Since the unfiltered value always contains a certain amount of noise, it is recommended to set the parameter to a value of contactor nominal current +15%. See the delivery specific circuit diagrams.

Settings

Parameter 20.27 CONT OPEN CUR.

If the delivery contains power cabinet (option +C108 or +C109), open current value must be set to this parameter as follows.

Approx. generator rating *P* [kW]	Power cabinet type	Stator contactor type	Qty	Parameter setting 20.27 CONT OPEN CUR [A]
1500	ICU800-67LC-1075/0575-7	AF1650	1	1650
2250	ICU800-67LC-1375/0575-7	AF1650	2	1980
2600	ICU800-67LC-1375/1125-7	AF2050	2	2460
3000	ICU800-67LC-1595/0865-7	AF2050	2	2460

Parameter 20.27 CONT OPEN CUR value can also be calculated as follows.

- In case of parallel connected contactors:

  $$20.27\ \text{CONT OPEN CUR} = n \cdot I_{n,contactor} \cdot 0{,}6$$

  where n is the number of contactors and $I_{n,contactor}$ is the nominal current of the contactor.
- In case of one contactor, the value for parameter 20.27 CONT OPEN CUR is the nominal current of the contactor.

Jumper settings

	Hardware configuration		
Jumpers	**Grid MCB, stator contactor**	**No grid MCB, stator MCB**	**Grid MCB, stator MCB**
X30.1:1 - X30.1:2		×	
X30.1:1 - X30.1:3		×	
X30.1:6 - X30.1:7	×		×
X30.2:1 - X30.2:3	×		

Stator air breaker control

RUN command activated:

- RO2 is closed. This gives 230 V AC to air breaker *undervoltage* relay.
- Sequence is halted until **rising edge** is received by DI2. This comes from the air breaker *ready* signal.
- RO3 is closed. This is connected to the air breaker ON signal.
- Torque control is released when DI3 receives acknowledge signal from the air breaker.

RUN command removed:

- RO2 and RO3 are opened at simultaneously.
- DTC modulation of rotor-side converter is stopped after DI3 acknowledge signal from the air breaker is opened.

Diagnostic information

RO2	Grid MCB (MCB1) control
RO3	Stator MCB (MCB3) control
DI2	Grid MCB status
DI3	Grid MCB tripped (1 = not tripped)
DI4	Stator MCB status
DI6	Stator MCB tripped (1 = not tripped)

When ON command is given to grid MCB, the ACS800-67LC trips on MCB1 ON FAILED if the statuses of RO2 and DI2 differ for more than 10 seconds. When OFF command is given to grid MCB, the ACS800-67LC trips on MCB1 OFF FAILED if the statuses of RO2 and DI2 differ for more than 1 second.

When ON command is given to stator MCB, the ACS800-67LC trips on MCB3 ON FAILED if the statuses of RO3 and DI4 differ for more than 10 seconds. When OFF command is given to stator MCB, the ACS800-67LC trips on MCB3 OFF FAILED if the statuses of RO3 and DI4 differ for more than 1 second.

Grid air breaker and stator contactor

RUN command activated:

Note: The RUN command cannot be activated if DI2 state is OFF. DI2 is connected to grid air breaker ‘ready’ signal.

- RO3 is closed. This closes the stator contactor.
- Torque control is released when DI3 receives an acknowledge signal from the stator contactor.

RUN command removed and stator current is below the given limit.

- RO3 is opened. This opens the stator contactor.

- DTC modulation of rotor-side converter is stopped after DI3 acknowledge signal from stator contactor is removed.

RUN command removed and stator current is above the given limit.

Note 1: RUN command is removed internally if any fault is detected.
- RO2 is closed. This opens the mains air breaker.
- Sequence is halted until DI2 state is OFF. This signals that the mains air breaker is open.
- RO2 is opened.
- RO3 is opened. This opens the stator contactor.

DTC modulation is stopped (if not already stopped) when DI3 acknowledge signal from stator contactor is OFF.

3

Start-up

What this chapter contains

This chapter instructs in starting-up the converter, setting the start-up parameters and configuring the control signals of the system. The start-up procedure must be performed in local control mode by using DriveWindow PC tool.

General

The following actions need to be performed when the converter is commissioned for the first time or each time when updating the converter software:

- setting the language
- entering the generator data according to the generator nameplate.

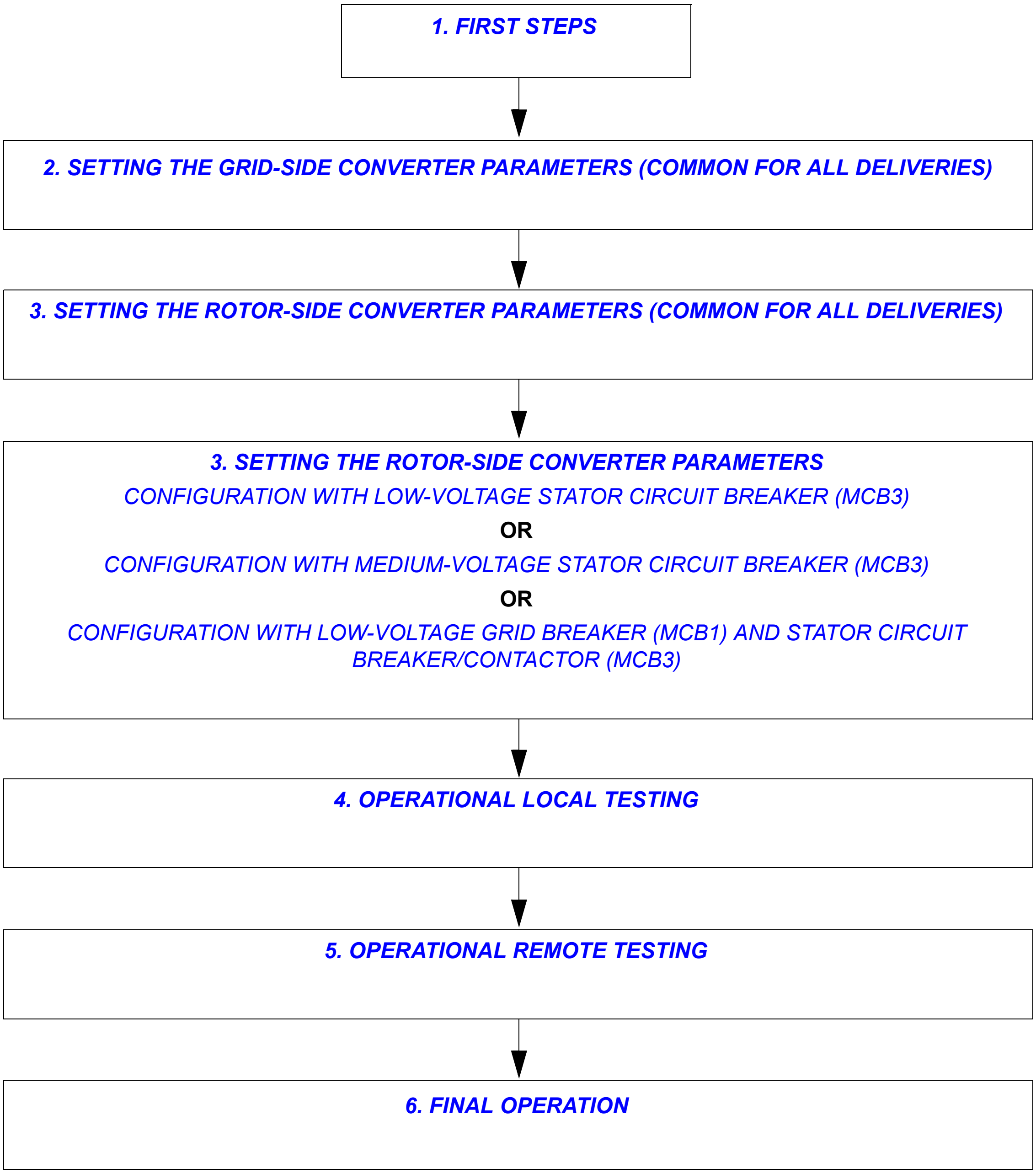
Note: It is not allowed to start the converter up more often than once in two minutes during commissioning. Avoid frequent start-ups not to damage charging circuit components.

For more information, see the following manuals:

Rotor-side converter (INU)	*ACS800-67(LC) doubly-fed induction generator control program firmware manual* [3AUA0000071689 (English)]
Grid-side converter (ISU)	*Grid-side control program for ACS800 wind turbine converters firmware manual* [3AUA0000075077 (English)]
DC chopper (ABRU)	*ABRU-0x DC choppers (+D150) and resistors (+D151) for ACS800-67LC/-77LC/-87LC wind turbine converters hardware manual* [3AUA0000076494 (English)]

Legend of the start-up procedure

This flowchart illustrates the start-up procedure.



Start-up procedure

The start-up procedure is described below. All selections available for a parameter or additional information on a parameter is marked with *. Parameter selection to be chosen or information on using DriveWindow PC tool is located in the most right-hand side column in the table.

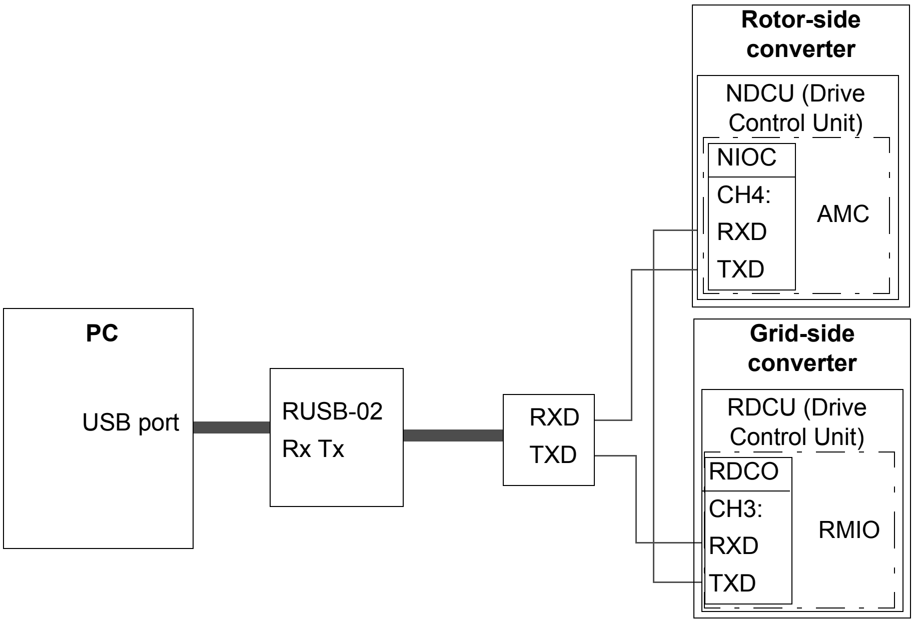
1. FIRST STEPS	
■ **SAFETY**	
⚠	**WARNING!** The safety instructions must be followed during the installation and start-up procedure. See the safety instructions in *ACS800-67LC hardware manual* [3AUA0000058400 (English)] and *ICU800-67LC incoming units (+C108/+C109) hardware manual* [3AUA0000071553 (English)].
☐	Only qualified electricians are allowed to install and start-up the converter.
☐	The coolant connections and circulation must be controlled when the converter is started up and during its operation.
☐	The generator shaft must be locked mechanically to ensure that the generator rotor does not rotate during the executing the commissioning.
■ **INSTALLATION**	
Check and ensure that:	
☐	The mechanical installation is performed according to the instructions given in
○	*ACS800-67LC hardware manual* [3AUA0000058400 (English)]
○	Option +C108 or +C109: *ICU800-67LC incoming units (+C108/+C109) hardware manual* [3AUA0000071553 (English)]
○	Option +D150: *ABRU-0x DC choppers (+D150) and resistors (+D151) for ACS800-67LC/-77LC/-87LC wind turbine converters hardware manual* [3AUA0000076494 (English)].
☐	The electrical installation is performed according to the instructions given in
○	*ACS800-67LC hardware manual* [3AUA0000058400 (English)]
○	Option +C108 or +C109: *ICU800-67LC incoming units (+C108/+C109) hardware manual* [3AUA0000071553 (English)]
○	Option +D150: *ABRU-0x DC choppers (+D150) and resistors (+D151) for ACS800-67LC/-77LC/-87LC wind turbine converters hardware manual* [3AUA0000076494 (English)].
☐	The installation is checked according to the checklists in
○	*ACS800-67LC hardware manual* [3AUA0000058400 (English)]
○	Option +C108 or +C109: *ICU800-67LC incoming units (+C108/+C109) hardware manual* [3AUA0000071553 (English)]
○	Option +D150: *ABRU-0x DC choppers (+D150) and resistors (+D151) for ACS800-67LC/-77LC/-87LC wind turbine converters hardware manual* [3AUA0000076494 (English)].

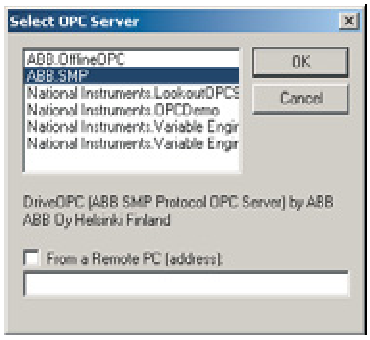
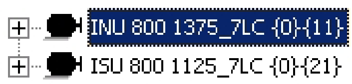
1. FIRST STEPS

■ POWER-UP AND DriveWindow CONNECTION

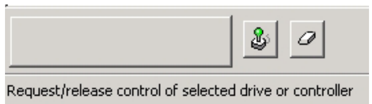
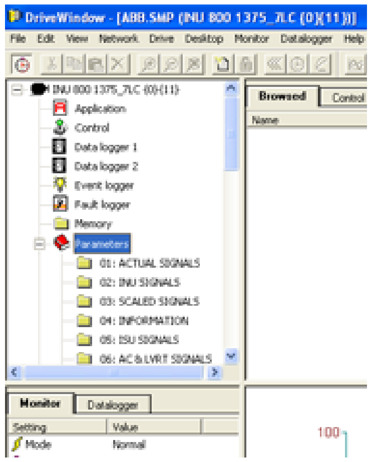
WARNING! Controlling a converter may cause personal injury or physical damage. You should have physical access to the converter, and you must be sure that the converter and the electromechanical system are clear to control (you can see the system, for example). Controlling a converter remotely may require extra precautions and is discouraged.

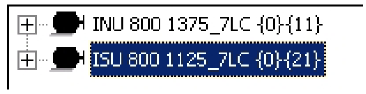
☐	Connecting voltage to the input terminals and auxiliary circuit • Make sure that it is safe to apply voltage. • Ensure that: - nobody is working on the unit or circuits that are wired from outside into the cabinet - covers of generator terminal boxes are in place. • Close the circuit breakers that connect the voltage to auxiliary devices, eg, fans, boards, main breaker/contactor control circuit, emergency stop circuit, 24 V DC power supply. • Check that cabinet covers are in place and close the doors. • Converter with 400 mm wide incoming unit (option +C111): Close the main switch disconnector (Q1). • Converter with grid-side air circuit breaker and stator contactor(s) (option +C108 or +C109): Rack the withdrawable breaker in.	To locate the circuit breakers, see the delivery-specific circuit diagrams and the cubicle designations on cabinet doors.
☐	Ensure that the grid and/or stator circuit switchgears is/are disabled and unintended connection is disabled (safety operation).	
☐	Option +C108 or +C109: Check and make appropriate settings for the main circuit breaker. For further information on the main circuit breaker settings, see section *Main circuit breaker settings in the start-up (option +C108 or +C109)* on page *120*.	
○	Set the frequency of the main circuit breaker according to the grid frequency in use (50 or 60 Hz). Factory setting is 50 Hz.	
☐	Enable the memory backup battery on the PPCS branching units (APBU) by setting actuator 6 of switch S3 to ON.	The branching units are located in the sliding frame of the auxiliary control cubicle. By default, the memory backup is switched off to save the battery.

<table>
<tr><th colspan="3">1. FIRST STEPS</th></tr>
<tr><td>☐</td><td colspan="2">Connect PC to the converter as a ring connection:
• Fibre optic cable connections between NDCU and RDCU control units channels CH3 and CH4.
• Note: If a NETA-01 module is connected, disconnect the fibre optic cables coming from the NETA-01 to the channel CH3 of the RDCO module and channel CH4 of the NIOC board.


For instructions on DriveWindow use, see page 90.</td></tr>
<tr><td>☐</td><td>Start DriveWindow PC tool and make connection to the converter by choosing ABB.SMP server and pressing OK button.</td><td>
</td></tr>
<tr><td>○</td><td>Check from browse tree pane that the connection to both converters is established properly.
Note: If all connected converters are not seen through the optical ring, check that the node addresses of NDCU and RDCU control units are set properly:
• Rotor-side converter (NDCU) AMC board node address 70.15 CH3 NODE ADDR should be 11
• Rotor-side converter (NDCU) AMC board node address 70.21 CH4 NODE ADDR should be 11
• Grid-side converter (RDCU) RMIO board node address 70.15 CH3 NODE ADDR should be 21.
Note: A new node address becomes valid only after the next power-up of the NDCU/RDCU control unit.</td><td>
</td></tr>
<tr><td>☐</td><td>Select and activate the rotor-side converter (INU) by clicking it in the browse tree pane.</td><td>
</td></tr>
</table>

1. FIRST STEPS

☐	Take local control by clicking the **Take/Release Control** button in the converter panel toolbar.	
○	Check that control is activated successfully. If control is taken successfully, status image, converter name, field for entering the reference value and command buttons are shown in the drive panel toolbar.	
☐	Open the parameter window in DriveWindow PC tool.	

2. SETTING THE GRID-SIDE CONVERTER PARAMETERS (COMMON FOR ALL DELIVERIES)		
For diagrams of the configurations, see page 49.		
Note: By double clicking a parameter you can enter to edit mode and change the value of the parameter.		
☐	Select and activate the grid-side converter (ISU) by clicking it in the browse tree pane.	
■ **SYSTEM CONTROL INPUTS**		
☐ ○	Enable parameters for editing: 16.02 PARAMETER LOCK * LOCKED/OPEN The lock is open. Parameter values can be changed.	OPEN
■ **REFERENCE SELECT**		
☐ ○	Choose the type for the used reactive power reference: 11.02 Q REF SELECT * PARAM 24.01 / AI1 / AI2 / AI3 / PARAM 24.02 Defines the source for the reactive power reference.	PARAM 24.02
■ **REACTIVE POWER**		
☐ ○	Choose the type for the used reactive power reference: 24.03 Q POWER REF2 SEL * PERCENT / kVAr / PHI / COSPHI / IQ REF / AC REF Selects the reference unit. Factory setting value is PERCENT.	**Note:** It is recommended to use the same reference value than in the rotor-side converter parameter 23.04 REACT POW REF SEL.
■ **WIND CONTROL**		
☐ ○	Check that RT function is disabled: 40.01 RT ENABLE * OFF / ON The RT function is not active. Recommended during the commissioning.	OFF
☐ ○	Check that the auxiliary measuring unit (NAMU-01) is enabled: 40.02 NAMU BOARD ENABLE * ON / OFF Enables the NAMU-01 voltage measuring unit if the value in parameter 01.11 MAINS VOLTAGE is correct and the fault led of NAMU-01 unit is not blinking.	ON
■ **OPTION MODULES**		
☐ ○	Check that the grid-side converter system control inputs are selected as follows: 98.02 COMM. MODULE * NO / FIELDBUS / ADVANT / N-FB / STD MODBUS / CACP / CASCADE / INU COM WIDE / INU COM LIM By activating this parameter the grid-side converter is controlled by the rotor-side converter as a cascade system.	CASCADE

2. SETTING THE GRID-SIDE CONVERTER PARAMETERS (COMMON FOR ALL DELIVERIES)		
○	98.11 AI/O EXT MODULE 1 * NOT IN USE / RAIO-SLOT1 / RAIO-SLOT2 / RAIO-DDCS By activating this parameter the inlet and outlet coolant temperatures are monitored.	RAIO-SLOT1
■ **START-UP DATA**		
☐	Check that the automatic grid-side converter identification run is activated:	
○	99.08 AUTO LINE ID RUN * NO / YES The identification run is requested automatically after the RMIO board power-up. The identification run starts automatically when the grid-side converter receives the start command.	YES

3. SETTING THE ROTOR-SIDE CONVERTER PARAMETERS (COMMON FOR ALL DELIVERIES)

For diagrams of the configurations, see page 49.

Note: By double clicking a parameter you can enter to edit mode and change the value of the parameter.

☐	Select and activate the rotor-side converter by clicking it in the browse tree pane.	
■ SYSTEM CONTROL INPUTS		
☐	Enable parameters for editing:	
○	16.01 PARAM LOCK * OFF / ON Editing certain parameters is disabled without opening the parameter lock.	OFF
○	16.02 PANEL PAR LOCK * OPEN / LOCKED The lock is open. Parameter values can be changed.	OPEN
☐	Check/Enter grid connection mode:	
○	16.20 GRID CONNECT MODE * MCB3 / MCB1+MCB3/A / MCB1+MCB3/B / MCB1+MCB3/C This selection is used with all ACS800-67LC construction types.	MCB1+MCB3/B
■ LIMITS		
☐	Enter the parameter values:	
○	20.05 USER POS TORQ LIM * maximum allowable motoring torque in % Factory setting value is 20.	
○	20.06 USER NEG TORQ LIM * minimum allowable generating torque in % Factory setting value is -20.	
○	20.21 SWITCH ON SPEED * speed level in rpm that enables the stator circuit synchronisation and grid interconnection Factory setting value is 950 rpm. For choosing the correct SWITCH ON SPEED and SWITCH OFF SPEED, see section *Wind turbine system operating speed area* on page 19.	
○	20.22 SWITCH OFF SPEED * speed level in rpm that forces the stator circuit disconnection from the grid Factory setting value is 925 rpm.	
■ FIELDBUS REFERENCES		
☐	Select the reactive power reference type:	
○	23.04 REACT POW REF SEL * PERCENT / KVAR / PHII / COSPHII / U_AC REF / I_R REF Factory setting value is KVAR.	**Note:** It is recommended to use the same reference value than in the grid-side converter parameter 24.03 Q POWER REF2 SEL.
■ TORQUE/POWER SELECTOR		
☐	Select the torque or power reference type:	

3. SETTING THE ROTOR-SIDE CONVERTER PARAMETERS (COMMON FOR ALL DELIVERIES)		
○	27.01 TORQUE SELECTOR * ZERO / SPEED / TORQUE / MINIMUM / MAXIMUM / ADD / POWER Defines the reference source selector for the rotor-side converter torque controller.	**Note:** TORQUE or POWER is intended to be used in wind turbine applications.
■ **FAULT FUNCTIONS**		
☐	Enter/Check FAULT FUNCTIONS parameter values:	
○	30.04 STATOR CURR TRIP * stator current trip level in A During commissioning, set parameter value to 500 A.	500 A
○	30.05 AC OVERVOLT TRIP * maximum allowable short-term grid overvoltage in V Factory setting value is 828 V.	
○	30.06 AC UNDERVOLT TRIP * minimum allowable short-term grid under voltage in V Factory setting value is 552 V.	
○	30.07 AC OVERFREQ TRIP * maximum allowable short-term over frequency in Hz Factory setting value is 65 Hz.	
○	30.08 AC UNDERFREQ TRIP * minimum allowable short-term under frequency in Hz Factory setting value is 45 Hz.	
○	30.09 OVERSPEED LIMIT * maximum allowable generator rotor mechanical speed in 2100 rpm For choosing the correct speed limits, see section *Wind turbine system operating speed area* on page *19*.	
○	30.10 UNDERSPEED LIMIT * minimum allowable generator rotor mechanical speed in 900 rpm	
■ **CROWBAR**		
○	Check that the crowbar type is selected correctly: 31.01 CROWBAR HW TYPE * PASSIVE CB / ACTIVE CB / ONLY GRID SU / 2 ACTIVE CBs * April 1, 2012 onwards: * PASSIVE CB / ACTIVE CB / ONLY GRID SU / 2 ACTIVE CBs / 1 REV2 CB / 2 REV2 CBs / 3 REV2 CBs / 4 REV2 CBs For choosing the correct CROWBAR HW TYPE, see section *Crowbar settings* on page *48*.	
■ **SPEED MEASUREMENT**		
☐	Check/Enter the SPEED MEASUREMENT parameters:	
○	50.01 SPEED SCALING * defines the speed reference that corresponds to integer value 20000 used in fieldbus control Factory setting value is 2000.	

