CSU100-1GAMP4-HV

DATASHEET

KEY FEATURES

- Output power: 100 kW
- DC, 1-ph or 3-ph AC output
- Four-quadrant operation
- Regenerative up to full power
- Scalable up to 600 kW & 3000 V DC
- AC output voltage L-L: 485 V RMS
- AC output current 1-ph: 120 ARMS
- DC output voltage: 820 V
- DC output current: 560 A
- Large-signal BW: 5 kHz
- Small-signal BW: 15 kHz
- Programmable V and I limits
- Voltage accuracy: 0,1%
- Current accuracy: 0,56%
- Peak efficiency: 95%
- Frequency accuracy: 1 mHz
- Meets IEEE 1547.1
- CE Certified

PHIL

GRID

RENEWABLE ENERGY

E-MOBILITY

AEROSPACE

MARINE

ACADEMIC RESEARCH

TESTING

EGSTON POWER

SYSTEM INTRODUCTION

The CSU100-1GAMP4-HV (COMPISO System Unit 100 – Single Group of four Amplifiers) is a galvanically isolated bidirectional 100 kW emulation and test system with four independent bidirectional switched-mode power amplifiers capable of operating in several predefined AC and DC operation modes as well as a wide range of user-defined Hadware-in-the-loop (HIL) based modes. The system can operate in current-control, voltage-control or mixed mode and is capable of acting as a source or sink with seamless transition between sourcing power and regenerating power back to the supply grid. Featuring large-signal bandwidth of 5 kHz and small-signal bandwidth of 15 kHz, the system can generate harmonics up to the 100th order (for 50 Hz fundamental) and interharmonics up to 15 kHz for smooth frequency sweeps. The CSU100-1GAMP4-HV is controlled by an EGSTON Real-Time (RT) Processor or external HIL systems via fast optic fiber (SFP – Small Form Factor Pluggable) or analog interface.

The optional 4QAC Source software application enables generation of arbitrary periodic waveforms whose amplitude, frequency, phase (time shift) and DC offset can be changed every 1 ms. The active and reactive power can be changed separately in each phase every 1 ms, enabling more complex test scenarios such as Low Voltage Ride Through, High Voltage Ride Through, and frequency drift.

The optional 4QDC Source software application is used to execute various DC tests, ranging from simple constant-current, constant-voltage or constant-power operation to more advanced scenarios such as emulation of PV arrays and batteries modelled on I-V curves.

The optional PowerSCOPE can be used to monitor system setpoints and generated output voltages and currents. It supports visualization and storage of up to 64 input channels with a sample rate of 250 kS/s per channel.