3. SETTING THE ROTOR-SIDE CONVERTER PARAMETERS (COMMON FOR ALL DELIVERIES)

○	50.04 PULSE NR * defines the number of the encoder pulses (eg, 1024 or 2048) Factory setting value is 2048.	
○	50.12 SP ACT FILT TIME * defines the time constant of the first order actual speed low pass filter in ms Factory setting value is 0 ms.	

START-UP DATA

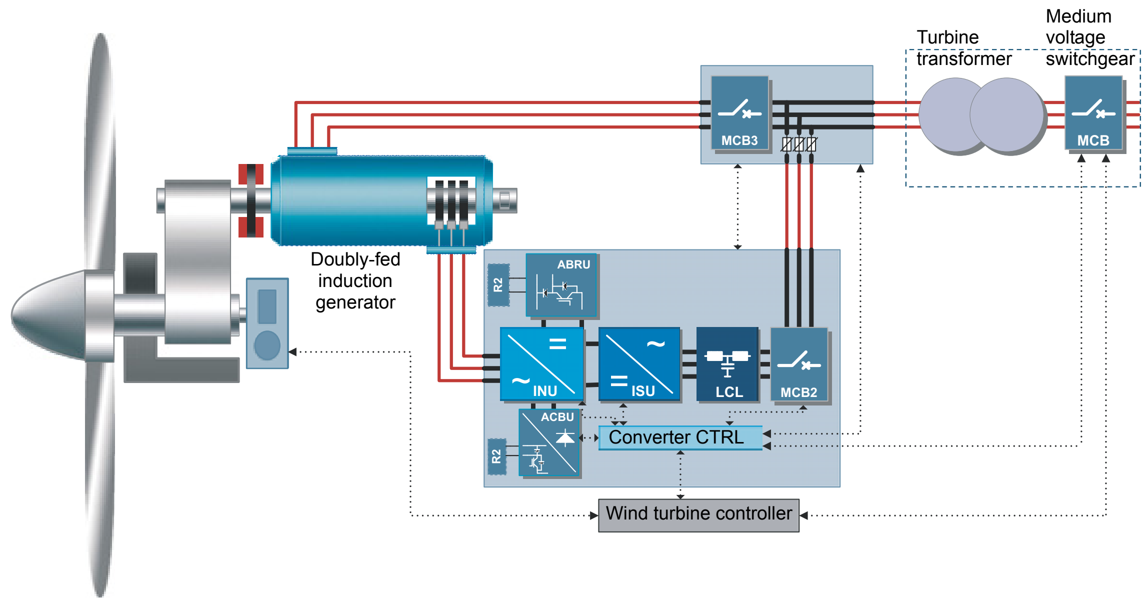
WARNING! Enter the start-up data exactly. Entering incorrect values results in wrong operation of the converter and/or entire system.

☐	For choosing the correct start-up data values, see section *Generator data* on page 97. Enter the START UP DATA parameters:	
○	99.02 MOTOR NOM VOLTAGE * rated stator voltage of the generator in V	
○	99.03 MOTOR NOM CURRENT * rated stator current of the generator A	
○	99.04 MOTOR NOM FREQ * rated stator frequency of the generator in Hz	
○	99.05 MOTOR NOM SPEED * rated speed of the generator in rpm	
○	99.06 MOTOR NOM POWER * rated speed of the system in rpm	
○	99.12 MOTOR NOM COSFII * rated power factor of the generator rotor	
○	99.14 MOTOR SYNC SPEED * rated synchronous speed of the generator in rpm	
○	99.15 MOTOR OPEN CKT V * rated open-circuit voltage of the generator rotor in V	
○	99.16 MOTOR NOM IM * rated magnetizing current of the generator rotor in A	
○	99.21 Rs * equivalent stator circuit resistance in stator reference frame in mOhm	
○	99.22 X1S * equivalent stator circuit leakage reactance in stator reference frame in mOhm	
○	99.23 X2S * equivalent rotor circuit leakage reactance in stator reference frame in mOhm	
○	99.24 XM * equivalent magnetizing reactance of the generator in stator reference frame in mOhm	
○	99.25 Rr * equivalent rotor circuit resistance in stator reference frame in mOhm	

3. SETTING THE ROTOR-SIDE CONVERTER PARAMETERS (COMMON FOR ALL DELIVERIES)		
○	99.27 MAX MEAS FLUX * maximum measurable grid and stator fluxes in Wb For choosing the correct MAX MEAS FLUX, see section *Stator current and voltage measurement* on page *94*.	
○	99.28 MAX MEAS IS * maximum measurable stator current in A For choosing the correct MAX MEAS IS, see section *Stator current and voltage measurement* on page *94*.	
■	**DATE AND TIME SETTING**	
☐	Enter the correct date and time settings: **Note:** Settings for NDCU-33CX real-time clock are defined. Settings are used by the fault logger.	
○	95.07 RTC MODE * SHOW / SET Time/date can be set manually.	SET
○	95.01 YEAR * four-digit unsigned integer number (eg, 2010)	
○	95.02 MONTH * two-digit unsigned integer number (eg,12)	
○	95.03 DAY * two-digit unsigned integer number (eg, 15)	
○	95.04 HOUR * two-digit unsigned integer number (eg, 12)	
○	95.05 MINUTE * two-digit unsigned integer number (eg, 15)	
○	95.06 SECOND * two-digit unsigned integer number (eg, 12)	
○	95.07 RTC MODE * SHOW / SET Real-time clock runs.	SHOW

3. SETTING THE ROTOR-SIDE CONVERTER PARAMETERS

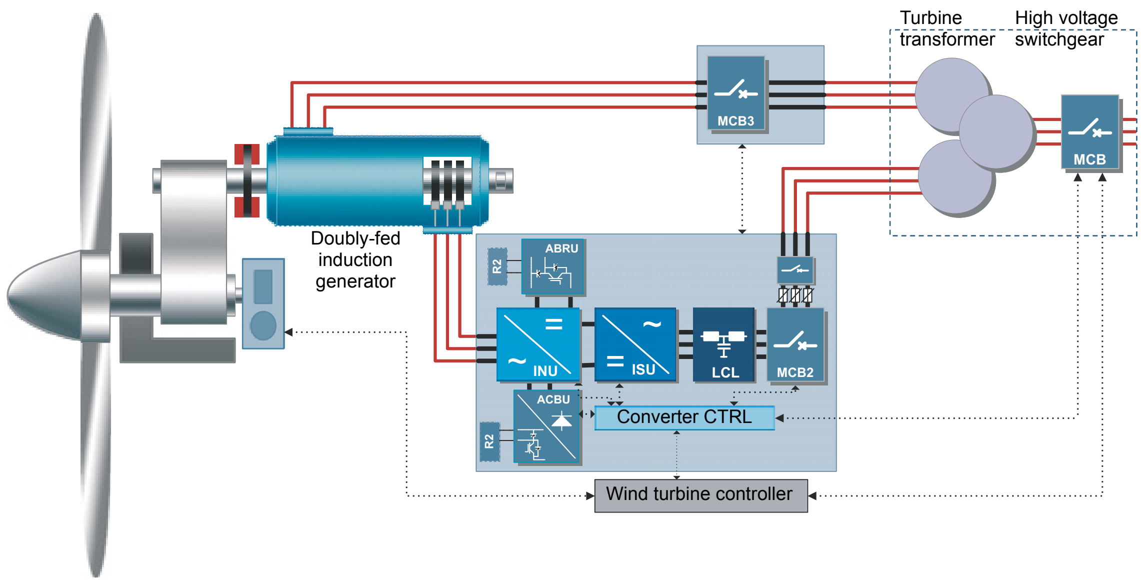
CONFIGURATION WITH LOW-VOLTAGE STATOR CIRCUIT BREAKER (MCB3)



☐	Select and activate the rotor-side converter by clicking it in the browse tree pane.	INU 800 1375_7LC {0}{11} ISU 800 1125_7LC {0}{21}
☐	Check/Enter parameters:	
○	20.27 CONT OPEN CUR * maximum allowable stator current in A that stator circuit switchgear can withstand (0 = function disabled, immediate stator circuit switchgear opening). See also section *Stator circuit connection to grid* on page *49*.	0

3. SETTING THE ROTOR-SIDE CONVERTER PARAMETERS

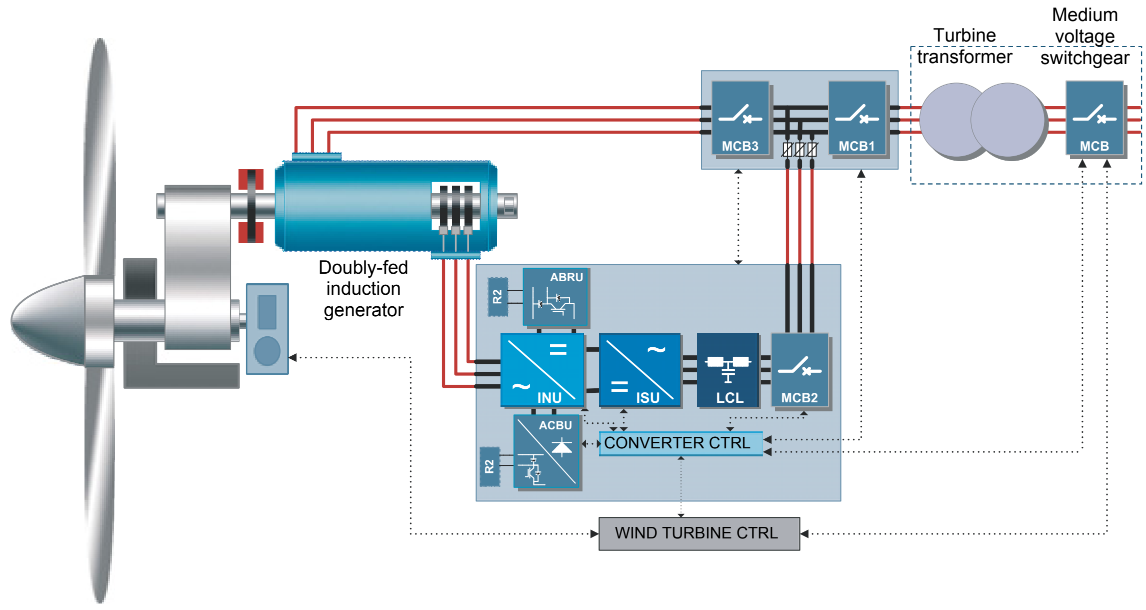
■ CONFIGURATION WITH MEDIUM-VOLTAGE STATOR CIRCUIT BREAKER (MCB3)



☐	Select and activate the rotor-side converter by clicking it in the browse tree pane.	
☐	Check/Enter parameters:	
○	20.27 CONT OPEN CUR * maximum allowable stator current in A that stator circuit switchgear can withstand (0 = function disabled, immediate stator circuit switchgear opening). See also section *Stator circuit connection to grid* on page *49*.	0

3. SETTING THE ROTOR-SIDE CONVERTER PARAMETERS

CONFIGURATION WITH LOW-VOLTAGE GRID BREAKER (MCB1) AND STATOR CIRCUIT BREAKER/CONTACTOR (MCB3)

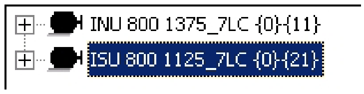
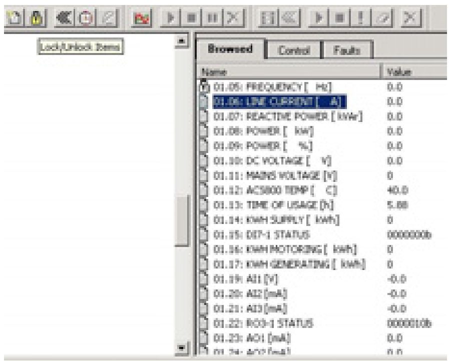


☐	Select and activate the rotor-side converter by clicking it in the browse tree pane.	
☐ ○	Check/Enter parameters: 20.27 CONT OPEN CUR * maximum allowable stator current in A that synchronizing stator circuit switchgear can withstand (0 = function disabled, immediate stator circuit switchgear opening). For choosing the correct CONT OPEN CUR, see section *Stator circuit connection to grid* on page *49*.	

4. OPERATIONAL LOCAL TESTING

■ PREPARATIONS

WARNING! The coolant circulation must be on before the converter is started and during its operation.

☐	Power down and power up the 230 V AC auxiliary supply to reboot all RDCU and NDCU control units.	F11 and F12 located in the auxiliary control unit
☐	Enable grid-side converter and rotor-side converter parameters for editing:	
○	Grid-side converter:	
	16.02 PARAMETER LOCK	OPEN
○	Rotor-side converter:	
	16.01 PARAM LOCK	OFF
	16.02 PANEL PAR LOCK	OPEN
☐	Open the main circuit switchgear from the locked position.	
☐	Select and activate the grid-side converter by clicking it in the browse tree pane.	
☐	Select and lock-out the following grid-side converter signals and parameters to the DriveWindow screen by using **Lock/Unlock Items** button in the standard toolbar:	
	01.05 FREQUENCY	
	01.06 LINE CURRENT	
	01.10 DC VOLTAGE	
	01.11 MAINS VOLTAGE	
	01.20 AI2 [mA]	
	01.32 EXT TMP 1 [C]	
	01.33 EXT TMP 2 [C]	
	03.03 50 HZ IDENTIFICA	
	03.04 60 Hz IDENTIFICA	
	40.09 RT U/Un MOD STOP	
	99.08 AUTO LINE ID RUN	
	Note: Parameters can be monitored actively in the window with the clock button.	
☐	Select and activate the rotor-side converter by clicking it in the browse tree pane.	

4. OPERATIONAL LOCAL TESTING

☐ Select and lock-out the following rotor-side converter signals and parameters to the DriveWindow Item sets panel by using **Lock/Unlock Items** button in the standard toolbar:

01.01 MOTOR SPEED

01.02 GENERATOR TORQUE

01.05 NET FREQUENCY

01.06 LINE CURRENT[A]

01.07 REACT POWER[kVAr]

01.08 POWER [kW]

01.10 DC VOLTAGE

01.11 MAINS VOLTAGE

01.12 PP TEMPERATURE

01.15 DI STATUS

01.17 ISU PP TEMP [C]

01.18 CABIN TEMP [C]

02.01 STATOR IS (RMS)

02.02 STATOR VOLTAGE

02.03 STATOR POWER

02.04 STATOR KVAR

02.06 ROTOR IR (RMS)

02.07 ROTOR VOLTAGE

02.08 ROTOR POWER

02.10 SWITCHING FREQ

05.01 ISU MAINS VOLT[V]

05.02 ISU CURRENT [A]

05.03 ISU POWER [kW]

05.04 ISU REACT P[kVAr]

05.06 ISU DI6-1 STATUS

05.08 ISU AI2 [mA]

05.30 ISU EXT1 TEMP [C]

05.31 ISU EXT2 TEMP [C]

06.11 CB BRIDGE VOLTAGE

06.12 CB IGBT VOLTAGE

06.13 CB IGBT TEMP

In case of two ACBU-A2 crowbar units:

- 6.31 CB2 BRIDGE VOLTAGE
- 6.32 CB2 IGBT VOLTAGE

08.01 MAIN STATUS WORD

08.10 CCU STATUS WORD

08.11 ISU STATUS WORD

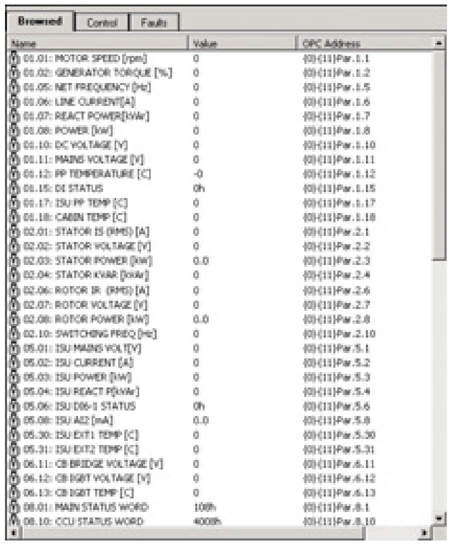
21.01 ISU LOCAL CTR WORD

21.08 MANUAL TRIGGER

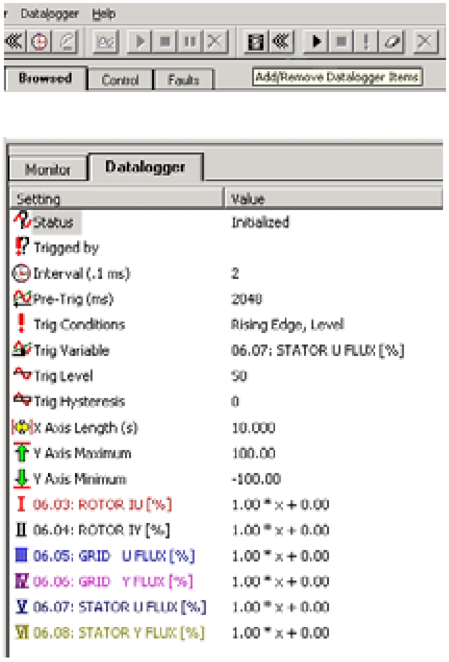
99.24 XM

99.26 XM CALIBRATED

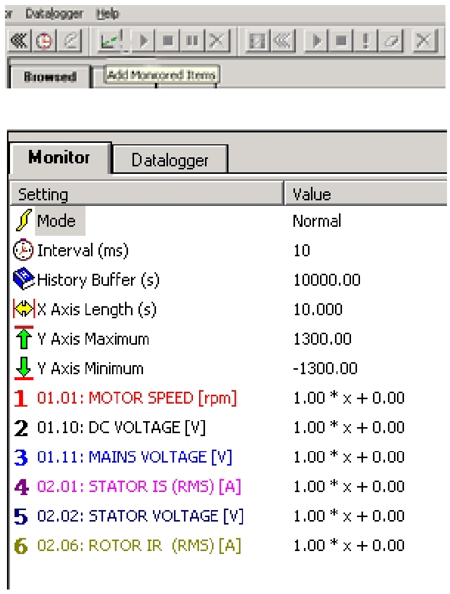
Note: Parameters can be monitored actively in the window with the clock button.



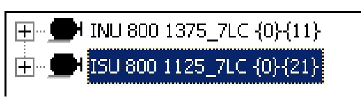
4. OPERATIONAL LOCAL TESTING

<table>
<tr>
<td>☐</td>
<td>Select/Set the following rotor-side converter signals and settings to the DriveWindow Trend Setting Pane's Datalogger 1 window:
• 06.03 ROTOR IU
• 06.04 ROTOR IY
• 06.05 GRID U FLUX
• 06.06 GRID Y FLUX
• 06.07 STATOR U FLUX
• 06.08 STATOR Y FLUX
Select/Set the following settings to the Datalogger 1 window:
• Interval = 2
• Pre-Trig = 50
• Trigg Conditions = Level, rising edge
• Trig Variable = 06.07 STATOR U FLUX
• Trigg Level = 50
• Trig Hysteresis = 0
• X Axis Length = 0.2
• Y Axis Maximum = 100
• Y Axis Minimum = -100
Note: To change the datalogger data, stop the datalogger first.</td>
<td>
</td>
</tr>
<tr>
<td>☐</td>
<td>Select/Set the following rotor-side converter signals and settings to the DriveWindow Trend Setting Pane's Datalogger 2 window:
In case of one ACBU-A2:
• 06.11 CB BRIDGE VOLTAGE
• 06.12 CB IGBT VOLTAGE
In case of two ACBU-A2:
• 06.11 CB BRIDGE VOLTAGE
• 06.12 CB IGBT VOLTAGE
• 06.31 CB2 BRIDGE VOLTAGE
• 06.32 CB2 IGBT VOLTAGE
<u>April 1, 2012 onwards:</u>
• 06.11 CB BRIDGE VOLTAGE
• 06.12 CB IGBT VOLTAGE
Select/Set the following settings to the Datalogger 2 window:
• Interval = 2
• Pre-Trig = 200
• Trigg Conditions = Level, Falling edge
• Trig Variable = 06.11 CB BRIDGE VOLTAGE
• Trigg Level = 700
• Trig Hysteresis = 2
• X Axis Length = 0.150
• Y Axis Maximum = 1200
• Y Axis Minimum = 0</td>
<td>
</td>
</tr>
</table>

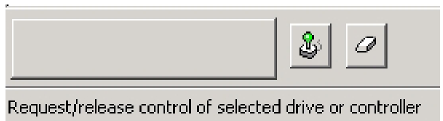
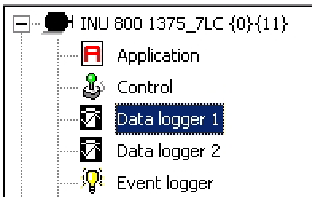
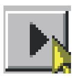
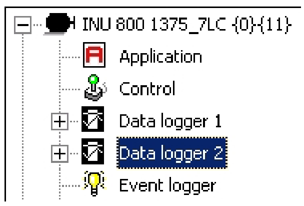
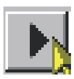
4. OPERATIONAL LOCAL TESTING

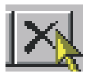
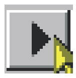
☐	Select/Set the following rotor-side converter signals and settings to the DriveWindow Trend Setting Pane's Monitor window: • 01.01 MOTOR SPEED [rpm] • 01.10 DC VOLTAGE [V] • 01.11 MAINS VOLTAGE [V] • 02.01 STATOR IS [RMS] • 02.02 STATOR VOLTAGE [V] • 02.06 ROTOR IR [RMS] Select/Set the following settings to the Monitor window: • Mode = Normal • Interval = 10 • History Buffer = 10000 • X Axis Length = 10 • Y Axis Maximum = 1300 (depends on the generator speed) • Y Axis Minimum = 0	
■	**GRID-SIDE CONVERTER LOCAL TESTING**	
	Internal communication between the grid-side converter and the rotor-side converter is checked by using the rotor-side converter parameters to start-up the grid-side converter.	
☐	Reset possible converter faults by clicking the **Reset Fault** button.	
☐	Check by using DriveWindow Item sets pane window that:	
○	The pressure sensor is measuring the cooling circulation pressure correctly: 01.20 AI2 [mA] See also section *Measurements of the pressure transmitter* on page *118*.	Measuring range: 0…10 bar 4…20 mA Normal operation pressure range: 5.9…10.1 mA (1.2…3.8 bar)
○	The temperature sensors are measuring the cooling circuit inlet and outlet temperatures correctly 01.32 EXT TMP 1 [C] LIQUID TEMPERATURE INLET 01.33 EXT TMP 2 [C] LIQUID TEMPERATURE OUTLET	Alarm and trip limits for temperature measurements are defined in the parameters: 30.21 EXT TMP 1 FLT LO (def = 4 °C) 30.22 EXT TMP 1 ALM LO (def = 7 °C) 30.23 EXT TMP 1 ALM HI (def = 46 °C) 30.24 EXT TMP 1 FLT HI (def = 56 °C) 30.27 EXT TMP 2 FLT LO (def = 4 °C) 30.28 EXT TMP 2 ALM LO (def = 7 °C) 30.29 EXT TMP 2 ALM HI (def = 60 °C) 30.30 EXT TMP 2 FLT HI (def = 65 °C)
☐	Check that the grid-side converter voltage measurement is adjusted correctly (NAMU-01 board):	
○	01.11 MAINS VOLTAGE * measurement is correct when the voltage corresponds to the level of the system phase-to-phase RMS voltage (eg, 690 Vac or 600 Vac)	~690 Vac or ~600 Vac

4. OPERATIONAL LOCAL TESTING

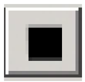
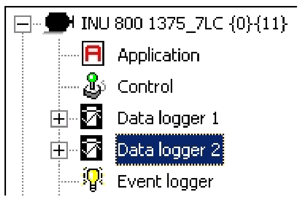
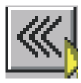
○	01.05 FREQUENCY * measurement is correct when the sign of the frequency is positive and it corresponds to the level of the system fundamental frequency (eg, 50 Hz or 60 Hz)	~50 Hz or ~60 Hz
□	Start the grid-side converter by setting the rotor-side converter parameter:	
○	21.01 ISU LOCAL CTR WORD * If the converter is in local control mode and has not been started, grid-side converter can be controlled with this parameter.	9h (hex)
□	Check by using DriveWindow's Item sets pane window that the following sequence is completed properly: • DC link is charged • Grid-side converter main contactor closed • Grid-side converter starts to modulate	
○	01.10 DC VOLTAGE * DC link is charged when the voltage level is approximately 980±10% Vdc or 850±10% Vdc Typical DC link voltage equals to sqrt(2)×U_n	~ 980 Vdc or ~850 Vdc
○	08.11 ISU STATUS WORD * Main contactor (MCB2) is closed and the grid-side converter is modulating when the status word equals to 27B7h (hex).	27B7h (hex)
○	01.06 LINE CURRENT * Modulation is active when the average line current is approximately 50 A	~ 15…50 A
□	Stop the grid-side converter by setting the parameter: 21.01 ISU LOCAL CTR WORD * If the converter is in local control mode and has not been started, grid-side converter can be controlled with this parameter.	0h (hex)
□	Check by using DriveWindow's Item sets pane window that the following sequence is completed properly: • Grid-side converter stops modulating • Grid-side converter main contactor opened • DC link is being discharged, which takes about 40 s.	
○	01.06 LINE CURRENT * Modulation is stopped when the average line current is 0 A.	0 A
○	08.11 ISU STATUS WORD * Main contactor (MCB2) is opened when the status word equals to 2B1h (hex).	2B1h (hex)
○	01.10 DC VOLTAGE * DC link is discharged when the voltage level is 0 Vdc (this may take a couple of minutes).	0
□	Select and activate the grid-side converter by clicking it in the browse tree pane.	

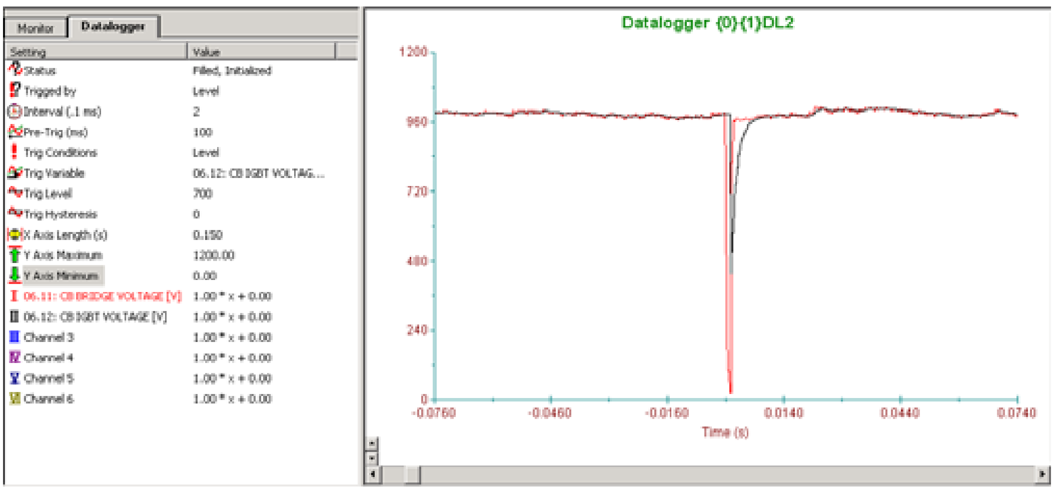
4. OPERATIONAL LOCAL TESTING

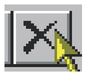
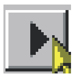
☐	Check that the grid-side converter is synchronized correctly to the grid:	
○	03.03 50 Hz IDENTIFIC * FALSE / TRUE If the nominal frequency is 50 Hz, the parameter 50 Hz IDENTIFIC is set to TRUE.	
○	03.04 60 Hz IDENTIFIC * FALSE / TRUE If the nominal frequency is 60 Hz, the parameter 60 Hz IDENTIFIC is set to TRUE.	
☐	Change the grid-side converter identification parameter: 99.08 AUTO LINE ID RUN * NO / YES Automatic identification is disabled.	NO
■	**ROTOR-SIDE CONVERTER LOCAL TESTING AT ZERO SPEED**	
	The converter general functionality (grid-side converter and rotor-side converter) is checked by using the rotor-side converter parameters to start-up the grid-side converter and rotor-side converter at zero speed.	
☐	Ensure that the generator shaft is mechanically locked.	
☐	Select and activate the rotor-side converter by clicking it in the browse tree pane.	
☐	Switch the rotor-side converter to local control mode by clicking the **Take/Release Control** button in the converter panel toolbar.	
☐	Reset possible converter faults by clicking the **Reset Fault** button.	
☐	Select dataloggers instead of monitor by clicking the **Datalogger** tab in the trend settings pane.	
☐	Select **Data logger 1** in the browse tree pane.	
○	Start the datalogger 1 by clicking the **Start Datalogger** button in the logger toolbar.	
○	Select Data logger 2 from the browse tree pane.	
○	Start the datalogger 2 by clicking the **Start Datalogger** button in the logger toolbar.	

4. OPERATIONAL LOCAL TESTING		
☐	Select monitor instead of the dataloggers by clicking the **Monitor** tab in the trend settings pane.	
○	Clear the monitor window by clicking the **Clear Monitor** button in the monitor toolbar.	
○	Start the monitor window by clicking the **Start or Continue Monitoring** button in the monitor toolbar.	
☐	Disable the stator circuit switchgear (MCB3) interconnection function by setting parameter: 21.02 DISABLE MCB CLOSE * YES / NO	YES
☐	Click the **Stop** button.	
☐	Start the converter by clicking the **Start** button.	
☐	Check by using DriveWindow's Item sets pane window that the following sequence is completed properly: • DC link is charged • Grid-side converter starts to modulate • Rotor-side converter starts to modulate	
○	01.10 DC VOLTAGE	~ 980 V DC ± 10% or ~ 850 V DC ± 10%
○	05.02 ISU CURRENT [A] * Modulation is active when the average line current is approximately 50 A.	~ 15…50 A
○	02.06 ROTOR IR (RMS) * Modulation is active when the average rotor current is approximately 50 A.	~ 50 A
☐	Check by using DriveWindow's Item sets pane window that crowbar(s) is/are measuring the voltages correctly:	
○	In case of one ACBU-A2: 06.11 CB BRIDGE VOLTAGE * The bridge voltage of the crowbar is correct when it is greater or equal than the DC link voltage (1.10 DC VOLTAGE). 06.12 CB IGBT VOLTAGE * IGBT voltage of the crowbar is correct when it is greater or equal than DC link voltage (1.10 DC VOLTAGE). 06.13 CB IGBT TEMP * Temperature of the crowbar IGBT is correct when it is approximately 25…40 °C.	

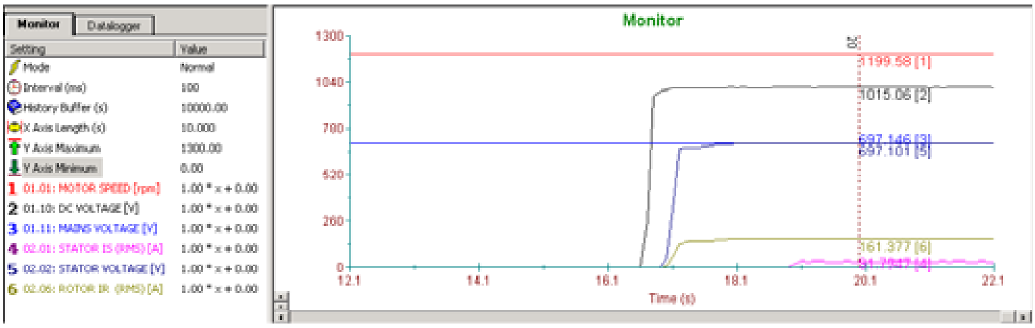
4. OPERATIONAL LOCAL TESTING

○	In case of two ACBU-A2: 06.11 CB BRIDGE VOLTAGE * The bridge voltage of the crowbar is correct when it is greater or equal than DC link voltage (1.10 DC VOLTAGE). 06.12 CB IGBT VOLTAGE * IGBT voltage of the crowbar is correct when it is greater or equal than DC link voltage (1.10 DC VOLTAGE). 06.13 CB IGBT TEMP * Temperature of the crowbar IGBT is correct when it is approximately 25…40 °C. <u>April 1, 2012 onwards:</u> 06.11 CB BRIDGE VOLTAGE * The bridge voltage of the crowbar is correct when it is greater or equal than the DC link voltage (1.10 DC VOLTAGE).	
☐	Stop the monitoring by clicking **Stop Monitoring** button in the monitor toolbar.	
☐	Test the crowbar(s) functionality by using automatic manual triggering function by setting the parameter:	
○	21.08 MANUAL TRIGGER * OFF / TRIGGER CB	TRIGGER CB
○	Select datalogger 2.	
○	Upload the current datalogger by clicking the **Upload Datalogger** button in the logger toolbar.	
○	Check that the measured diode bridge voltage (6.11 CB BRIDGE VOLTAGE) drops for a short period of time when triggered.	

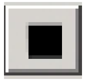


4. OPERATIONAL LOCAL TESTING		
☐	Stop the converter with the **Stop** button.	
■	**ROTOR-SIDE CONVERTER LOCAL TESTING: LOW-VOLTAGE STATOR CIRCUIT BREAKER**	
☐	Disable the stator circuit switchgear grid interconnection by setting parameter: 21.02 DISABLE MCB CLOSE	YES
☐	Check by using DriveWindow's Item sets pane window that the wind turbine rotates the rotor within acceptable speed range: 01.01 MOTOR SPEED * It is recommended to make local testing by using sub-synchronous speed area (eg, in case of 4-pole generator speed area is 1050...1300 rpm). If the wirings between the pulse encoder (NTAC, located in the auxiliary control unit) and generator speed sensor (tachometer) are done correctly the measured speed is positive.	
☐	Check that the dataloggers (datalogger 1 and datalogger 2) are in Running and Initialized mode.	
☐	Select monitor instead of the dataloggers by clicking the **Monitor** tab in the trend settings pane.	
○	Clear the monitor window by clicking the **Clear Monitor** button in the monitor toolbar.	
○	Start the monitor window by clicking the **Start or Continue Monitoring** button in the monitor toolbar.	
☐	Start the converter by clicking the **Start** button.	
○	Check by using DriveWindow's Trend Setting Pane's Monitor window that the selected signals are behaving normally: 01.01 MOTOR SPEED [rpm] 01.10 DC VOLTAGE [V] 01.11 MAINS VOLTAGE [V] 02.01 STATOR IS [RMS] 02.02 STATOR VOLTAGE [V] 02.06 ROTOR IR [RMS]	

4. OPERATIONAL LOCAL TESTING



○ Stop the monitoring by clicking the **Stop Monitoring** button in the monitor toolbar.



○ Check by using DriveWindow's Item sets pane window that the following sequence is completed properly:

99.24 XM and 99.26 XM CALIBRATED

* If parameter values differ ±20%, stop the converter and see section *Mutual inductance Xm and rotor resistance Rr calculations* on page *99* for calculating the correct value for the 99.24 XM.

☐ Stop the converter with the **Stop** button.

☐ Upload datalogger 1 and check that the rotor-side converter measurements and cablings are done correctly:

○ NUIM board measurement:

- Check that the amplitude values of 06.05 GRID U FLUX and 06.07 STATOR U FLUX are equal and in the same phase.
- Check that the amplitude values of 06.06 GRID Y FLUX and 06.08 STATOR Y FLUX are equal and in the same phase.
- Check that the phase angle displacement between X and Y FLUXES is in 90° (π/2 rad) and U FLUX is leading and Y FLUX is lagging.

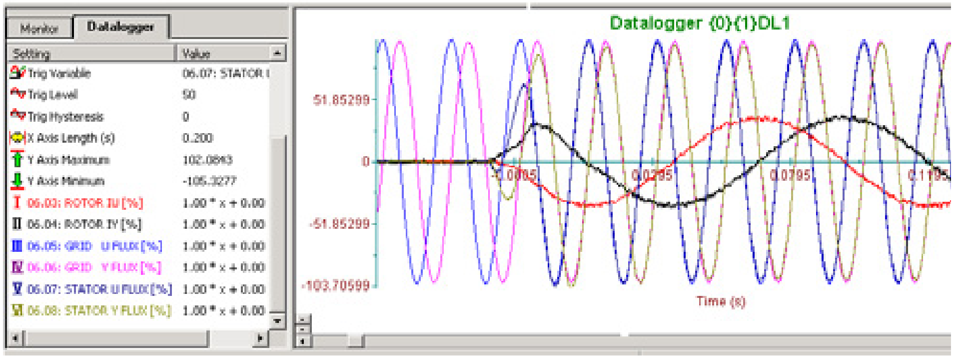
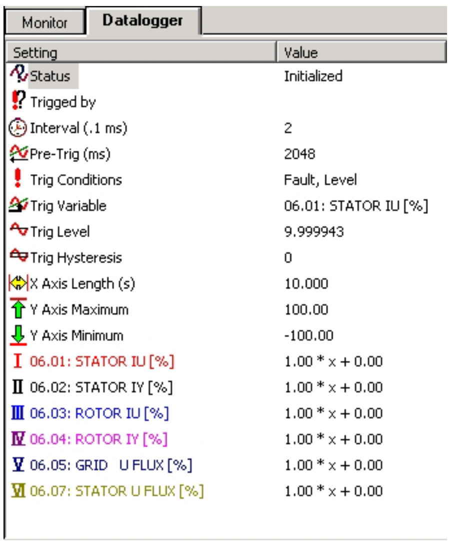
○ Rotor cabling:

- Check that the amplitudes of 06.03 ROTOR IU and 06.04 ROTOR IY are equal.
- Check that the phase angle displacement between 06.03 ROTOR IU and 06.04 ROTOR IY is 90° (π/2 rad).

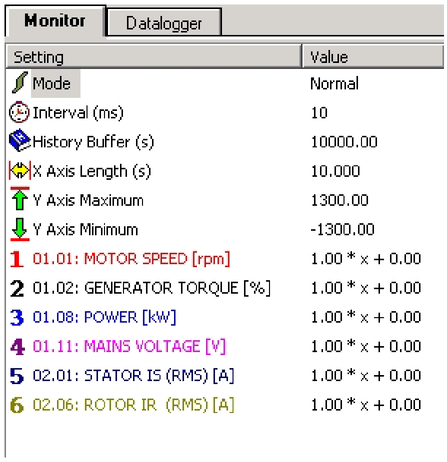
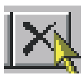
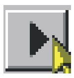
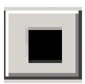
* 06.03 ROTOR IU is leading and 06.04 ROTOR IY is lagging when operating in the sub-synchronous area.

06.03 ROTOR IU is lagging and 06.04 ROTOR IY is leading when operating in the super-synchronous area.

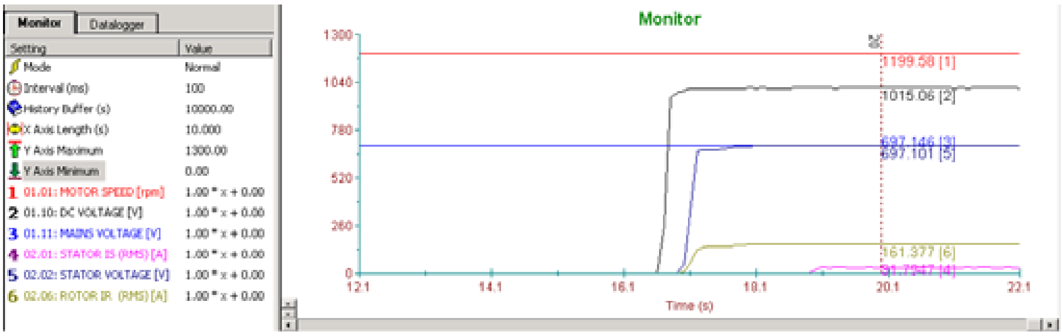
4. OPERATIONAL LOCAL TESTING

		
☐	Enable the stator circuit switchgear grid interconnection by setting parameter:	
○	21.02 DISABLE MCB CLOSE	NO
	* If grid synchronisation proceeds properly, stator circuit switchgear stays closed.	
☐	Select/Set the following rotor-side converter signals and settings to the DriveWindow Trend Setting Pane's Datalogger 1 window: • 06.01 STATOR IU • 06.02 STATOR IY • 06.03 ROTOR IU • 06.04 ROTOR IY • 06.05 GRID U FLUX • 06.07 STATOR U FLUX Select/Set the following settings to the Datalogger 1 window: • Interval = 2 • Pre-Trig = 2048 • Trigg Conditions = Level, Fault • Trig Variable = 06.01 STATOR IU • Trigg Level = 10 • Trig Hysteresis = 0 • X Axis Length = 10 • Y Axis Maximum = 100 • Y Axis Minimum = -100	

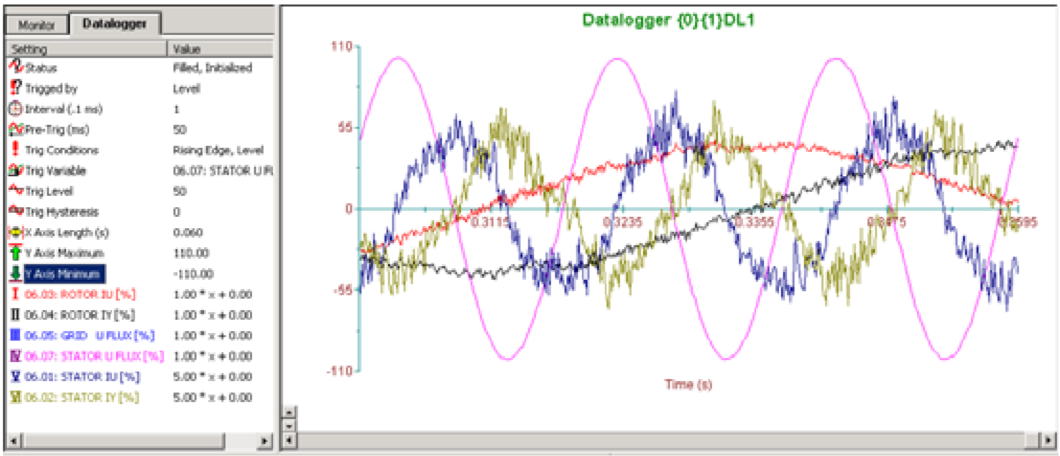
4. OPERATIONAL LOCAL TESTING

☐	Select/Set the following rotor-side converter signals and settings to the DriveWindow Trend Setting Pane's Monitor window: • 01.01 MOTOR SPEED [rpm] • 01.02 GENERATOR TORQUE • 01.08 POWER [kW] • 01.11 MAINS VOLTAGE [V] • 02.01 STATOR IS [RMS] • 02.06 ROTOR IR [RMS] Select/Set the following settings for the Monitor window: • Mode = Normal • Interval = 10 • History Buffer = 10000 • X Axis Length = 10 • Y Axis Maximum = 1300 • Y Axis Minimum = -1300	
☐	Check that all dataloggers (datalogger 1 and datalogger 2 from the grid-side and rotor-side converters) are in Running and Initialized mode.	
☐	Select monitoring instead of the dataloggers by clicking the **Monitor** tab in the trend settings pane.	
○	Clear the monitor window by clicking the **Clear Monitor** button in the monitor toolbar.	
○	Start the monitor window by clicking the **Start or Continue Monitoring** button in the monitor toolbar.	
☐	Start the converter by clicking the **Start** button.	
☐	Check the system stability by entering a small torque/ power reference, eg, 15%:	
○	In case of parameter 27.01 TORQUE SELECTOR set to TORQUE reference control mode: 25.04 TORQUE REF A * The system stability is correct if the actual torque value 01.02 GENERATOR TORQUE follows the given torque reference value.	15%
○	In case of parameter 27.01 TORQUE SELECTOR set to POWER reference control mode: 26.01 POWER REF * The system stability is correct if the actual power value 01.08 POWER [kW] follows the given power reference value.	15%
○	Stop the monitoring by clicking the **Stop Monitoring** button in the monitor toolbar.	

4. OPERATIONAL LOCAL TESTING

○	Check by using DriveWindow's Trend Setting Pane's Monitor window that the selected signals are behaving normally: 01.01 MOTOR SPEED [rpm] 01.10 DC VOLTAGE [V] 01.11 MAINS VOLTAGE [V] 02.01 STATOR IS [RMS] 02.02 STATOR VOLTAGE [V] 02.06 ROTOR IR [RMS]	
		
☐	Clear the torque/power reference set point value:	
○	In case of parameter 27.01 TORQUE SELECTOR set to TORQUE reference control mode: 25.04 TORQUE REF A * The system stability is correct if the actual torque value 01.02 GENERATOR TORQUE follows the given torque reference value.	0%
○	In case of parameter 27.01 TORQUE SELECTOR set to POWER reference control mode: 26.01 POWER REF * The system stability is correct if the actual power value 01.08 POWER [kW] follows the given power reference value.	0%
☐	Stop the converter with the **Stop** button.	
☐	Upload datalogger 1 and check that rotor-side converter measurements and cablings are done correctly:	
○	Stator cabling: • Check that the amplitudes of 06.01 STATOR IU and 06.02 STATOR IY are equal. • Check that the phase angle displacement between 06.01 STATOR IU and 06.02 STATOR IY is 90° (π/2 rad). * 06.01 STATOR IU is leading and 06.02 STATOR IY is lagging when operating in the sub-synchronous area. 06.01 STATOR IU is lagging and 06.02 STATOR IY is leading when operating in the super-synchronous area.	