SYSTEM DESCRIPTION & OPERATION MODES

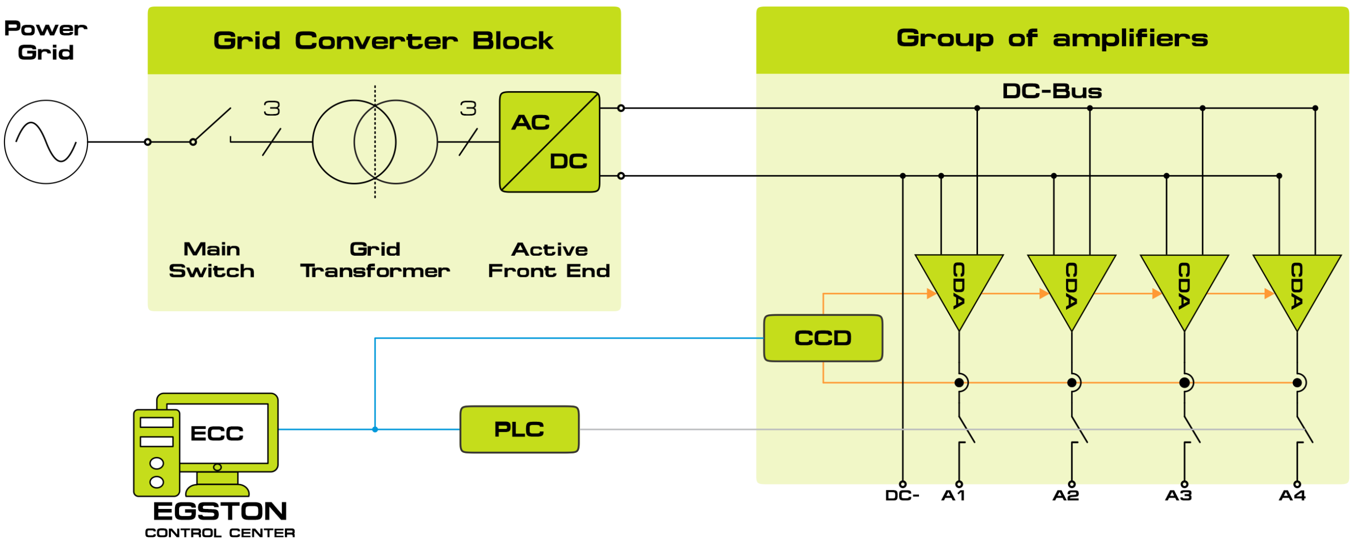


Figure 1. Simplified block diagram of the CSU100-1GAMP4-HV system.

The CSU100-1GAMP4-HV connects to a three-phase+N power grid (three-phase four-wire system) via a galvanic isolation transformer. A protective earth (PE) connection providing adequate grounding must also be available. The system can be adapted to any three-phase power grid voltage from 400–690 V at 50/60 Hz. The transformer feeds an Active Front End (AFE) that converts the grid's AC voltage to a controlled DC-link voltage. The maximum active power that can be sourced from or regenerated to the grid is 100 kW. The CSU100-1GAMP4-HV consists of four COMPISO Digital Amplifiers (CDAs). This amplifier group is controlled by one COMPISO Control Device (CCD) and one Programable Logic Controller (PLC). The output voltage and current of each amplifier are measured at its output terminal.The CSU100-1GAMP4-HV consists of two cabinets and a desktop PC with EGSTON Control Center (ECC) software used to monitor, configure and control the system operating in any of the standard operation modes illustrated in Figure 2.