4. OPERATIONAL LOCAL TESTING



☐	Disable the stator current fault trip limit by entering rotor-side converter parameter: 30.04 STATOR CURR TRIP * Stator overcurrent trip limit function is disabled.	0 A

GRID-SIDE CONVERTER AND DC CHOPPER LOCAL TESTING

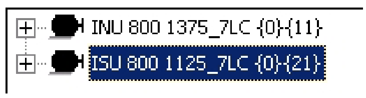
If the converter is not equipped with a DC chopper option (+D150 or +150/+151), continue to the next section.

☐	Configure the ABRU option(s) according to the instructions given in *ABRU-0x DC choppers (+D150) and resistors (+D151) for ACS800-67LC/-77LC/-87LC wind turbine converters hardware manual* [3AUA0000076494 (English)].	

FINALIZING THE PARAMETERISATION

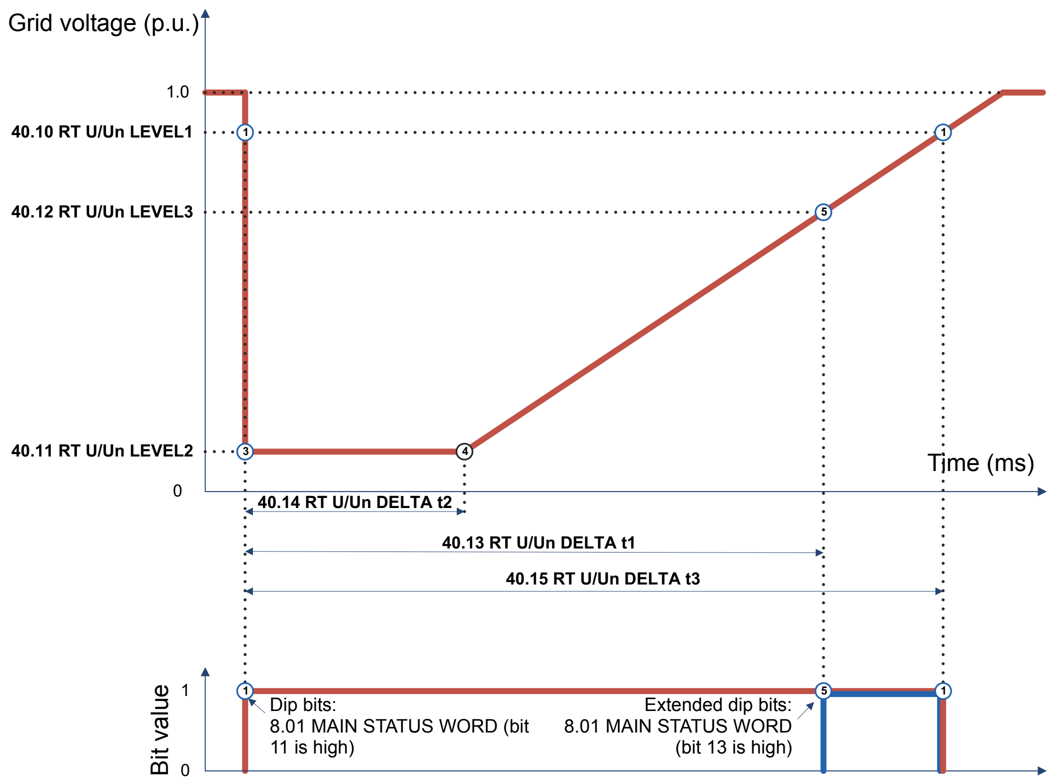
If there is no grid fault ride-through requirements for the wind turbine, continue to the next section.

GRID-SIDE CONVERTER GRID FAULT RIDE-THROUGH PARAMETERISATION

☐	Select and activate the grid-side converter by clicking it in the browse tree pane.	
☐	Activate grid-side converter fault ride-through function by entering the parameter: 40.01 RT ENABLE * ON = ride-through function is activated.	ON
☐	Select the type of voltage that the grid fault ride-through functions are based on (grid code specific): 40.04 PHASE MEAS ENA * OFF / ON OFF = Phase-to-phase voltage measurement ON = Phase-to-ground voltage measurement Factory setting value is ON.	

4. OPERATIONAL LOCAL TESTING

☐	Check that the grid-side converter modulation stop parameter is adjusted correctly: 40.09 RT U/Un MOD STOP * Grid-side converter modulation stops since the value of 01.11 MAINS VOLTAGE falls below the adjusted value of this parameter. Factory setting value is 10%.	
☐	Configure the grid-side converter grid fault ride-through voltage tripping levels according to the applied requirements (grid code specific):	**Note:** For entering correct grid fault tripping levels, see section *Setting the grid fault ride-through parameters* on page *42*.



Enter the AC voltage tripping levels:

40.10 RT U/Un LEVEL1

40.11 RT U/Un LEVEL2

40.12 RT U/Un LEVEL3

Enter the AC voltage tripping time durations:

40.13 RT U/Un DELTA t1

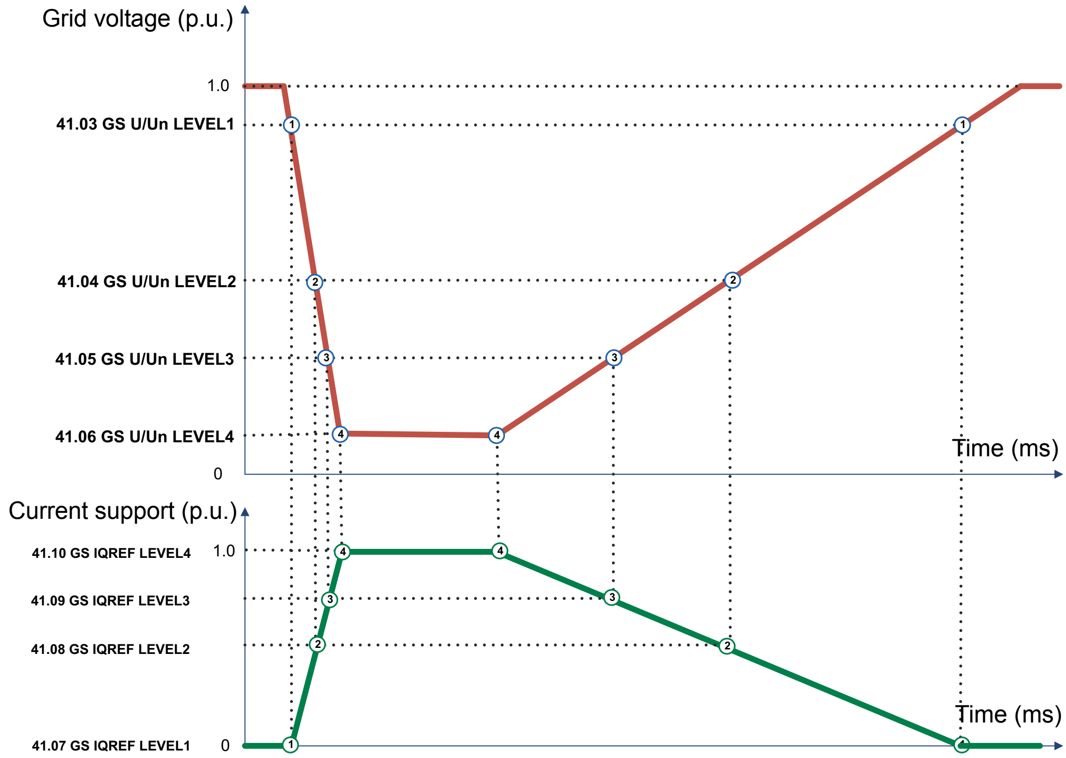
40.14 RT U/Un DELTA t2

40.15 RT U/Un DELTA t3

☐	Activate the grid-side converter grid support mode according to the applied requirements (grid code specific): 41.01 GRID SUPPORT MODE ON = grid support mode activated Grid support reference is used at normal voltage dip when 08.01 MAINS STATUS WORD bit 11 LEVEL1 DIP is set but bit 12 EXTENDED DIP is not set.	ON **Note:** If there is no grid support requirement during fault ride-through event, continue to the next section.

4. OPERATIONAL LOCAL TESTING

☐	Select the voltage method that the grid support is based on (grid code specific): 41.02 GS HIGHEST U ENA * If this parameter is enabled, converter uses highest RMS voltage for grid support instead of positive sequence voltage.	
☐	Configure the grid-side converter grid fault ride-through grid support parameters according to the applied requirements (grid code specific):	**Note:** For entering correct grid support levels, see section *Setting the grid fault ride-through parameters* on page *42*.



	Enter the AC voltage levels for grid support function: 41.03 GS U/Un LEVEL 1 41.04 GS U/Un LEVEL 2 41.05 GS U/Un LEVEL 3 41.06 GS U/Un LEVEL 4 Enter the reactive current grid support levels: 41.07 GS IQREF LEVEL 1 41.08 GS IQREF LEVEL 2 41.09 GS IQREF LEVEL 3 41.10 GS IQREF LEVEL 4	
☐	42.11 PLIM DIP COEF	
☐	42.13 GS GAIN ENABLE	
☐	42.14 GRID SUPPORT LIM	
☐	42.15 IMAX DIP	

4. OPERATIONAL LOCAL TESTING

■ GRID-SIDE CONVERTER TRANSIENT OVERVOLTAGE PARAMETERISATION

☐	Configure the transient overvoltage tripping levels according to the applied requirements (grid code specific). Enter the AC transient overvoltage tripping levels: 40.20 TRP VOLT PEAK 40.21 TRP VOLT LEV Enter the AC transient overvoltage tripping time duration: 40.22 TRP VOLT TIME	**Note:** If there are no grid transient overvoltage requirements, continue to the next section.
☐	Select the voltage method that the transient overvoltage protection is based on (grid code specific): 40.23 TRP VOLT SEL * POS SEQ / RMS VOLTAGE Factory setting value is RMS VOLTAGE.	

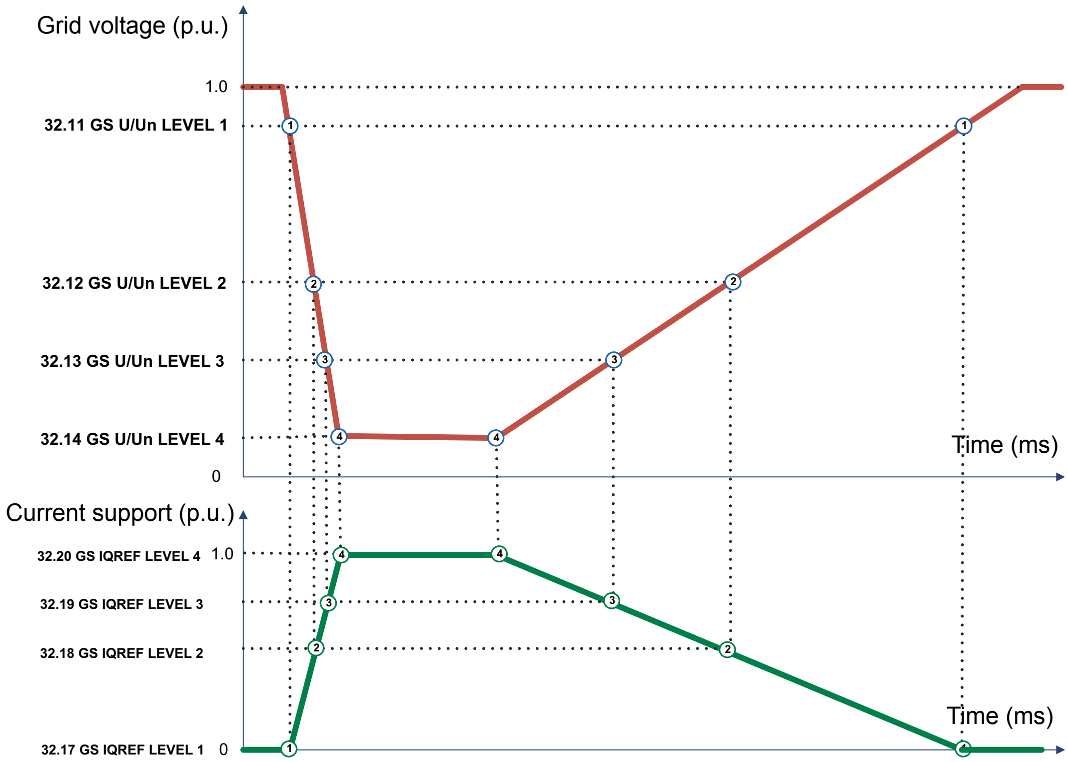
■ ROTOR-SIDE CONVERTER GRID FAULT RIDE-THROUGH PARAMETERISATION

☐	Select and activate the rotor-side converter by clicking it in the browse tree pane.	
☐	Configure rotor-side converter grid fault ride-through voltage tripping levels according to the applied requirements (grid code specific). For entering correct grid fault tripping levels, see section *Setting the grid fault ride-through parameters* on page *42*. Parameter setting examples are given in section *Parameter setting examples according to grid code* on page *46*. Enter the AC voltage tripping levels: 32.03 RT U/Un LEVEL1 32.04 RT U/Un LEVEL2 32.05 RT U/Un LEVEL3 32.10 RT U/Un LEVELHYST Enter the AC voltage tripping time durations: 32.06 RT U/Un DELTA t1 32.07 RT U/Un DELTA t2 32.08 RT U/Un DELTA t3 32.09 RT U/Un DELTA t4	**Note:** If you set parameter 32.41 ENVELOPE PAR SEL to PAR2, DriveWindow must be reconnected to access to the new parameters 32.42…32.88.
☐	Activate the rotor-side converter grid support mode according to the applied requirements (grid code specific): 32.01 GRID SUPPORT MODE Factory setting value is OFF.	**Note:** If there is no grid support requirements during the grid fault ride-through event, continue to the next section.

4. OPERATIONAL LOCAL TESTING

☐ Configure the rotor-side converter grid fault ride-through grid support parameters according to the applied requirements (grid code specific):

Note: For entering correct grid support levels, see section *Setting the grid fault ride-through parameters* on page *42*.



Enter the AC voltage levels for grid support function:

32.11 GS U/Un LEVEL 1

32.12 GS U/Un LEVEL 2

32.13 GS U/Un LEVEL 3

32.14 GS U/Un LEVEL 4

Enter the reactive current grid support levels:

32.17 GS IQREF LEVEL 1

32.18 GS IQREF LEVEL 2

32.19 GS IQREF LEVEL 3

32.20 GS IQREF LEVEL 4

☐ Configure the rotor-side converter grid support parameters during a fault clearance according to the applied requirements (grid code specific).

Enter the AC voltage levels for grid support function during a fault clearance:

32.15 GS U/Un LEVEL 5

32.16 GS U/Un LEVEL 6

Enter the reactive current grid support levels during a fault clearance:

32.21 GS IQREF LEVEL 5

32.22 GS IQREF LEVEL 6

Set the current priority selectors:

32.35 PRIORITY t<t4

32.36 PRIORITY t>t4

4. OPERATIONAL LOCAL TESTING		
☐	Configure the rotor-side converter grid support parameters after a fault clearance according to the applied requirements (grid code specific). Enter the AC voltage levels for grid support function after a fault clearance: 32.23 GS AFTER DIP Enter the reactive current grid support time duration after a fault clearance: 32.24 GS TIME AFTER DIP	**Note:** If there are no requirements concerning this event, continue to the next checkpoint.
☐	Enter the reactive current support restoring ramp time of the rotor-side converter: 32.25 KVAR RISE TIME * Defines the ramp time for the grid support reactive current reference starting from zero.	
☐	Enter the rotor-side converter torque restoring ramp time: 32.26 TORQUE RISE TIME * Defines the ramp time for the torque reference starting from zero.	
☐	Enter the maximum allowed active power of the rotor-side converter during a grid fault ride-through event: 32.29 RT MAX POWER * maximum allowed active power during the grid fault ride-through event.	
☐	In order to allow the stator circuit switchgear (MCB3) to open during a grid fault ride-through event, set the rotor-side converter parameter: 33.01 MCB CONTROL Factory setting value is NO = not activated.	

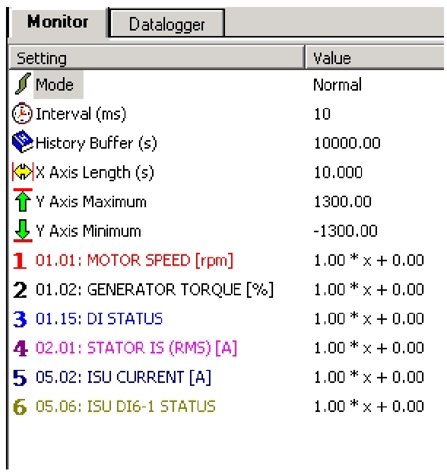
5. OPERATIONAL REMOTE TESTING

■ REMOTE TESTING WITH FIELDBUS COMMUNICATION

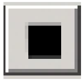
☐	Start the wind turbine system to a speed within its speed range using the wind turbine PLC. **Note:** The speed must be within the limits defined by parameters: • 20.21 SWITCH ON SPEED and 20.22 SWITCH OFF SPEED • 30.09 OVERSPEED LIMIT and 30.10 UNDERSPEED LIMIT	
☐	Start the converter with the PLC start command.	
☐	Check and ensure that: ○ Main Control Word sequences are working properly 07.01 MAIN CTRL WORD ○ Torque/Power reference is correct 25.04 TORQUE REF A or POWER REF ○ Reactive power/voltage reference is correct 23.05 REACT POW REF or UC REF ○ PLC measurement signals are read and scaled properly D SET 11 (VAL1…VAL3) D SET 13 (VAL1…VAL3) D SET 13 (VAL1…VAL3) D SET 17 (VAL1…VAL3)	

■ EXTERNAL SAFETY CIRCUIT TEST

WARNING! An emergency stop at full speed or torque stresses the wind turbine mechanically and can damage it.

☐	Start the wind turbine system to a speed within its speed range using the wind turbine PLC.	
☐	Select/Set the following rotor-side converter signals and settings to the DriveWindow Trend Setting Pane's Monitor window: • 01.01 MOTOR SPEED [rpm] • 01.02 GENERATOR TORQUE • 01.15 DI STATUS • 02.01 STATOR IS (RMS) • 05.02 ISU CURRENT [A] • 05.06 ISU DI6-1 STATUS Select/Set the following settings for the Monitor window: • Mode = Normal • Interval = 10 • History Buffer = 10000 • X Axis Length = 10 • Y Axis Maximum = 1300 • Y Axis Minimum = -1300	
☐	Open the wind turbine safety chain circuit eg, by pushing the emergency stop button anywhere in the wind turbine when the converter is running with small speed and torque.	

5. OPERATIONAL REMOTE TESTING

☐	Stop the monitoring by clicking the **Stop Monitoring** button in the monitor toolbar.	
☐	Check that the main breakers are opened and the generator coasts to stop based on the wind turbine pitch system. ○ 01.15 DI STATUS ○ 05.06 ISU DI6-1 STATUS	
☐	Check that signal 01.02 GENERATOR TORQUE goes down to zero immediately.	

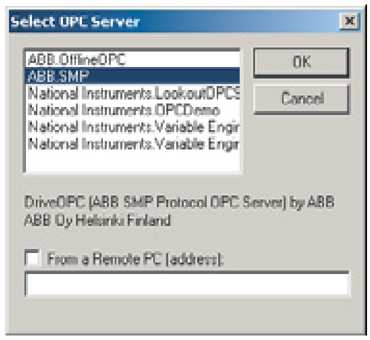
6. FINAL OPERATION		
■	**ETHERNET CONNECTION TEST**	
☐	Check and ensure that the wind turbine and converter starts are disabled.	
☐	Disconnect the PC from the converter and reconnect all optical fibres in their correct order between the NETA-01 and the RDCU and NDCU control units.	
☐	Configure the NETA-01 module according to the instructions given in section *How to configure the NETA-01 Ethernet Adapter Module* on page *105*.	
■	**STORING THE CONVERTER FIRMWARE TO PC**	
	After a start-up or any service operations, the new parameter values must always be documented:	
☐	Disable the grid-side converter and rotor-side converter parameters editing:	
○	Grid-side converter: 16.02 PARAMETER LOCK	 LOCKED
○	Rotor-side converter: 16.01 PARAM LOCK 16.02 PANEL PAR LOCK	 ON LOCKED
☐	Take a full backup file (.bpg) of the grid-side converter software:	
○	Disconnect the optical fibres from the RDCU CH3, connect PC optical fibres to the RDCU and follow the instructions given in section *How to create a full Backup Package and save it in .BPG format* on page *107*.	
○	Save the grid-side converter parameters in a parameter file (.dwp) by following the instructions given in section *How to save a parameter file (.dwp) to the PC* on page *110*.	
☐	Take a full backup file (.bpg) of the rotor-side converter software:	
○	Connect PC optical fibres to the NDCU CH3 and follow the instructions given in section *How to create a full Backup Package and save it in .BPG format* on page *107*.	
○	Save the rotor-side converter parameters in a parameter file (.dwp) by following the instructions given in section *How to save a parameter file (.dwp) to the PC* on page *110*.	

STARTING DriveWindow AND TAKING/RELEASING CONVERTER LOCAL CONTROL

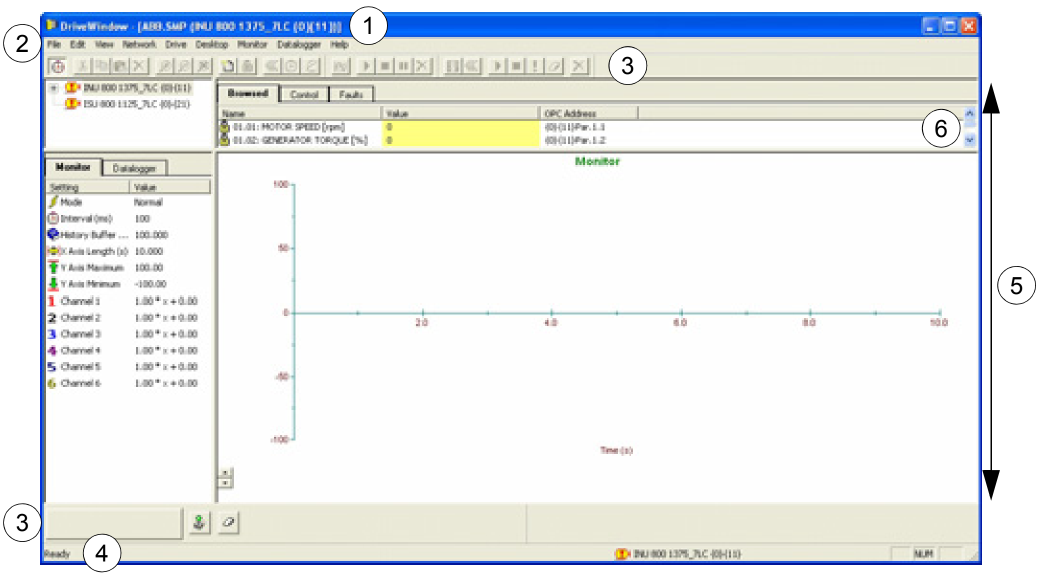
WARNING! Controlling a converter may cause personal injury or physical damage. You should have physical access to the converter, and you must be sure that the converter and the electromechanical system are clear to control (you can see the system, for example). Controlling a converter remotely may require extra precautions and is discouraged.

☐ Start DriveWindow PC tool.

○ Choose ABB.SMP and press **OK** button.



○ Short overview of the PC tool:

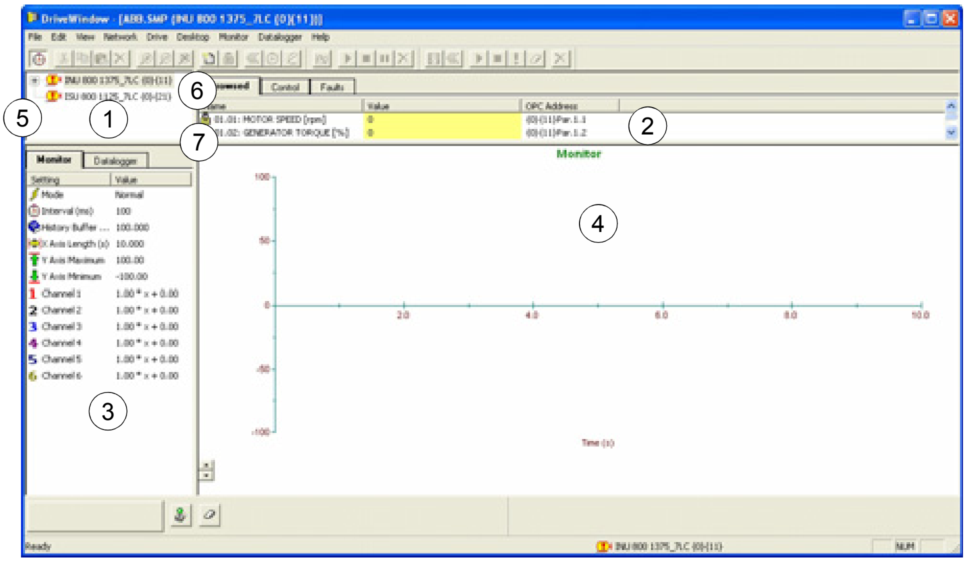


The user interface consists of the following parts:

1. Title bar
2. Menu bar
3. Toolbars
4. Status bar
5. Window area
6. Scrollbars are shown within the windows if scrolling is possible.

STARTING DriveWindow AND TAKING/RELEASING CONVERTER LOCAL CONTROL

☐ Check that both converters are connected:



The window area of DriveWindow is split by horizontal and vertical splitters into four panes:

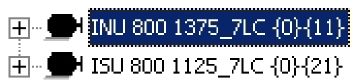
1. Browse tree pane
2. Item sets pane
3. Trend settings pane
4. Trend display pane.

Panes can be resized by:

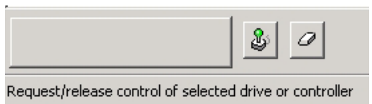
5. dragging the horizontal splitter up or down
6. dragging the vertical splitter left or right
7. dragging the splitter cross-point to a new position.

☐ Take control of the converter:

○ Select and activate the rotor-side converter by clicking it in the browse tree pane.



○ Click the **Take/Release Control** button in the converter panel toolbar.

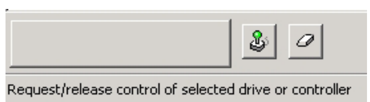


○ Check that the control is activated successfully.

* If control is taken successfully, status image, converter name, field for entering the reference value and command buttons are shown in the drive panel toolbar.

☐ Since you do not need to control the converter any more, release the control as follows:

- Check that the reference value is zero.
- Stop the converter.
- Release the control of the converter.



4

Practical examples, questions and answers

What this chapter contains

This chapter contains examples on how to determine values for critical parameter settings.

Setting up the fieldbus

Fieldbus interfaces

For descriptions of the fieldbus connections, refer to

- *ACS800 grid-side control program firmware manual* [3AUA0000075077 (English)]
- *ACS800-67(LC) doubly-fed induction generator control program firmware manual* [3AUA0000071689 (English)]
- *ACS800-67LC wind turbine converters hardware manual* [3AUA0000058400 (English)]
- fieldbus adapter manuals.

Entering start-up data and torque settings

Calculating/setting the motor nominal torque

Parameters 99.05 MOTOR NOM SPEED and 99.06 MOTOR NOM POWER contain motor nominal speed (rpm) and power. Is it correct that the motor nominal torque is calculated from these two values? Is there any other way of setting the motor nominal torque? We could not find a parameter for it.

Answer

- Yes, nominal torque (100%) is calculated from the values of parameters in group 99 START-UP DATA.
- No, there is no other way of setting the nominal torque.

Torque set-point

Is it possible to send to the converter a torque set-point that is higher than 100% continuously or for a short period? What will happen?

Answer

Torque is limited by parameters 20.05 USER POS TORQ LIM and 20.06 USER NEG TORQ LIM. The parameters should be set to values which are achievable with the generator-drive current capacity combination defined in the design.

If the torque reference given by the turbine controller is too high (ie, the pull-out torque of the generator or current capacity of the converter have been reached), the converter will limit the torque.

In extreme cases, if the torque reference is remarkably higher than what is allowed by the generator-drive current capacity combination, and the limitation of current by limiting torque does not succeed, the converter will trip on overcurrent. It stops operation immediately and the torque on the generator shaft disappears. Necessary overspeed and safety system dynamics margins must be maintained in the system design.

Stator current and voltage measurement

NUIM-6x voltage measurement

Voltages U1,V1 and W1 are measured at both sides of the stator circuit breaker/ contactor(s). The 690 V AC grid voltage is connected to the Voltage and Current Measurement unit (NUIM).

Stator flux is measured through a low pass filter which has different time constants for 690 V AC and 575 V AC. The control program must know which one is in use. The used voltage is defined as follows:

	Parameter	**Setting**
For 690 V / 50 Hz	99.27 MAX MEAS FLUX	≤ 2.43936 Wb
	99.33 NUIM61 PHS OFFSET	≤ 47.06 deg
For 575 V / 60 Hz	99.27 MAX MEAS FLUX	≤ 1.605 Wb
	99.33 NUIM61 PHS OFFSET	≤ 44.35 deg
For 690 V / 60 Hz	99.27 MAX MEAS FLUX	≤ 2.407 Wb
	99.33 NUIM61 PHS OFFSET	≤ 44.35 deg

NUIM-1x voltage measurement

If voltage measurement is accomplished using an instrument voltage transformer the measurement board used is of the type NUIM-10C. In this case the maximum measureable flux must be calculated by the formula:

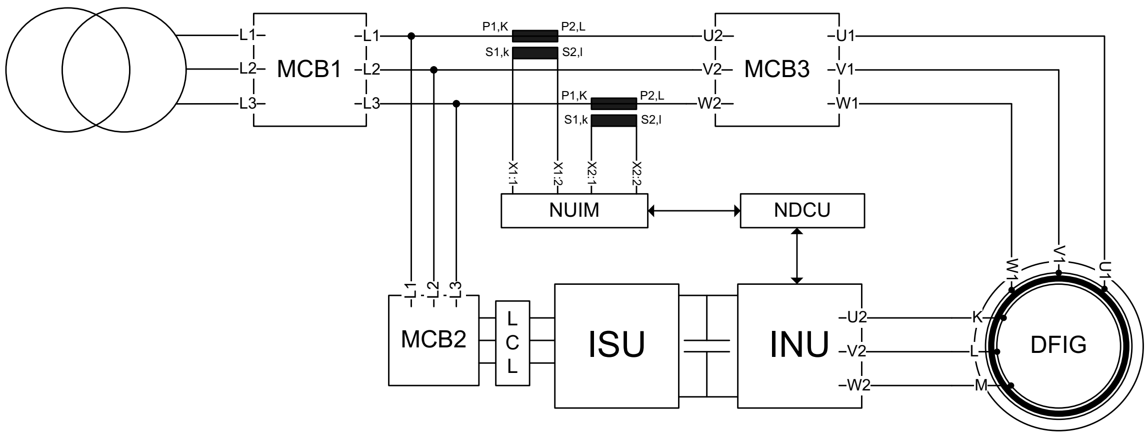
$$\text{99.27 MAX MEAS FLUX} = \frac{Un1}{Un2} \cdot \frac{5.963541 \cdot \sqrt{1 + (f \times 0.065175)^2}}{f}$$

- *Un*1 = voltage transformer primary side voltage in volts (V)
- *Un*2 = voltage transformer secondary side voltage in volts (V)
- f = grid frequency in hertz (Hz)

For more information on the NUIM Voltage and Current Measurement unit, see *ACS800-67LC wind turbine converters hardware manual* [3AUA0000058400 (English)].

NUIM-1x and NUIM-6x current measurements

Two stator currents are measured from phases U1 and W1 through current transformers (CT). The CT ratio is the ratio of primary current input to secondary current output at full load. For example a CT with a ratio of 2500:1 is rated for 2500 primary amperes at full load and will produce 1 A of secondary current when 2500 A flow through the primary. If the primary current changes the secondary current output will change accordingly. For example if 1500 A flow through the 2500 A rated primary the secondary current output will be 0.6 A (1500 : 2500 = 0.6 : 1).



The maximum measurable stator current must be set by a parameter. The value is calculated with the following equation:

$$99.28\ \text{MAX MEAS IS} = \frac{4{,}5\ \text{V}}{2{,}73333\ \text{ohm}} \cdot \text{CT}$$

CT = current transformer ratio

Settings for parameter 99.28 MAX MEAS IS:

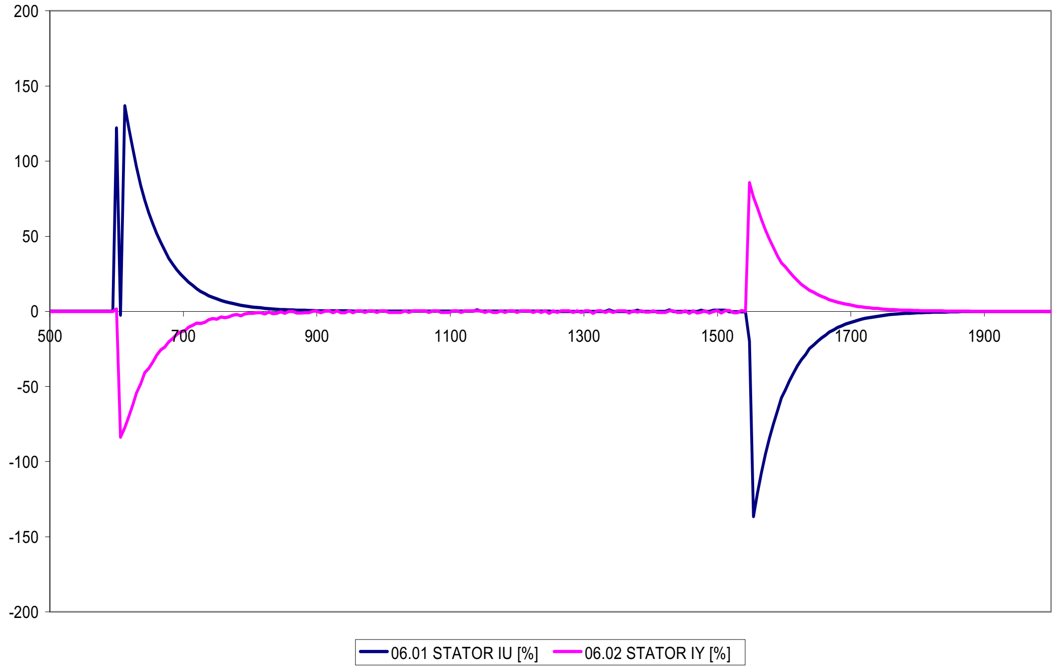
Rated primary current [A]	Rated secondary current [A]	Setting for parameter 99.28 MAX MEAS IS [A]
2000	1	3293
2500	1	4116
3000	1	4939
4000	1	6585
4000	1	6585

The polarity of a current transformer is determined by the direction the coils are wound around the core (clockwise or counterclockwise) and the way the leads are brought out of the transformer case. Current transformers have subtractive polarity and following designations for installation: P1: primary current, line-facing direction; P2: primary current, load-facing direction; and S1: secondary current. Correct polarity has to be taken into account when installing and connecting current transformer to power metering.

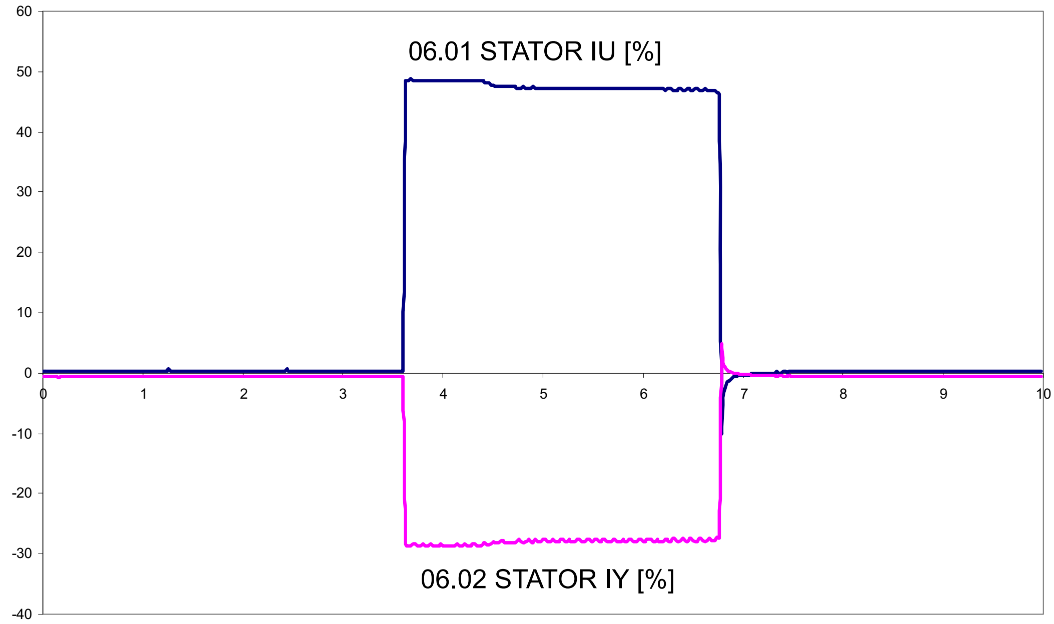
Sometimes it is not possible to install current transformers mechanically so that current flow is from P1 to P2 which is standard. This means that measurement polarity is reversed. In this case the polarity can be corrected by entering a negative value in this parameter.

Disabling automatic offset calibration during start-up

Automatic offset calibration can be disabled with parameter 21.07 BATTERY TEST when the stator current polarity is checked during start-up procedure. If offset calibration is enabled (parameter 21.07 BATTERY TEST is set to NO) when the external battery (1.5 V) is connected in parallel with the stator current transformers, the measured waveforms may be distorted as shown below.



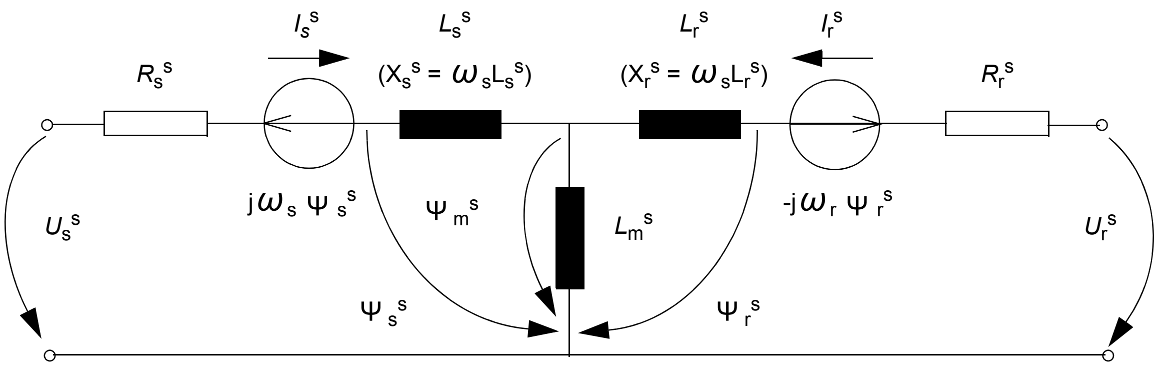
If offset calibration is disabled (parameter 21.07 BATTERY TEST is set to CONNECT BATT), the waveforms behave as shown below.

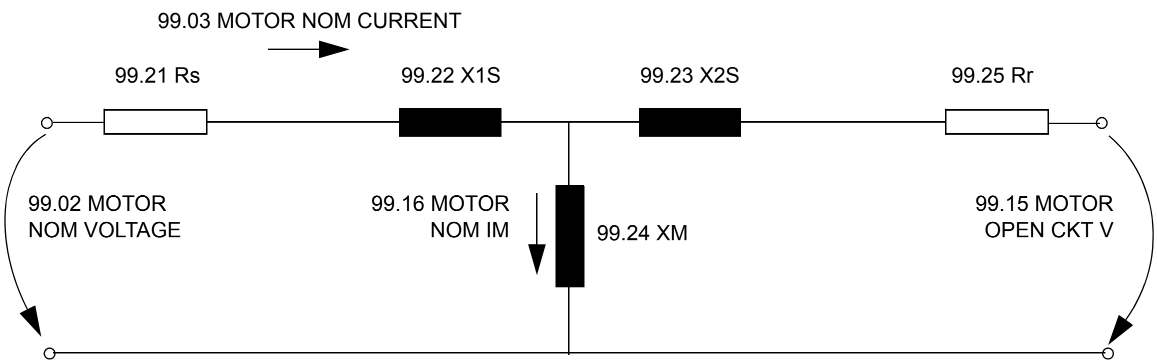


Generator data

■ Generator rating plate equivalent circuit parameters

The equivalent circuit of the generator is shown below. Note that the equivalent circuit is to be are derived looking from the stator-side ie, the voltages and currents are reflected on the stator-side. To calculate the equivalent rotor circuit parameters (resistance and inductance) from the rotor-side to stator-side, appropriate stator-to-rotor conversion ratio information should be used.





Note: Open-circuited voltage when the rotor is mechanically locked and nominal stator voltage is connected to the stator circuit.

Since the application measures both rotor- and stator-side quantities, the identification run method is not used with doubly-fed induction generator control. The control needs to be given the following data (from the generator data sheet) manually.

Generator data	Parameter
Rated stator voltage	99.02 MOTOR NOM VOLTAGE
Rated stator current	99.03 MOTOR NOM CURRENT
Rated stator frequency	99.04 MOTOR NOM FREQ
Rated generator nominal speed (rotor short-circuited)	99.05 MOTOR NOM SPEED **Note:** As generator, positive slip.
Rated generator power	99.06 MOTOR NOM POWER **Note:** See the calculations below.
P.F (rotor short-circuited)	99.12 MOTOR NOM COSFII
Generator synchronous speed	99.14 MOTOR SYNC SPEED

Generator data	Parameter
Transformation ratio between the stator and the rotor. Defined when rotor shaft is mechanically locked and nominal stator voltage is fed to the stator windings.	99.15 MOTOR OPEN CKT V **Note:** Rotor open-circuit voltage.
Long time rotor current limitation	99.16 MOTOR NOM IM **Note:** I_M is not needed in the slip ring generator model. I_M is used for defining the maximum allowed long time rotor current limit.
Stator resistance (R_s)	99.21 Rs
Stator leakage reactance	99.22 X1S
Rotor leakage reactance	99.23 X2S
Mutual reactance	99.24 XM **Note:** See the equation on page 99.
Rotor resistance (R_r)	99.25 Rr **Note:** R_r must be referred to the stator frame. See the equation on page 99.

Note: Some generator manufacturers give equivalent circuit data for delta connection. In that case the given reactance values must be divided by three.

Generator nominal power calculation

Generator values must be given at 50 Hz (60 Hz). These values are not equal to the wind turbine nominal values. Wind turbine nominal power is achieved with 100% torque reference at the nominal wind turbine speed.

Calculate the generator nominal power with the following equation.

$$\text{99.06 MOTOR NOM POWER} = \frac{\text{99.05 MOTOR NOM SPEED} \cdot \text{Wind turbine nom. power}}{\text{Wind turbine nom. speed}}$$

Example:

Nominal operating point: Wind turbine nominal power is 1600 kW, wind turbine nominal speed is 1770 rpm and generator nominal speed is 1511 rpm.

With 100% torque reference at 1770 rpm, the wind turbine output is 1600 kW, when parameter 99.06 MOTOR NOM POWER value is

99.06 MOTOR NOM POWER = (1511 rpm · 1600 kW) / 1770 rpm = 1365 kW.

Equivalent circuit values parameterisation

When the equivalent circuit values are given for star connection and the rotor values are reduced to the stator reference frame, the equivalent circuit values are set to the parameters as shown in the table below.

Parameter	Equivalent circuit value	Often marked as
99.21 Rs	R_s	R_1
99.22 X1S	$X_s = L_s \times \omega$	X1 σ
99.23 X2S	$X_r = L_r \times \omega$	Xr σ’
99.24 XM	$X_m = L_m \times \omega$	X_h
99.25 Rr	R_r	R_2’

Note: If the equivalent circuit values are given for delta connection, the values for parameters 99.21 Rs, 99.22 X1S, 99.23 X2S, 99.24 XM and 99.25 Rr must be divided by three.

X2σ' and R_2' must be reduced to the stator reference frame. Reducing is marked with ' and it is calculated as shown below.

$$99.23\ \text{X2S} = \frac{\text{X2}\ \sigma}{\left(\frac{\text{99.15 MOTOR OPEN CKT V}}{\text{99.02 MOTOR NOM VOLTAGE}}\right)^2}$$

$$99.25\ \text{Rr} = \frac{\text{R}_2}{\left(\frac{\text{99.15 MOTOR OPEN CKT V}}{\text{99.02 MOTOR NOM VOLTAGE}}\right)^2}$$

If only generator rating plate values are known, such rating plate values are needed that are given when rotor is short-circuited. Power factor must be below 1. First magnetizing current of the generator is calculated as shown below:

$$\text{99.16 MOTOR NOM IM} = \text{99.03 MOTOR NOM CURRENT} \cdot \sqrt{1 - \text{99.12 MOTOR NOM COSFII}^2}$$

Mutual inductance X_m and rotor resistance R_r calculations

Mutual inductance X_m (rotor-side converter parameter 99.24 XM) is calculated with the following equation:

$$99.24\ \text{XM} = \frac{\text{99.02 MOTOR NOM VOLTAGE}}{\sqrt{3} \cdot \text{99.16 MOTOR NOM IM}}$$

The rotor resistance R_r (rotor-side converter parameter 99.25 Rr) reduced to the stator reference frame (R2PH on the ABB generator equivalent circuit data) is calculated with the following equation:

$$99.25\ \text{Rr} = \frac{\mathit{R2PH}}{\left(\frac{\text{99.15 MOTOR OPEN CKT V}}{\text{99.02 MOTOR NOM VOLTAGE}}\right)^2}$$

X1S and X2S are typically about 5% of the X_m. R_s and R_r are typically about 0.5% of the X_m.

Current measurement of the grid-side converter

Why does the actual signal 01.06 LINE CURRENT indicate no-load current and differ from the measured grid current?

The main circuit of the grid-side converter is shown below. Current is fed to the LCL filter to compensate the capacitors in no-load situations when current at the input to the converter (point a) is zero. However, as current is measured at the input of the IGBT Supply Unit (point b), the line current measurement signal indicates compensated current also in no-load situations.