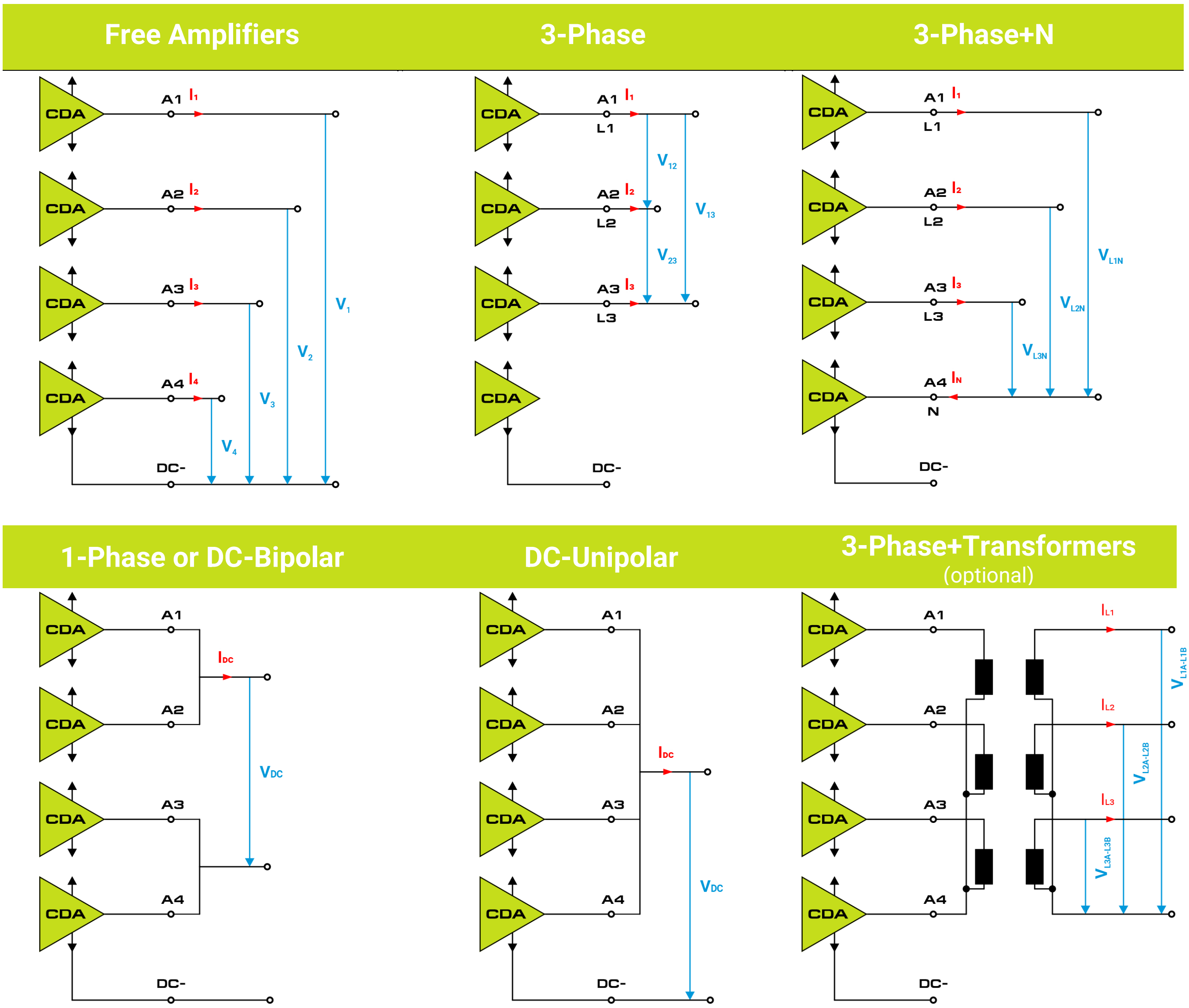


Figure 2. CSU100-1GAMP4-HV operation modes.

The available voltage, current and power range in each operation mode are listed in Table 1. In each operation mode, the system can either operate as a power source or regenerate power back to the grid. The values listed in Table 1. are valid for both directions. In order to increase the output voltage in three-phase operation modes, with or without the neutral terminal, a third harmonic injection can be used. Output power is limited to 100 kW in DC bipolar and DC unipolar operation modes by voltage or current derating, as illustrated in Figure 3.

Table 1. Available voltage, current and power range in each operation mode.

Operation mode: Free amplifiers (all values are per CDA)		
AC mode[1]		
DC offset voltage	V_{DC}	420 V_{DC}
Minimum AC voltage	V_{min}	0 V_{RMS}
Maximum AC voltage	V_{max}	280 V_{RMS}
Minimum AC current	I_{min}	0 A_{RMS}
Maximum AC current	I_{max}	120 A_{RMS}
Maximum active power	P_{max}	33,6 kW
Maximum apparent power	S_{max}	33,6 kVA
DC mode (unipolar)		
Minimum DC voltage	V_{min}	20 V_{DC}
Maximum DC voltage	V_{max}	820 V_{DC}
Minimum DC current	I_{min}	-140 A_{DC}
Maximum DC current	I_{max}	140 A_{DC}
Maximum power	P_{max}	100 kW
Operation mode: Three-phase + N		
Minimum LL voltage	$V_{LL\ min}$	0 V_{RMS}
Maximum LL voltage	$V_{LL\ max}$	485 V_{RMS}
Maximum LN voltage	$V_{LN\ max}$	280 V_{RMS}
Minimum current	$I_{L\ min}$	0 A_{RMS}
Maximum current	$I_{L\ max}$	120 A_{RMS}
Maximum active power	P_{max}	100 kW
Maximum apparent power	S_{max}	100 kVA
Operation mode: Three-phase		
Minimum LL voltage	$V_{LL\ min}$	0 V_{RMS}
Maximum LL voltage	$V_{LL\ max}$	485 V_{RMS}
Minimum current	$I_{L\ min}$	0 A_{RMS}
Maximum current	$I_{L\ max}$	120 A_{RMS}
Maximum active power	P_{max}	100 kW
Maximum apparent power	S_{max}	100 kVA

Table 1. (continued)

Operation mode: Three-phase + N (with 3rd harmonic injected)		
Minimum LL voltage	$V_{LL\ min}$	0 V_{RMS}
Maximum LL voltage	$V_{LL\ max}$	555 V_{RMS}
Maximum LN voltage	$V_{LN\ max}$	320 V_{RMS}
Minimum current	$I_{L\ min}$	0 A_{RMS}
Maximum current	$I_{L\ max}$	120 A_{RMS}
Maximum active power	P_{max}	100 kW
Maximum apparent power	S_{max}	100 kVA
Operation mode: Three-phase (with 3rd harmonic injected)		
Minimum LL voltage	$V_{LL\ min}$	0 V_{RMS}
Maximum LL voltage	$V_{LL\ min}$	555 V_{RMS}
Minimum current	$I_{L\ min}$	0 A_{RMS}
Maximum current	$I_{L\ max}$	120 A_{RMS}
Maximum apparent power	S_{max}	100 kVA
Operation mode: Three-phase + transformers ($n = V_s/V_p$; x = 1, 2, 3)		
Minimum voltage	V_{Lx}	0 V
Maximum voltage	$V_{Lx\ max}$	n × 485 V
Minimum current	$I_{Lx\ min}$	0 A
Maximum current	$I_{Lx\ max}$	(1/n) × 120 A
Maximum power	S_{max}	100 kVA
Operation mode: Single-phase[2]		
Minimum voltage	V_{min}	0 V_{RMS}
Maximum voltage	V_{max}	565 V_{RMS}
Maximum current	I_{max}	240 A_{RMS}
Maximum active power	P_{max}	100 kW
Maximum apparent power	S_{max}	100 kVA
Operation mode: DC bipolar		
Minimum voltage	V_{min}	-800 V
Maximum voltage	V_{max}	800 V
Minimum current	I_{min}	-280 A
Maximum current	I_{max}	280 A
Maximum power	P_{max}	100 kW
Operation mode: DC unipolar		
Minimum voltage	V_{min}	20 V
Maximum voltage	V_{max}	820 V
Minimum current	I_{min}	-560 A
Maximum current	I_{max}	560 A
Maximum power	P_{max}	100 kW

[1] The CDA output voltage has a DC offset of 420 V (with respect to the DC- terminal).
[2] Due to single-phase load on the AFE, power derating applies if the frequency of the output voltage is less than 100 Hz, as shown in Figure 8

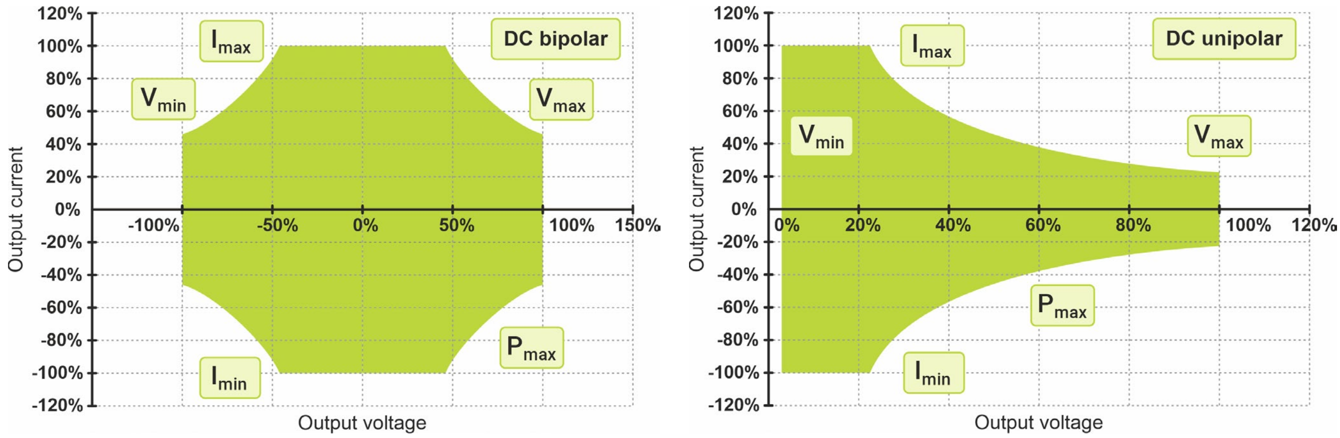


Figure 3. Power limits for DC bipolar and DC unipolar operation modes.

For all AC operation modes, the maximum available output voltage is reduced at higher output frequencies as illustrated in Figure 4 (for resistive loads) and Figure 5 (for inductive loads). This reduction is due to an increased voltage drop across the internal output filter at higher output frequencies. Output voltage derating additionally applies at frequencies above 5 kHz to avoid overheating the output filter capacitors, as illustrated in Figure 6, and output current derating at higher frequencies is necessary to avoid overheating the internal output inductor, as illustrated in Figure 7.