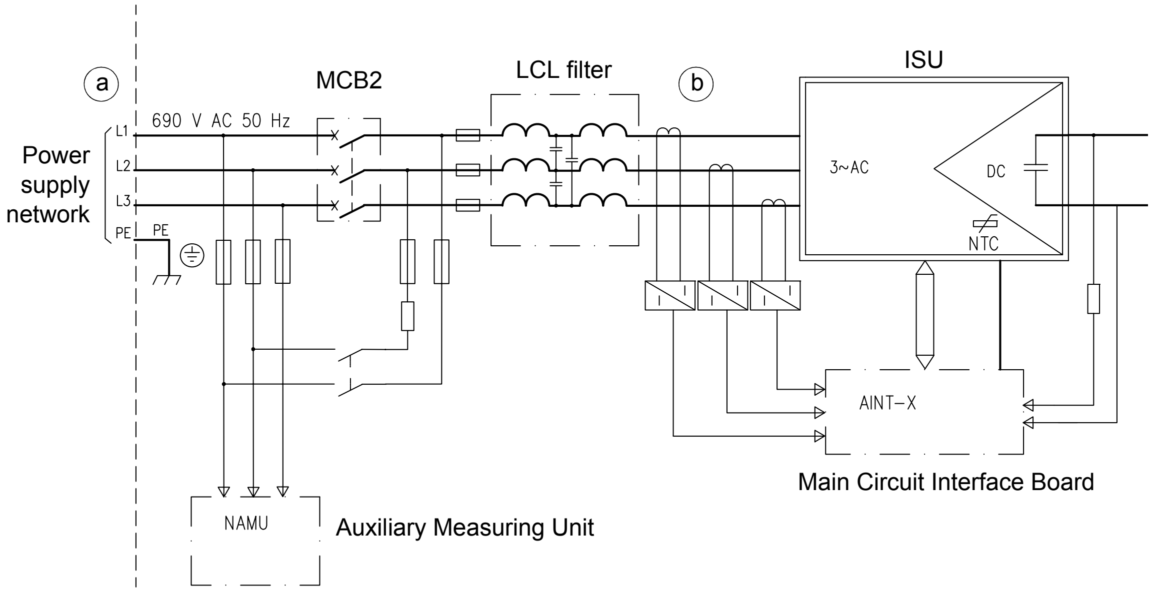
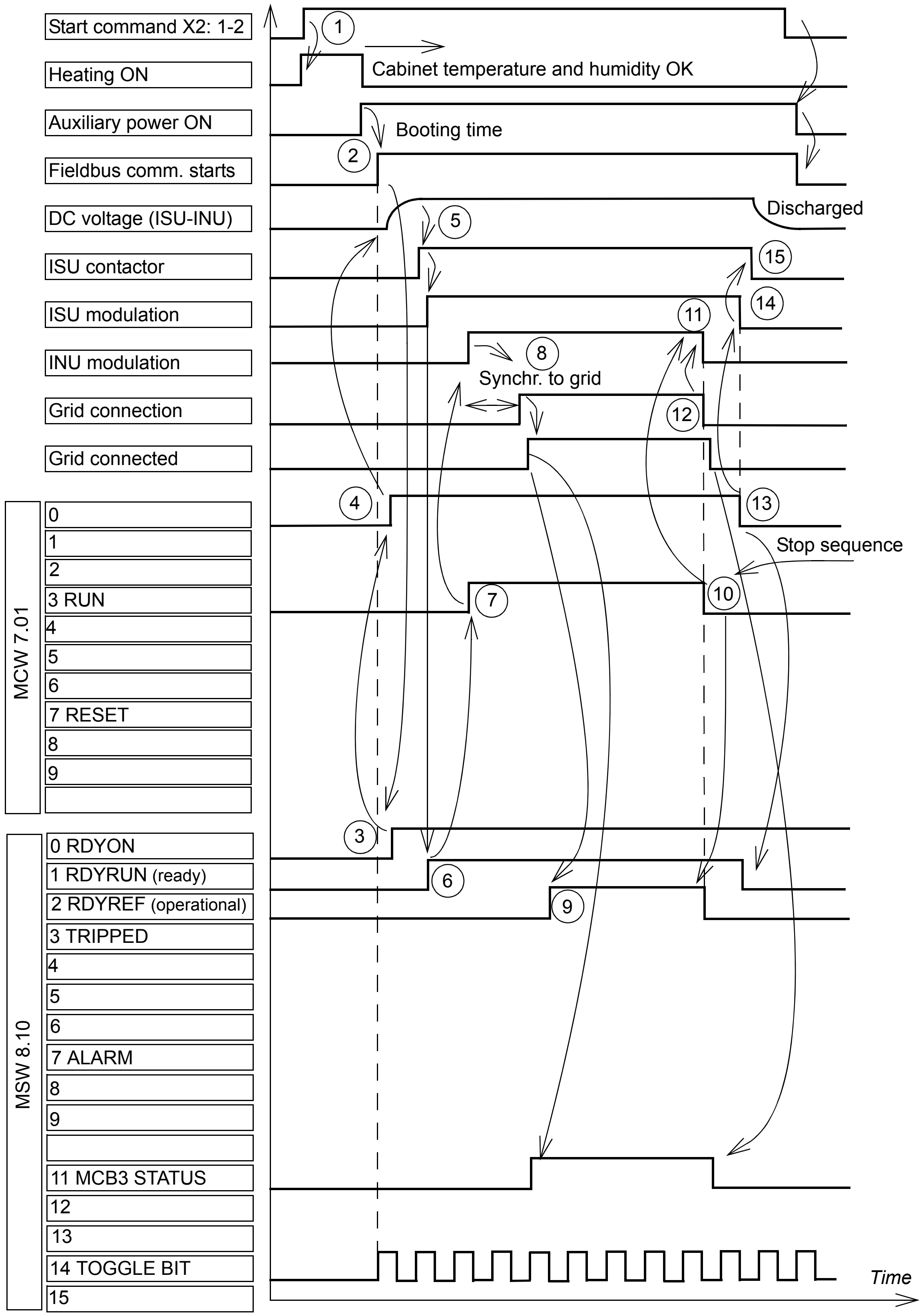


ABB Drives communication profile

The following sections show control sequence examples using the ABB Drives communication profile. The Main Control Word (MCW) is the principal means of controlling the converter from an external control system. The Control Word is sent to the converter by the external control system. The converter switches between its states according to the bit-coded instructions of the Control Word. The Main Status Word (MSW) contains status information, sent to the external control system by the converter.

Starting sequence

The starting sequence of the wind turbine converter is shown below.



Fault sequence, profile B

An example of the control sequence after a fault situation is described below.

Step	Command / end state	Description	8.10 CCU STATUS WORD bits after command														7.01 MAIN CONTROL WORD		
			ISU RDYREF	MCB internal trip	MCB ON	Low voltage for ride through	remote	torque reduction	alarm	crowbar triggered	-	OFF 2 N STA	tripped	rdyref	rdyrun	rdyon	RESET	RUN	ON
			b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0	b7	b3	b0
1	RUN=1	Device is running.	1	0	1	0	1	0	0	0	0	1	0	1	1	1	0	1	0
2		Device is tripped for any reason, stator is immediately disconnected from the grid and after that ISU is disconnected from the grid.	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	1	0
3	RUN=0	Run command must be removed.	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0
4	RESET=1	Fault is reseted.	0	0	0	0	1	0	0	0	0	1	0	0	0	1	1	0	0
5	RESET=0	RESET command must be removed.															0	0	0

Device is ready for restart.

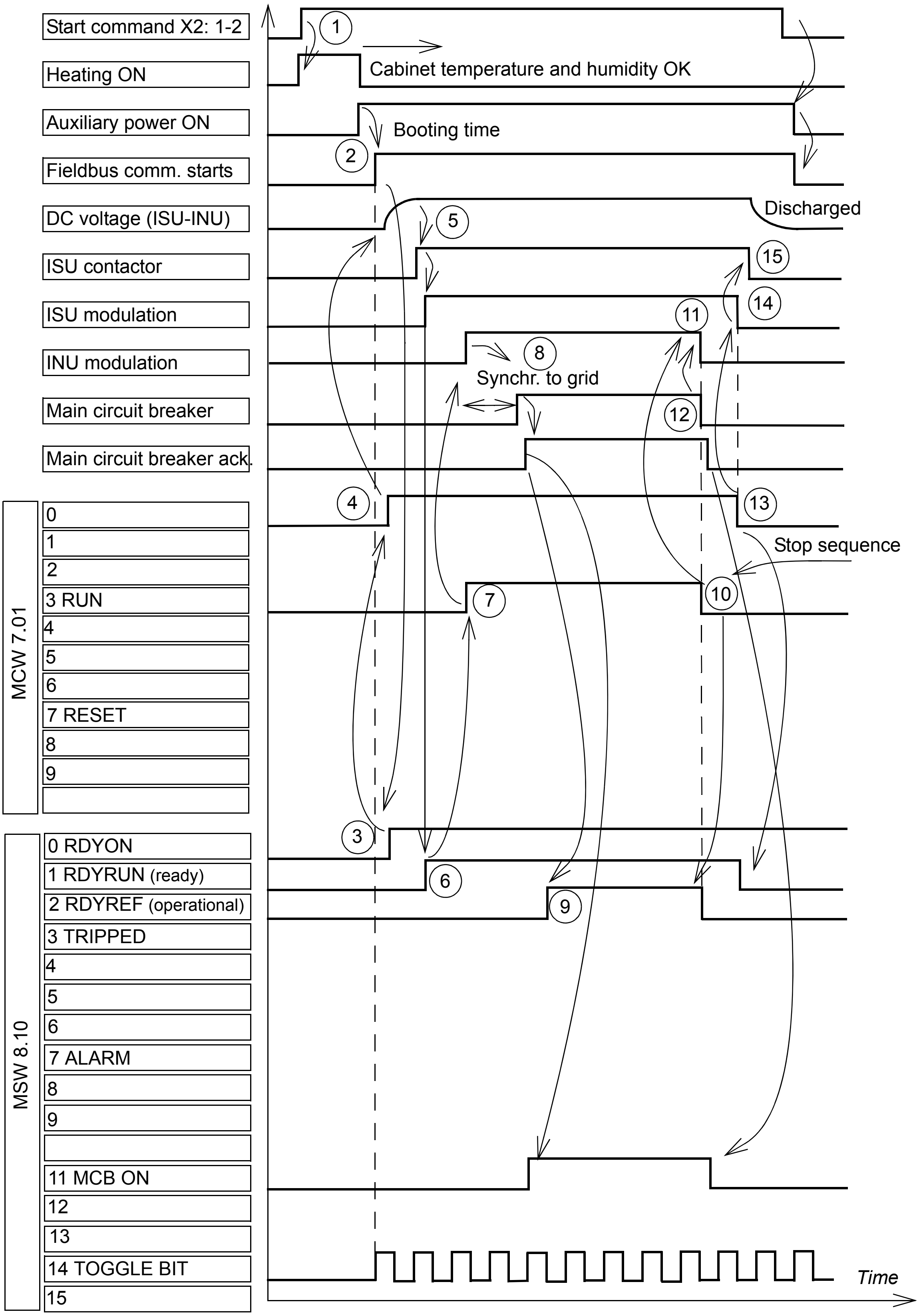
Normal stop sequence, profile B

An example of the control sequence after a normal stop is described below.

Step	Command / end state	Description	8.10 CCU STATUS WORD bits after command														7.01 MAIN CONTROL WORD		
			ISU RDYREF	MCB internal trip	MCB ON	Low voltage for ride through	remote	torque reduction	alarm	crowbar triggered	-	OFF 2 N STA	tripped	rdyref	rdyrun	rdyon	RESET	RUN	ON
			b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0	b7	b3	b0
1	RUN=1	Device is running.	1	0	1	0	1	0	0	0	0	1	0	1	1	1	0	1	0
2	RUN=0	Device is requested to stop. Stator current is controlled to zero, stator is disconnected from the grid and both INU and ISU modulation is stopped and ISU is disconnected from the grid.	0	0	0	0	1	0	0	0	0	1	0	0	1	1	0	0	0
3	RUN=0	When speed is below SWITCH-OFF speed.	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	0

Starting sequence when the ISU is started first separately

ABB Drives profile



Normal start and stop sequence, ABB drives profile

An example of the control sequence is described below.

Step	Command / end state	Description	8.10 CCU STATUS WORD bits after command														7.01 MAIN CONTROL WORD		
			ISU RDYREF	MCB internal trip	MCB ON	Low voltage for ride through	remote	torque reduction	alarm	crowbar triggered	-	OFF 2 N STA	tripped	rdyref	rdyrun	rdyon	RESET	RUN	ON
			b13	b12	b11	b10	b9	b8	b7	b6	b5	b4	b3	b2	b1	b0	b7	b3	b0
1	RUN, ON = 0	Device is at a standstill, no fault.	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	0
2	ON=1	DC bus is charged, ISU contactor is closed and ISU modulation is started.	1	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	1
		When speed is above SWITCH-ON speed.	1	0	0	0	1	0	0	0	0	1	0	0	1	1	0	0	1
3	RUN=1	INU is started, synchronised to the grid and stator is connected to the grid.	1	0	1	0	1	0	0	0	0	1	0	1	1	1	0	1	1
4	RUN=0	Stator current is controlled to zero, stator is disconnected from the grid and INU modulation is stopped.	1	0	0	0	1	0	0	0	0	1	0	0	1	1	0	0	0
5	ON=0	ISU modulation is stopped, ISU contactor is opened and DC bus is discharged.	0	0	0	0	1	0	0	0	0	1	0	0	1	1	0	0	0
6		When speed is below SWITCH-OFF speed.	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	0

Datasets

The datasets used for transmitting and receiving actual signals and parameters are shown in chapter *Communication details*.

Fieldbus signals

For signals used in the software interface with a specific fieldbus, refer to the software interface specification delivered with the converter.

How to configure the NETA-01 Ethernet Adapter Module

Configure the NETA-01 Ethernet Adapter Module as follows:

1. Follow instructions given in chapter *Quick start-up guide* in *NETA-01 Ethernet adapter module user's manual* [3AFE64605062 (English)] to connect to the module. The instruction on setting the IP address is given below.

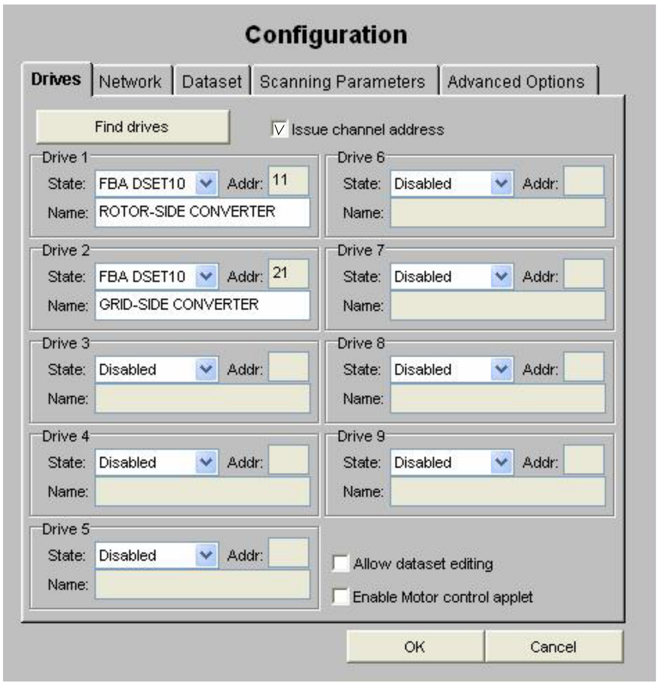
   Set the IP address of the NETA module with ARP protocol commands. The PC has to be configured for the point-to-point connection.

   - Set all configuration DIP switches to OFF position. Switch the auxiliary 24 V DC power on.
   - Open the DOS prompt on the PC.
   - Type 'arp -s <IP address> <MAC address>'
     Substitute <MAC address> with the MAC address of your module eg, 00-30-11-02-02-90. The MAC address is printed on the label on the side of the module. Substitute <IP address> with the IP address you want to use for the module eg, 10.0.0.7. Ask your network administrator for a free IP address. Type 'arp' at the command prompt for more instructions.
   - Type 'ping <IP address>'
   - Type 'arp -d <IP address>'

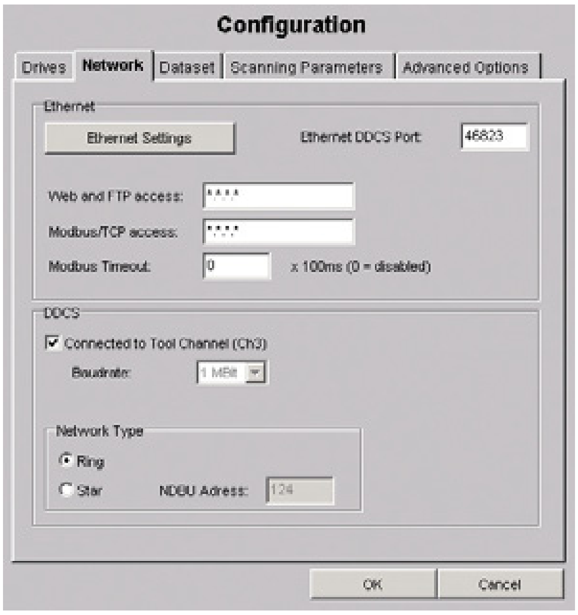
   The module will adopt the IP address specified in the 'arp -s' command after restarting the module.

2. Open the web pages of the module as follows:
   - Open the Web browser eg, Internet Explorer.
   - Write http:// and the IP address into the browser's address bar and press **Enter**.
   - Fill in the authorization information. User name: admin. Password: admin.
3. Access the **Configuration** menu.
4. Open the **Drives** tab and click the **Find drives** button. Make sure that the **Issue channel address** checkbox is ticked.
5. Change the **State** field of the activated converters from FBA DSET to FBA DSET10 and give appropriate names to the converters in the **Name** fields.

6. Check that the **Allow dataset editing** and **Enable Motor control applet** checkboxes are not ticked.



7. Go to the **Network** tab and check that the **Connected to Tool Channel (Ch3)** is selected.
8. If the converter has only one rotor-side converter and one grid-side converter, select network type **Ring**.
9. Save settings by clicking **OK** and rebooting the module.



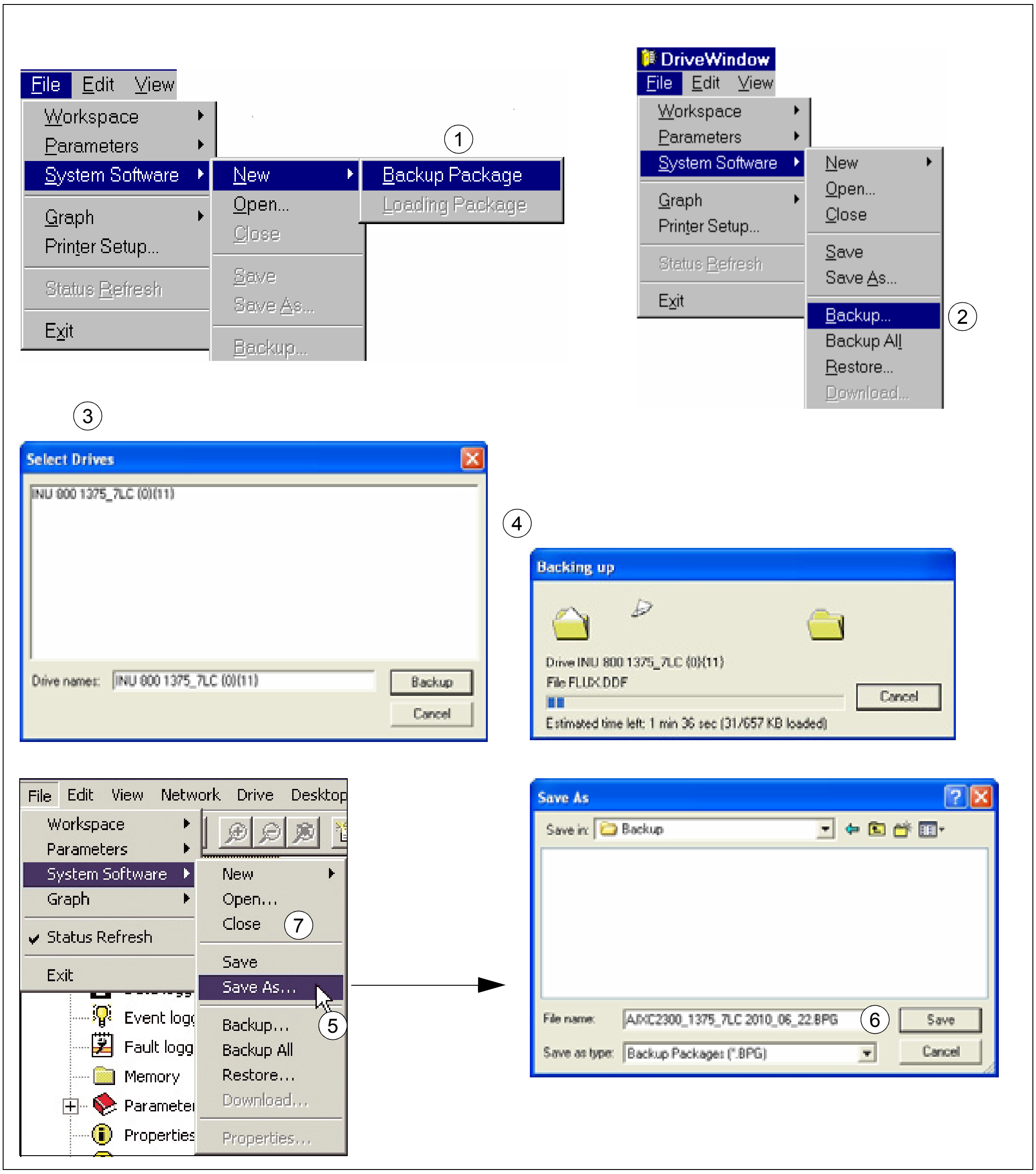
Converters with one rotor-side converter and one grid-side converter

How to create a full Backup Package and save it in .BPG format

While creating a Backup Package, the converter must be in remote control (not controlled from the DriveWindow).

Make a Backup Package with DriveWindow separately from each converter as follows:

1. Open a new backup folder by selecting from the **File** menu **System Software** / **New** / **Backup Package**.
2. Select from the **File** menu **System Software** / **Backup** command.
3. Select the appropriate converter and press **Backup**.
4. The backing up takes a few minutes.
5. Select from the File menu **System Software / Save as** command. Select a folder where you will save the Backup Package.
6. Give a file name to your Backup Package and press **Save**.
7. Close your folder by selecting from the **File** menu **System Software** / **Close** command.



What is a Backup Package

A Backup Package is similar to a Loading Package. It is a single PC file with a filename extension of .BPG.