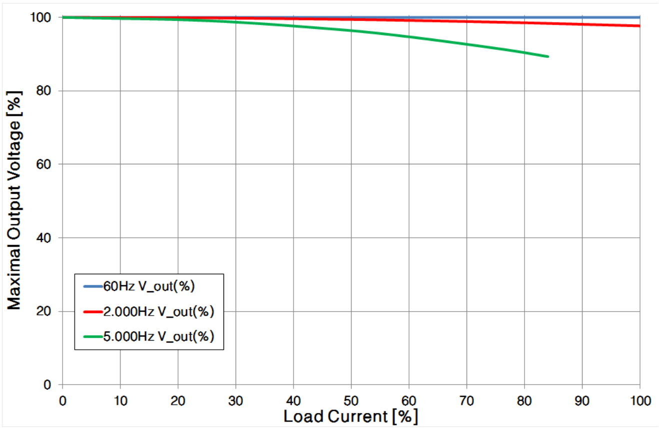


Figure 4. Maximum AC output voltage VS resistive load current

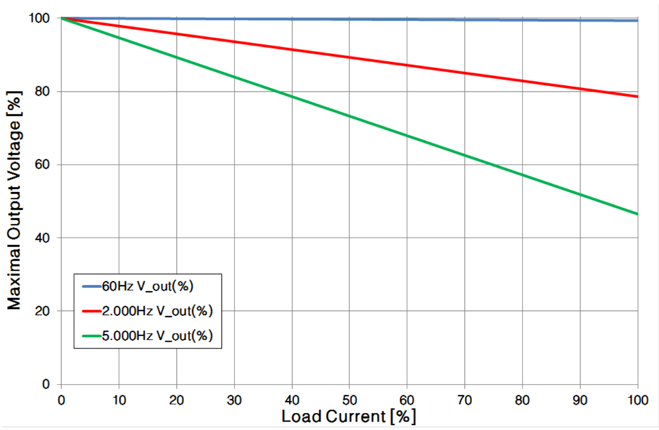


Figure 5. Maximum AC output voltage VS inductive load current.

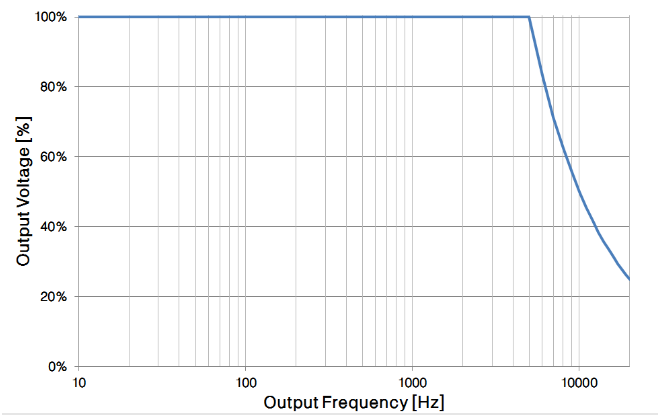


Figure 6. Maximum output voltage versus output frequency.

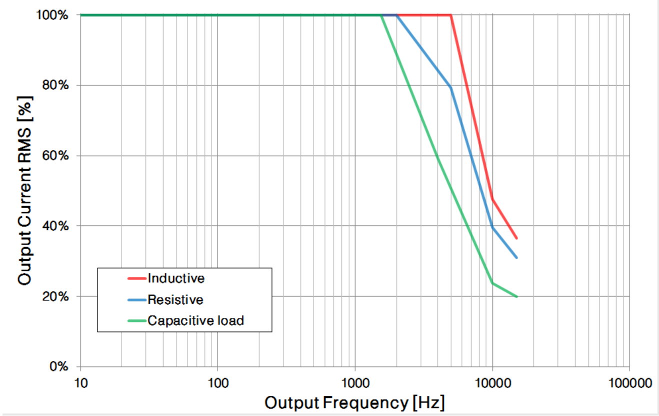


Figure 7. Maximum output current versus frequency for different load types.

When the standard system operates in single-phase operation mode with an output frequency lower than 100 Hz, the maximum power at the system's output must be reduced, as illustrated in Figure 8. Derating is introduced to limit variation of the DC link voltage, which changes at twice the output frequency, and is determined by the capacitance of the internal DC-link capacitors in the system. The blue line in Figure 8 represents the output power of the standard system, and the red line represents the power of the system with the additional 33 mF capacitors in the DC link. The 100% of PMAX (Smax) corresponds to respective values from Table 1 for Single-phase mode.

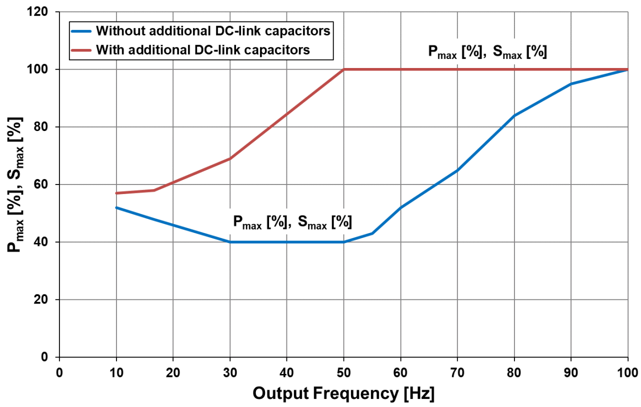


Figure 8. Power derating in single-phase operation mode.