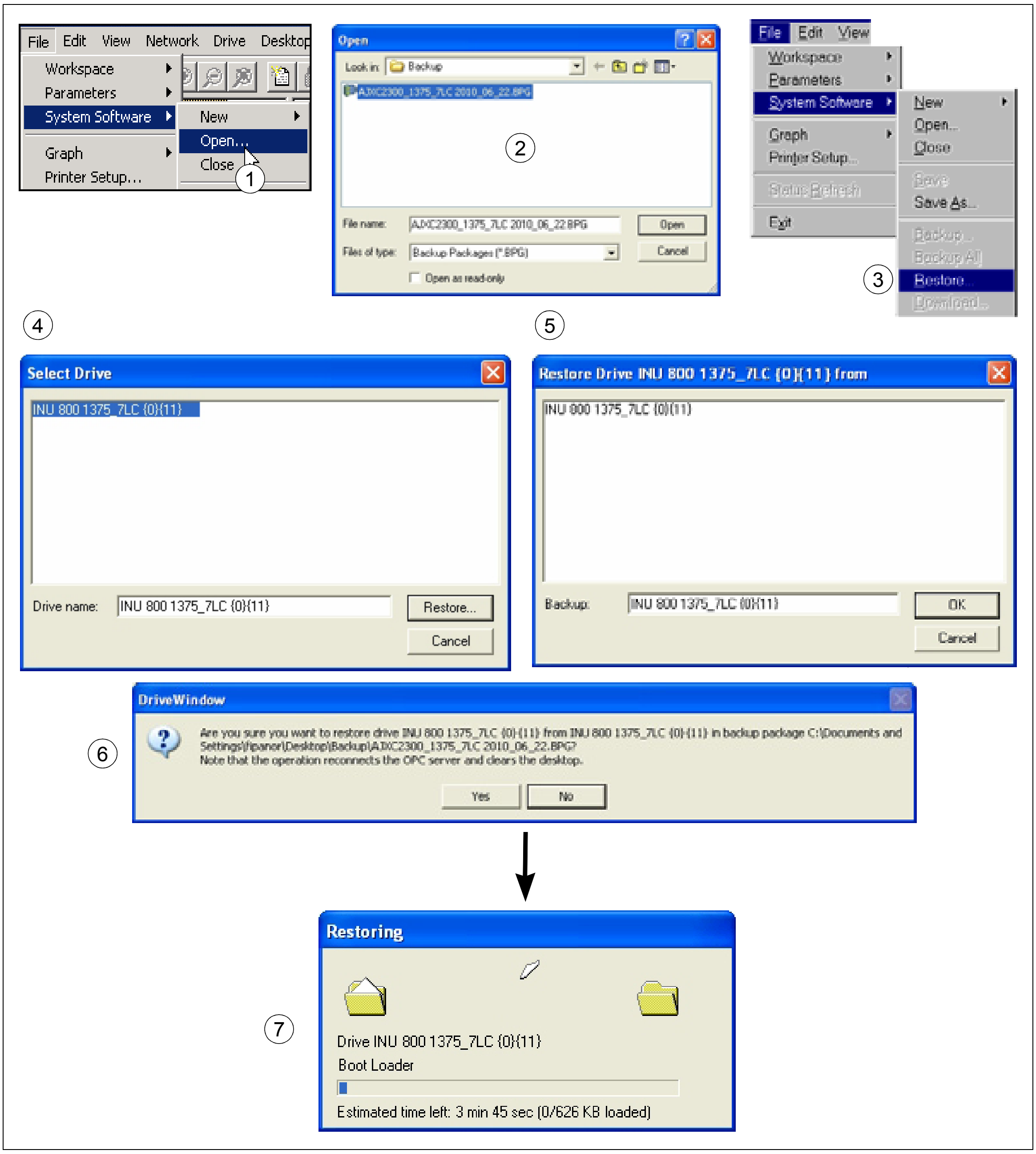
A Backup Package can be opened, saved, saved with a new name and closed. Backup and restore commands can be performed only if a Backup Package is open.

How to restore a backup file into the RDCU or NDCU board

Restore a backup file into the RDCU or NDCU board as follows:

1. Select from the **File** menu **System Software** / **Open** command.
2. In the **Open** box, select the backup package and press **Open**.
3. Select **System Software** / **Restore** command.
4. Select the converter into which you want to restore the backup file.
5. Select the right backup file from the backup folder. (It may contain more than one backup.)
6. If you are sure of the restoring, press **Yes**.
7. Do not operate the converter or PC during the restoring.

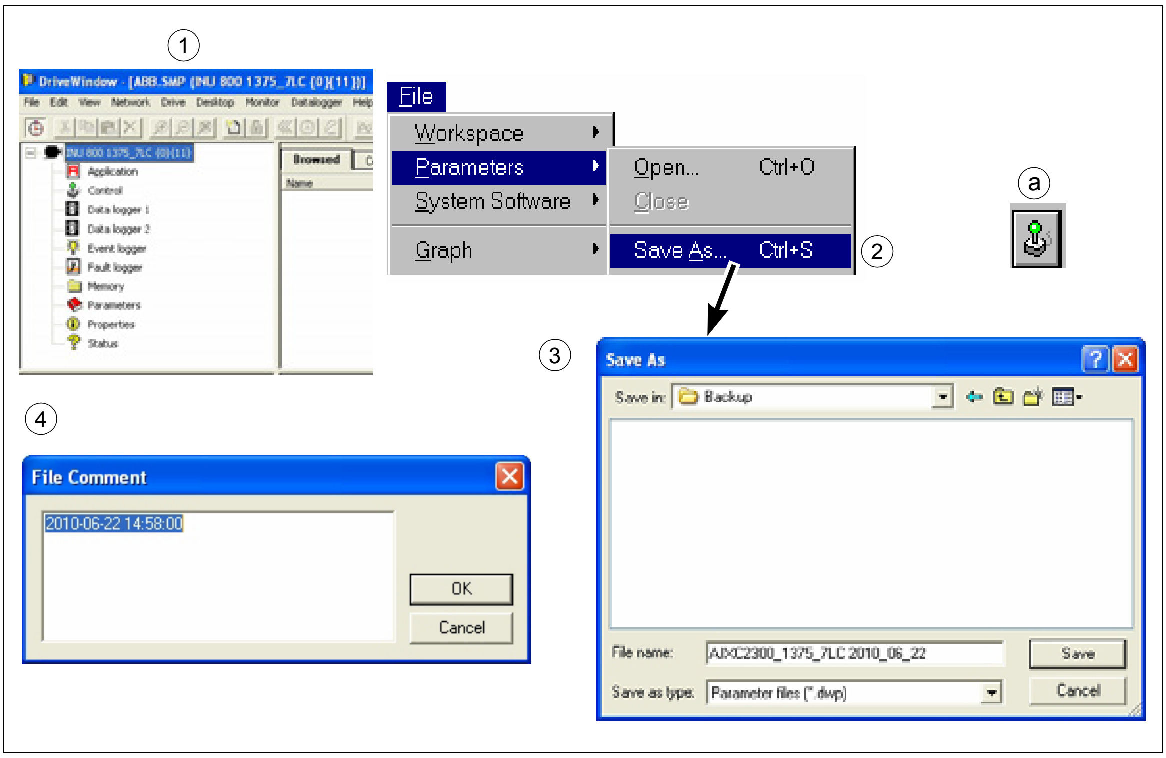
Note: You cannot restore any converter while another converter is in local control.



How to save a parameter file (.dwp) to the PC

Save a parameter file to the PC with DriveWindow as follows:

1. Select the converter.
2. From the **File** menu, select **Parameters** / **Save as** command. If the command is disabled (gray), press the **Drive / Take Control** button (a).
3. Give a file name, locate the file in your hard disc and press **Save**.
4. Write a comment and press OK.



Note: If the converter is running while the parameter file is saved, it will not be possible to edit the parameters off-line. The parameter file remains in the read-only status. Therefore, create always a full Backup Package for backup purposes. See section *How to create a full Backup Package and save it in .BPG format* on page *107*.

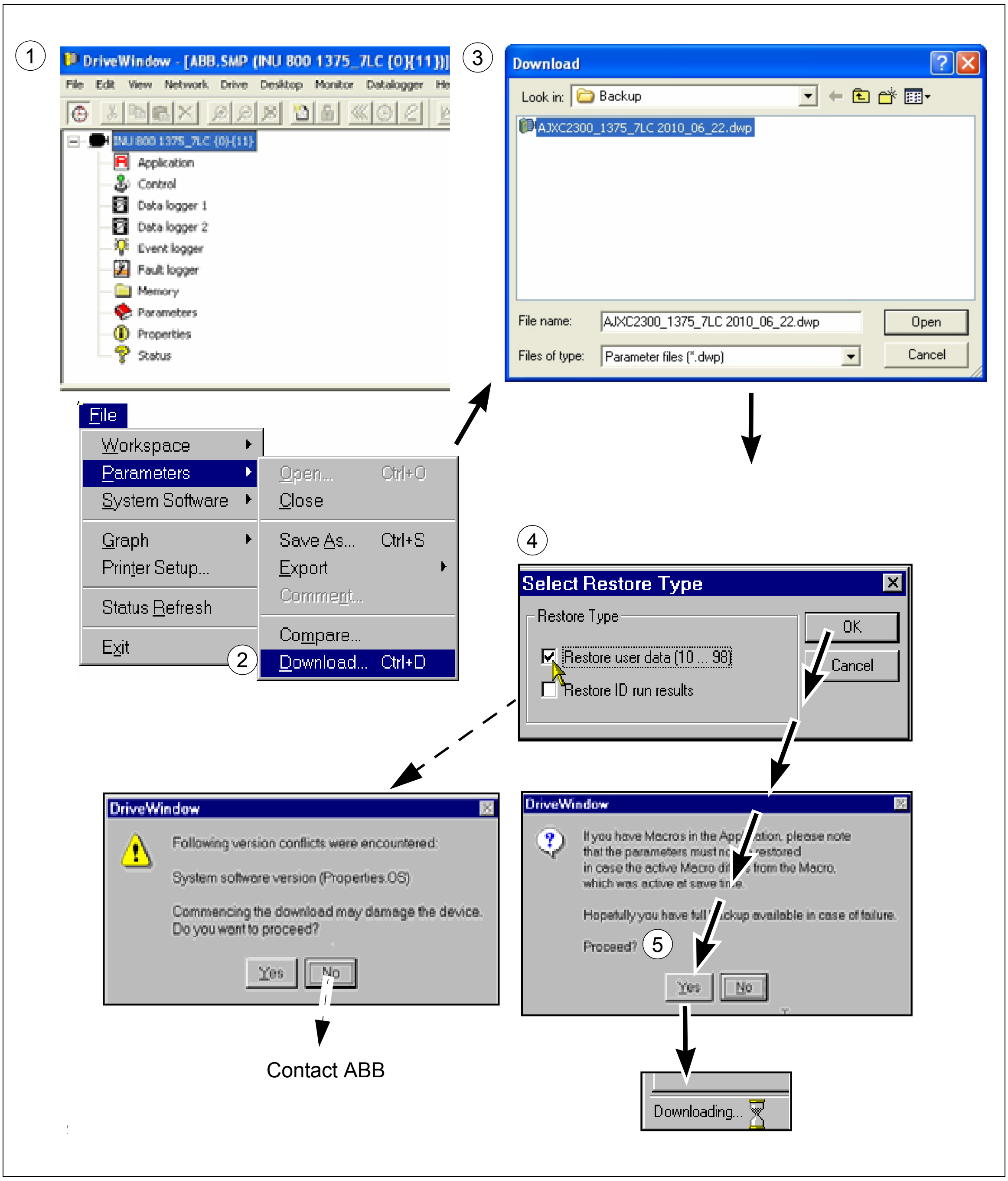
How to download parameters into the converter

Download parameters into the converter as follows:

1. In the remote control mode, select the converter.
2. From the **File** menu, select the **Parameters**/**Download** command.
3. In the **Download** box, select the backup file and press **Open**.
4. Tick “Restore user data (10…98)” for the restore type. Press **OK**.

   Note: Set parameters into group 99 manually afterwards.
5. If you are sure to proceed, press **Yes**. If Version conflict info appears, contact ABB.

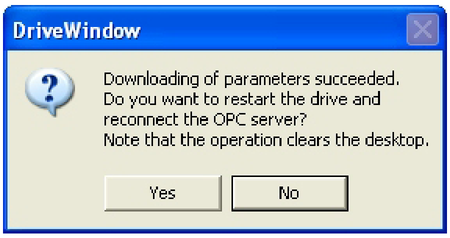
Note: After downloading, check the parameters of groups 56 and 58 if an Adaptive Program is in use.



How to update the firmware

1. Before updating the firmware it is recommended to create a full Backup Package of the old firmware in RDCU and NDCU boards and save the old parameter file. For details, see sections *How to create a full Backup Package and save it in .BPG format* and *How to save a parameter file (.dwp) to the PC*.
2. Connect the fibre optic connectors to the board to be updated (RDCU or NDCU). Change the node address (70.15 CH3 NODE ADDR) of the board to be updated to 1 or to the same value as the default value in the update package (11 for INU, 21 for ISU). Download the new firmware version as instructed in section *How to restore a backup file into the RDCU or NDCU board*.
3. Set your converter type. Do the following settings in order to access those parameters:
   INU
   16.01 PARAM LOCK to OFF
   16.03 PASS CODE to 1
   ISU
   16.02 PARAMETER LOCK to OPEN
   16.03 PASS CODE to 2303
   A reboot is needed to validate the converter type selected. Switch the auxiliary voltage off and back on.
4. Download the old parameter file that was saved in step 1. For details, see section *How to download parameters into the converter*.
5. Force the new parameters into FLASH by selecting **Yes**.

6. If downloading of the parameters is succeeded, following note appears. Select **Yes**, and the update is ready and the updated board is connected.



If parameter download fails, an error note appears:

1. Compare the parameters to the parameter settings given in section *Communication parameter settings*.
2. Do the start-up checks and settings as instructed in chapter *Start-up*.

Communication parameter settings

INU

Parameter	Setting	Note
16.20 GRID CONNECT MODE	MCB1+MCB3/B	
31.01 CROWBAR HW TYPE	ACTIVE CB 2 ACTIVE CBs 1 REV2 CB* 2 REV2 CBs*	In case of one crowbar In case of two crowbars In case of one crowbar* In case of two crowbars*
70.15 CH3 NODE ADDR	11	
70.21 CH4 NODE ADDR	11	
97.01 DEVICE NAME	INU 800 xxxx_7LC	Use the correct converter type
99.27 MAX MEAS FLUX	2.43936 2.805279	Default value when using NUIM-62C board To be set manually when using NUIM-10C board
99.28 MAX MEAS IS	3293 4116 4939 6585 6585	Set according to power type. See also section *NUIM-1x and NUIM-6x current measurements* on page 95.

* April 1, 2012 onwards.

In addition, the fieldbus module settings must be made. See the *ACS800-67(LC) doubly-fed induction generator control program firmware manual* [3AUA0000071689 (English)].

ISU

Parameter	Setting	Note
11.02 Q REF SELECT	2402	
14.05 DO2 BIT NUMBER	3	
30.04 DI4 EXT EVENT	DI4=1 ALARMS	
30.13 DI7 EXT EVENT	DI7=0 FAULTS	To be set when DC chopper is included in the delivery
30.20 EXT TMP 1 AI1 SEL	1xPTC100	
30.21 EXT TMP 1 FLT LO	4 degrees	
30.22 EXT TMP 1 ALM LO	7 degrees	
30.23 EXT TMP 1 ALM HI	46 degrees	
30.24 EXT TMP 1 FLT HI	56 degrees	
30.25 EXT TMP 1 DELAY	4 s	
30.26 EXT TMP 2 AI2 SEL	1xPTC100	
30.27 EXT TMP 2 FLT LO	4 degrees	
30.28 EXT TMP 2 ALM LO	7 degrees	
30.29 EXT TMP 2 ALM HI	60 degrees	
30.30 EXT TMP 2 FLT HI	65 degrees	
30.31 EXT TMP 2 DELAY	4 s	
40.02 NAMU BOARD ENABLE	ON	
70.15 CH3 NODE ADDR	21	
70.19 CH0 HW CONNECTION	RING	
70.20 CH3 HW CONNECTION	RING	
71.01 CH0 DRIVEBUS MODE	NO	
90.02 D SET 10 VAL 2	2301, DC VOLT REF	
90.03 D SET 10 VAL 3	2402, Q POWER REF2	
90.04 D SET 12 VAL 1	15804, FAN SPEED RUN MIN	
92.02 D SET 11 VAL 2	108, POWER	
92.03 D SET 11 VAL 3	107, REACTIVE POWER	
92.04 D SET 13 VAL 1	911, SUPPLY FAULT WORD	
92.05 D SET 13 VAL 2	912, SUPPLY ALARM WORD	
92.06 D SET 13 VAL 3	115, DI6-1 STATUS	
92.07 D SET 15 VAL 1	122, RO3-1 STATUS	
92.08 D SET 15 VAL 2	106, LINE CURRENT	
92.09 D SET 15 VAL 3	111, MAINS VOLTAGE	
92.10 D SET 17 VAL 1	119, AI1 [V]	
92.11 D SET 17 VAL 2	120, AI2 [mA]	

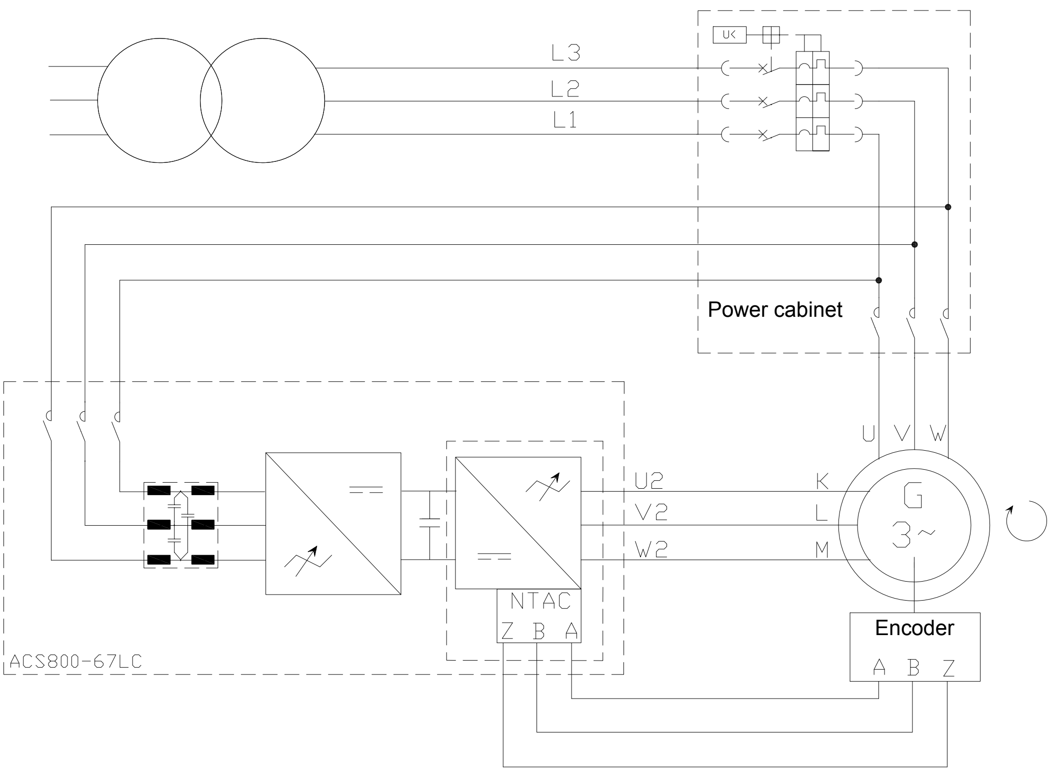
Parameter	Setting	Note
92.12 D SET 17 VAL 3	121, AI3 [mA]	
92.13 D SET 19 VAL 1	112, PP TEMP	
92.14 D SET 19 VAL 2	406, CONV NOM POWER	
92.15 D SET 21 VAL 1	132, EXT TMP 1	
92.16 D SET 21 VAL 1	133, EXT TMP 2	
92.17 D SET 21 VAL 2	134, EXT TMP 3	
92.18 D SET 21 VAL 2	135, EXT TMP 4	
93.01 D SET 23 VAL 1	1901, DATA 1	
93.02 D SET 23 VAL 2	1902, DATA 2	
98.01 COMMAND SEL	MCW	
98.02 COMM. MODULE	CASCADE	
98.11 AI/O EXT MODULE 1	RAIO-SLOT1	

How to change the rotation direction of the generator

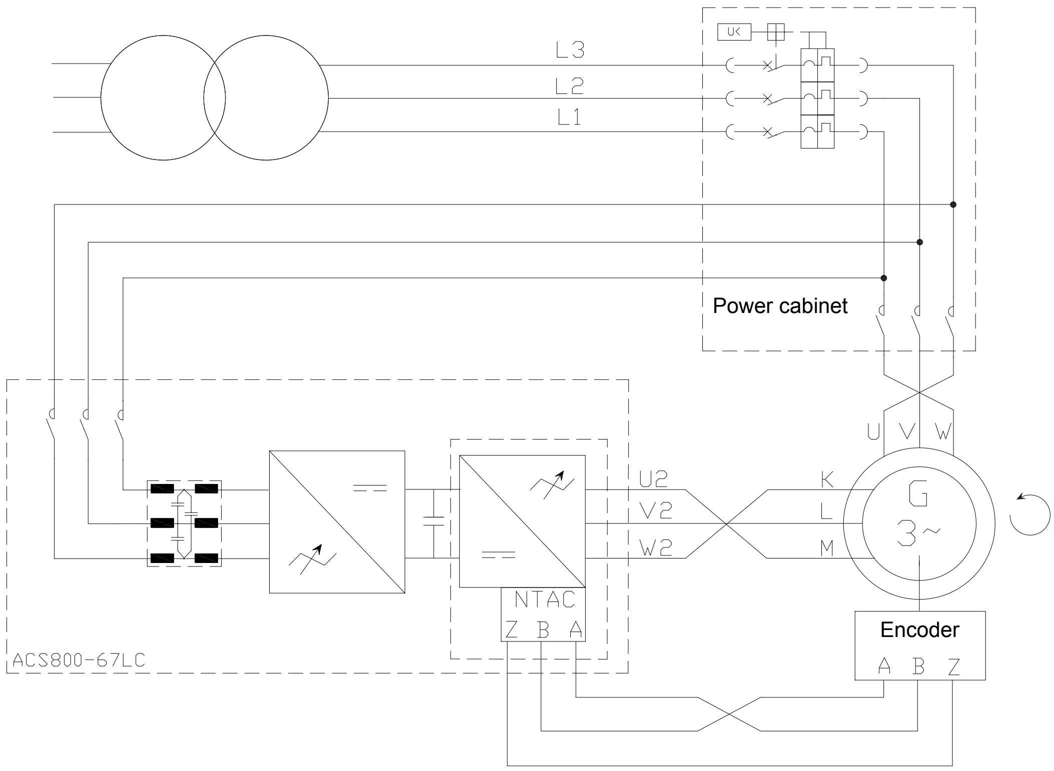
General

Terminal markings of the ABB generators for the stator (U, V, W) and rotor (K, L, M) are based on IEC 60034-8. The terminal markings are arranged so that the clockwise rotation is obtained when the alphabetical sequence of the letters (for example U1, V1, W1) corresponds to the time sequence of the system phase voltages. The phase sequence of the secondary winding (for example K, L, M) must correspond to the phase sequence of the primary winding (for example U, V, W). In counterclockwise rotation the time sequence of the system phase voltages are reversed by rearranging the supply cables (for example L2 and L3 in the case of 3-phase cabling). If the rotation direction of the generator is changed, U, V, W are changed to V, U, W. Respectively K, L, M are changed to L, K, M. Grid connections L1, L2, L3 connect to V, U, W and rotor connections U1, V1, W1 connect to L, K, M in counterclockwise rotation.

Clockwise rotation at drive end (D end)



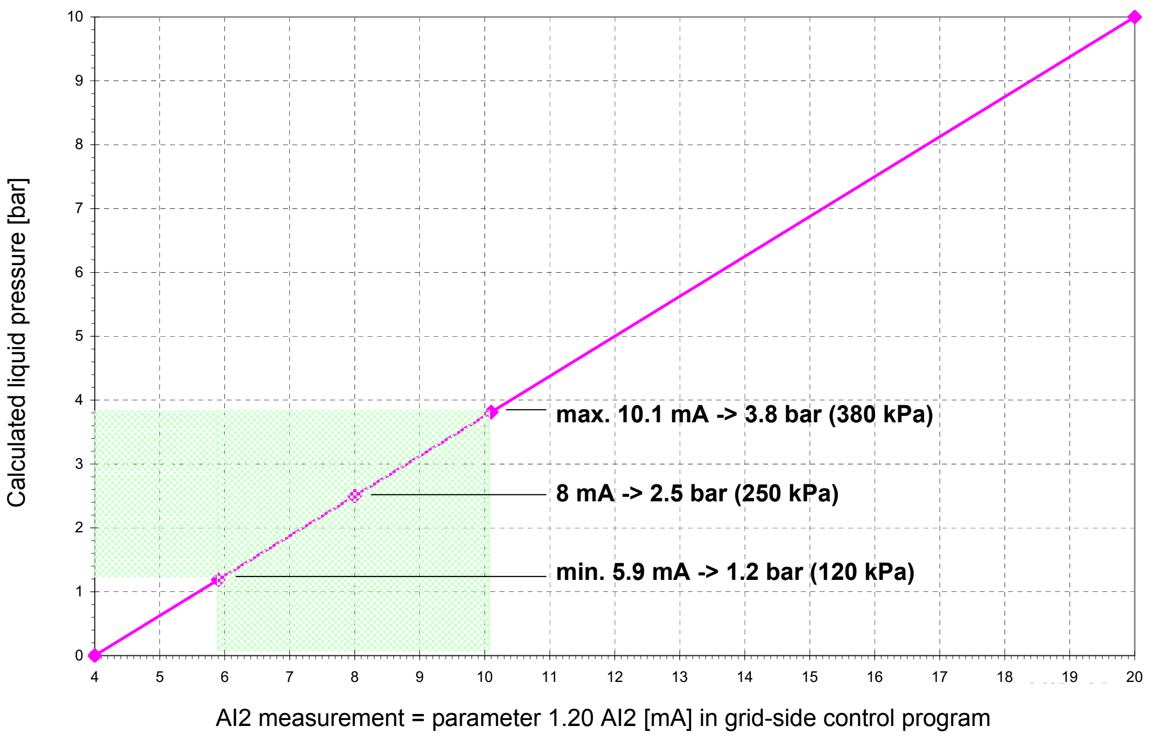
Counterclockwise rotation at drive end (D end)



Measurements of the pressure transmitter

Current signal is converted into pressure unit (bar). The diagram below shows the conversion principle.

Liquid pressure vs. AI2 measurement



$$y = 0{,}625x - 2{,}5$$

Measuring range for the pressure sensor is 0…10 bar (0…1000 kPa) and 4…20 mA. Minimum and maximum limits for the pressure is shown in the diagram above in green. Fault limits for measurement are set in grid-side control program.

How to download the diagnostics of APBU branching unit

APBUDL is a tool program for APBU datalogger control and data upload. It is highly recommended to use the APBUDL program with the RUSB-01 adapter. With following instructions the datalogger file is downloaded for further analysis.

Program file is APBUDL.exe. These files are also needed in the same directory or in the system directory: Dwc_ddcp.dll, amctvb.dll, amctooli.dll.

Status:

- No communication (No communication between PC and APBU board)
- APBU found (Communication OK, logic version of APBU board)
- Status (Status of loggers; if data collection is on: logging. If logger has triggered: data ready)

Commands:

- u = Upload a logger
- t = Trig user logger
- l = Start user logger
- q = Quit

Data upload:

- u = Upload a logger
- Define how many percent of the samples is uploaded (1…100)
- Define which logger is uploaded (F/L/U) [First/Last/User]

Following files will be created:

First Logger: first.csv

Last Logger: last.csv

User Logger: user.csv

Note: Files must be renamed.

Main circuit breaker settings in the start-up (option +C108 or +C109)

Set the correct trigger limits for the main circuit breaker protections (LSI) as described in the tables below.

SACE Emax E3S-A20/230/LSI				Setting	Trigger threshold
L	Overload protection	I1 + k	=	0.7 + 0.075	(0.7 x 2000 A) + (0.075 x 2000 A) = 1550 A_{RMS}
	Trip time curve	t1	=	3	3 s (3 x I1 = 4650 A_{RMS})
S	Selective short-circuit protection	I2	=	1.5	1.5 x 2000 A = 3000 A_{RMS}
	Trip time curve	t2	=	I>I2 0.3 s	0.3 s
I	Instantaneous short-circuit protection	I3	=	3	3.0 x 2000 A = 6000 A_{RMS}
		Frequency	=	50	(or 60 Hz)
		InN	=	OFF	

SACE Emax E3S-A25/230/LSI				Setting	Trigger threshold
L	Overload protection	I1 + k	=	0.9 + 0.025	(0.9 x 2500 A) + (0.025 x 2500 A) = 2312.5 A_{RMS}
	Trip time curve	t1	=	3	3 s (3 x I1 = 6937.5 A_{RMS})
S	Selective short-circuit protection	I2	=	1.5	1.5 x 2500 A = 3750 A_{RMS}
	Trip time curve	t2	=	I>I2 0.3 s	0.3 s
I	Instantaneous short-circuit protection	I3	=	3	3.0 x 2500 A = 7500 A_{RMS}
		Frequency	=	50	(or 60 Hz)
		InN	=	OFF	

SACE Emax E4S-A32/230/LSI				Setting	Trigger threshold
L	Overload protection	I1 + k	=	0.8 + 0.025	(0.8 x 3200 A) + (0.025 x 3200 A) = 2640 A_{RMS}
	Trip time curve	t1	=	3	3 s (3 x I1 = 7920 A_{RMS})
S	Selective short-circuit protection	I2	=	1.5	1.5 x 3200 A = 4800 A_{RMS}
	Trip time curve	t2	=	I>I2 0.3 s	0.3 s
I	Instantaneous short-circuit protection	I3	=	3	3.0 x 3200 A = 9600 A_{RMS}
		Frequency	=	50	(or 60 Hz)
		InN	=	OFF	

SACE Emax E4S-A36/230/LSI				Setting	Trigger threshold
L	Overload protection	I1 + k	=	0.8 + 0.05	(0.8 x 3600 A) + (0.05 x 3600 A) = 3060 A_{RMS}
	Trip time curve	t1	=	3	3 s (3 x I1 = 9180 A_{RMS})
S	Selective short-circuit protection	I2	=	1.5	1.5 x 3600 A = 5800 A_{RMS}
	Trip time curve	t2	=	I>I2 0.3 s	0.3 s
I	Instantaneous short-circuit protection	I3	=	3	3.0 x 3600 A = 10800 A_{RMS}
		Frequency	=	50	(or 60 Hz)
		InN	=	OFF	

SACE Emax E4S-A40/230/LSI				Setting	Trigger threshold
L	Overload protection	I1 + k	=	0.9 + 0.075	(0.9 x 4000 A) + (0.075 x 4000 A) = 3900 A_{RMS}
	Trip time curve	t1	=	3	3 s (3 x I1 = 11700 A_{RMS})
S	Selective short-circuit protection	I2	=	1.5	1.5 x 4000 A = 6000 A_{RMS}
	Trip time curve	t2	=	I>I2 0.3 s	0.3 s
I	Instantaneous short-circuit protection	I3	=	3	3.0 x 4000 A = 12000 A_{RMS}
		Frequency	=	50	(or 60 Hz)
		InN	=	OFF	

5

Tracing the source of warnings, limits and faults

What this chapter contains

This chapter describes the warnings, limits and faults of the converter and refers to descriptions of the warning and fault messages and LEDs given in other manuals.

Warnings

Abnormal statuses are indicated by the warning words and messages.

Limits

The converter control programs limit, for example, current, torque, power, speed and overvoltage. The performance of the limiters can be controlled by parameters.

The activation of the limits is indicated in limit words, for example in signals 08.03 LIMIT WORD 1 and 08.04 LIMIT WORD 2 in the System Control Program.

Current limit

Current is typically limited if it reaches either the rated value of the converter or the user-defined value, parameter 20.04 MAXIMUM CURRENT in the System Control Program.

Torque limit

The converter calculates shaft torque every 25 microsecond.

Torque is typically limited when

- the limit defined by parameter 20.05 USER POS TORQ LIM is met

- some factor in the torque reference chain requires it
- the pull-out torque of the generator approaches the torque reference.

Power limit

Parameters 20.17 P MOTORING LIM and 20.18 P GENERATING LIM define the maximum allowed power flows.

Faults

The converter protects itself with many functions. When a protection function is activated, the converter is immediately stopped (tripped) to avoid damages. A fault does not necessary mean that there is any material failure in the converter.

How to identify the fault and what to do in a specific fault situation

Each RMIO board contains a fault logger. The latest faults and warnings are stored together with the time stamp at which the event was detected. The fault logger collects 64 of the most recent available pieces of information concerning faults (such as fault, warning, reset and system messages) into the fault buffer in the RAM memory. The latest 16 inputs are stored to the flash memory at the beginning of an auxiliary power supply loss if an internal +24 V power supply is used.

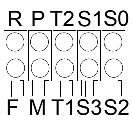
Each RMIO board also contains data loggers 1 and 2. They are used to monitor signals and to store them for later retrieval and analysis. The contents of the data loggers are stored to the RAM memory.

The fault logger can be browsed in DriveWindow under the **Fault** tab and the data loggers under the **Data logger** tab. For more information, refer to *DriveWindow user's manual* [3BFE64560981 (English)].

Compare the warning and fault messages of the fault logger to the messages listed in the firmware manual. Most warning and fault causes can be identified and corrected using the information in the fault tracing tables.

Before contacting ABB, see section *Further information* on page *12*.

LEDs of the converter

Location		**LED**	**When LED is lit**
RMIO-02			
	V30	Red	Converter in fault state
	V22	Green	The 5 V power supply on the board is OK.
Control panel mounting platform			
		Red	Converter in fault state
		Green	The main 24 VDC power supply for the control panel and the RMIO board is OK.
AINT-12			
	V203	Green	The 5 V power supply on the board is OK.
	V309	Green	Converter operation is enabled.
	V310	Red	Prevention of unexpected start is ON.
	V311	Green	The 24 V power supply for the gate drivers is OK.
AITF-01C*			
	V203	Green	The 5 V power supply on the board is OK.
	V309	Green	Converter operation is enabled.
	V310	Red	Prevention of unexpected start is ON.
	V311	Green	The 24 V power supply for the gate drivers is OK.
AFIN-01			
	V13	Green	The 5 V power supply on the board is OK.
	V14	Green	The converter is running.
	V15	Yellow	Motor thermal switch is active (open).
	V16	Red	Motor overcurrent
APOW-01			
	V16	Green	The 24 V output voltage is ON.
AMC-33**			
	F	Red	Internal fault: LED is on during program boot.
	R	Green	Not in use with the current software version
	M	Green	RESET signal is ON.
	P	Green	Auxiliary voltage is OK.
	T1...T2	Yellow	DDCC channels CH0 (T1) and CH3 (T2) are receiving data.
	S1	Yellow (blinking)	Application program is running.
	S0...S3	Yellow	Not in use with the current software version
APBU-44			
	V18 A (upper)	Green	The 3.3 V power supply voltage is OK.
	V18 B (lower)	Green	Backup battery voltage is OK. LED does not indicate missing battery or the OFF state of the battery ON/OFF switch in APBU board revision D or earlier.
	V19 A (upper)	Yellow	Master channel (CNTL) is sending data.
	V19 B (lower)	Yellow	Master channel (CNTL) is receiving data.
NPBU-42			
	V5	Green	The 5 V logic voltage is OK. (RESET is inactive.)
	V13	Green	AMC channel is receiving data.
	V8	Green	AMC channel is sending data.
	V20-23	Green	INT channel CH1...4 is receiving data.
	V18	Red	Internal configuration fault
	V24, V26	Red	For test use only

* Located on the crowbar unit.

**Located on the NDCU-33 unit.

Warning and fault messages

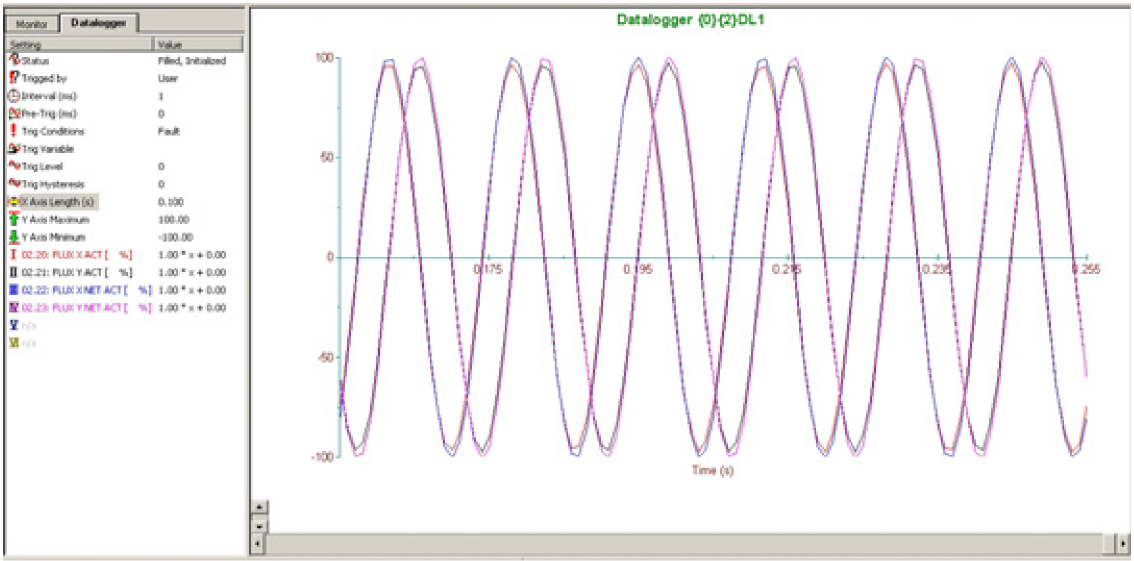
Refer to

- *ACS800 grid-side control program firmware manual* [3AUA0000075077 (English)]
- *ACS800-67(LC) doubly-fed induction generator control program firmware manual* [3AUA0000071689 (English)].

Checking the phase sequence of grid-side converter voltage measurement

If an OVERCURRENT fault or GRID SYNC FAIL fault occurs during the start-up when the operation of the converter is tested, or if the grid fault ride-through function fails, make the checks described in the table below.

Action	
☐	Check the value of grid-side converter parameter 01.11 MAINS VOLTAGE. Refer to *Grid-side control program for ACS800 wind turbine converters firmware manual* [3AUA0000075077 (English)]. If the voltage level is correct, the communication between NAMU-01 board and DDCS channel 2 of the grid-side converter control board is OK.
☐	Check the phase sequence of the grid-side converter grid voltage measurement:
○	Monitor the following grid-side converter signals with DriveWindow Datalogger at 1 ms intervals: 02.22 FLUX X NET ACT (NAMU-01 measured signal) 02.23 FLUX Y NET ACT (NAMU-01 measured signal) 02.20 FLUX X ACT (converter actual signal) 02.21 FLUX Y ACT (converter actual signal).
○	Start the Datalogger and trigger it manually. Upload Datalogger information. An example view of the Datalogger is shown below.



○	If signals 02.22 FLUX X NET ACT and 02.20 FLUX X ACT are in phase and signals 02.23 FLUX Y NET ACT and 02.21 FLUX Y ACT are in phase, the measurement phase sequence is OK. **Note:** If the signals are not in phase, check the grid voltage measurement cabling of the grid-side converter NAMU-01 measuring unit and correct the phase sequence. See *ACS800-67LC wind turbine converters hardware manual* [3AUA0000058400 (English)].

Faults in measurements

Fault	Cause	What to do
Pulse encoder pulses or zero pulse are missing or wrong	Generator overcurrent fault Speed / position / RTAC module fault	If the encoder is of unisolated type, check that the cable is grounded only on converter side. In case of wrong encoder direction, check the pulse encoder phasing (A/B channels). Check the type and connection of the encoder; differential encoder is recommended.
Current value is wrong. Torque actual value does not correspond to the reference value. There is reactive power without reference. Torque oscillates and overcurrent fault occurs. Current imbalance fault Earth fault	Faulty current transformer inside ISU or INU module Wrong values in parameter group 99 in the inverter control program	Check the current transformer. Check the values in parameter group 99.

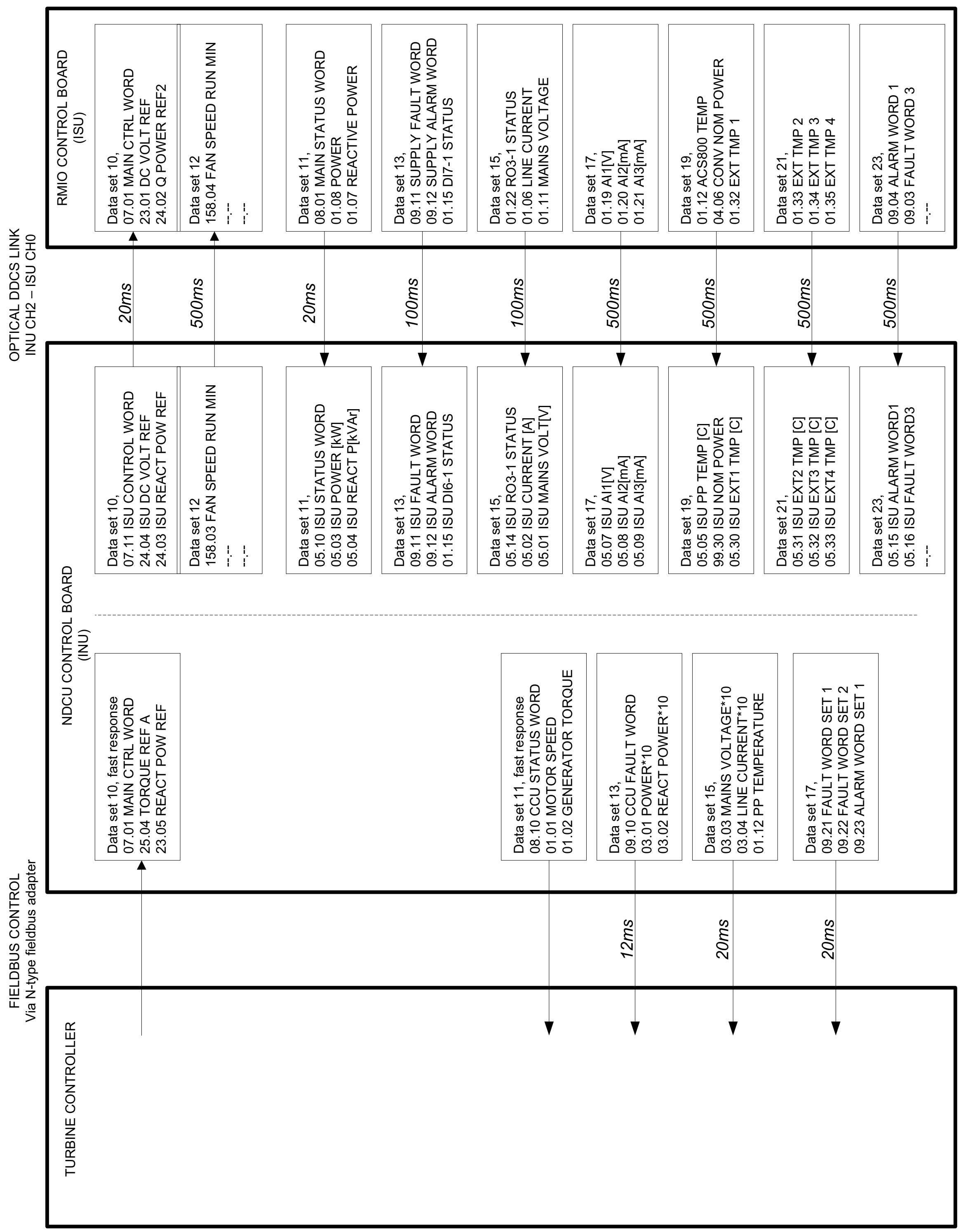
6

Communication details

What this chapter contains

This chapter shows the transmitted and received actual signals and parameters of the turbine controller and converter.

Acyclic signals and parameters are transmitted and received as requested. Cyclical communication is performed at fixed intervals.


RMIO CONTROL BOARD (ISU)
Data set 10, 07.01 MAIN CTRL WORD 23.01 DC VOLT REF 24.02 Q POWER REF2
Data set 12 158.04 FAN SPEED RUN MIN --.-- --.--
Data set 11, 08.01 MAIN STATUS WORD 01.08 POWER 01.07 REACTIVE POWER
Data set 13, 09.11 SUPPLY FAULT WORD 09.12 SUPPLY ALARM WORD 01.15 DI7-1 STATUS
Data set 15, 01.22 RO3-1 STATUS 01.06 LINE CURRENT 01.11 MAINS VOLTAGE
Data set 17, 01.19 AI1[V] 01.20 AI2[mA] 01.21 AI3[mA]
Data set 19, 01.12 ACS800 TEMP 04.06 CONV NOM POWER 01.32 EXT TMP 1
Data set 21, 01.33 EXT TMP 2 01.34 EXT TMP 3 01.35 EXT TMP 4
Data set 23, 09.04 ALARM WORD 1 09.03 FAULT WORD 3 --.--
OPTICAL DDCS LINK INU CH2 – ISU CH0
20ms
500ms
20ms
100ms
100ms
500ms
500ms
500ms
500ms
NDCU CONTROL BOARD (INU)
Data set 10, 07.11 ISU CONTROL WORD 24.04 ISU DC VOLT REF 24.03 ISU REACT POW REF
Data set 12 158.03 FAN SPEED RUN MIN --.-- --.--
Data set 11, 05.10 ISU STATUS WORD 05.03 ISU POWER [kW] 05.04 ISU REACT P[kVAr]
Data set 13, 09.11 ISU FAULT WORD 09.12 ISU ALARM WORD 01.15 ISU DI6-1 STATUS
Data set 15, 05.14 ISU RO3-1 STATUS 05.02 ISU CURRENT [A] 05.01 ISU MAINS VOLT[V]
Data set 17, 05.07 ISU AI1[V] 05.08 ISU AI2[mA] 05.09 ISU AI3[mA]
Data set 19, 05.05 ISU PP TEMP [C] 99.30 ISU NOM POWER 05.30 ISU EXT1 TMP [C]
Data set 21, 05.31 ISU EXT2 TMP [C] 05.32 ISU EXT3 TMP [C] 05.33 ISU EXT4 TMP [C]
Data set 23, 05.15 ISU ALARM WORD1 05.16 ISU FAULT WORD3 --.--
Data set 10, fast response 07.01 MAIN CTRL WORD 25.04 TORQUE REF A 23.05 REACT POW REF
Data set 11, fast response 08.10 CCU STATUS WORD 01.01 MOTOR SPEED 01.02 GENERATOR TORQUE
Data set 13, 09.10 CCU FAULT WORD 03.01 POWER*10 03.02 REACT POWER*10
Data set 15, 03.03 MAINS VOLTAGE*10 03.04 LINE CURRENT*10 01.12 PP TEMPERATURE
Data set 17, 09.21 FAULT WORD SET 1 09.22 FAULT WORD SET 2 09.23 ALARM WORD SET 1
FIELDBUS CONTROL Via N-type fieldbus adapter
12ms
20ms
20ms
TURBINE CONTROLLER

Further information

Product and service inquiries

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

Product training

For information on ABB product training, navigate to www.abb.com/drives and select *Training courses*.

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