GENERAL SYSTEM PROPERTIES

The electrical properties presented in Table 2 are valid for an ambient temperature of 25°C.

Table 2. General system properties

System properties		
Number of independent amplifiers		4
Rated system power	P_{OUT}	100 kW
System overload for 60 s	I_{OUT_60s}	1,2 × I_{OUT} (only for DC operation modes)
System overload for 2 s	I_{OUT_2s}	1,35 × I_{OUT} (only for DC operation modes)
Peak system efficiency	η	95% (at rated output power)
Output harmonics range		Up to the 100th harmonic at 50 Hz fundamental
Interharmonics and subharmonics		0,1 Hz to 5 kHz (full voltage) 5–15 kHz (reduced voltage)
Adjustable limits		Current, voltage
Adjustable trips		Current, voltage, power
System protections		Overvoltage, overcurrent, short circuit, overtemperature, humidity
Rated insulation voltage		1600 V_{DC} (output-to-output and output-to-ground)
Connection to main supply		Permanent
Overvoltage category		II
Protection class		I
Degree of pollution		2
Relative humidity		Average:75% Maximum: 85% for up to 30 days, distributed evenly over the year
Operating temperature		5-30°C
Maximum altitude		2000 m
Ingress protection		IP20 (per IEC 60529)
Noise level (sound pressure level)		< 82 dB (at operator's normal position and bystanders' positions)

Table 2. (continued)

Certification		
CE Certified		
The product conforms with the following harmonized standards:		
Safety requirements		EN 61010-1:2020 EN 62477-1:2012 IEC 61000-6-2:2016
Radio-frequency disturbance		EN 55011:2016 + A1:2017
Electromagnetic interference		EN IEC 61000-6-2:2019
The product is compliant with the following European regulations:		
Low Voltage Directive		2014/35/EU
EMC Directive		2014/30/EU
RoHS Directive		2011/65/EU
Grid converter block		
Grid Connection Type		Three-phase four-wire
Rated input power	S_{IN}	130 kVA
Rated input voltage	V_{AC}	400 V_{RMS} ±10% (or 480 V_{RMS} ±10%)
Input frequency range	f	47,5–63 Hz
Rated input current	I_{IN}	188 A_{RMS} (for 400 V_{RMS} input), 156 A_{RMS} (for 480 V_{RMS} input)
Inrush current	I_{INRUSH}	1005 A_{PEAK}
Power factor	PF	≈1 (also with partial load and at energy regeneration)
Input current THD	THDi	< 5%
DC-link voltage	$V_{DC\text{-}link}$	850 V
CDA electrical characteristics		
Maximum DC power	P_{DC}	115 kW (continuous)
Maximum AC power [3]	P_{AC}	33,6 kVA (continuous)
Output freq. large signal[3]	f_{OUT_LS}	0,1 Hz to 5 kHz
Output freq. small signal[3]	f_{OUT_SS}	5–15 kHz
Output frequency resolution[3]		±1 mHz
Output phase resolution[3]		±0,01°
Output voltage THD[3]	THDu	< 0,04% (at 50/60 Hz, no load condition) < 0,09% (at 400 Hz, no load condition)
Switching frequency	f_{SW}	125 kHz
Delay time (typical)	t_d	28 µs (setpoint-to-output)
Voltage slew rate	SR	12 V/µs (maximum slew rate of output voltage with a resistive load)
Output voltage accuracy		±1 V
Output current accuracy		±1,4 A (current offset compensation available)
Output voltage ripple	ΔV_{OUT}	3 Vpp maximum

Table 2. (continued)

Output contactors		
Rated operational voltage	U_e	1800 V_{DC} or V_{AC} RMS
Rated insulation voltage	U_i	1800 V_{DC} or V_{AC} RMS
Rated operational current	I_e	250 A
Max making current DC τ = 15 ms (per pole)		5000 A
Max making current AC cos φ = 0.8 (per pole)		5000 A
Max breaking current DC τ = 15 ms (per pole)		500
Max breaking current AC cos φ = 0.8 (per pole)		800 A
Voltage and current measurement		
Voltage measurement range		±1000 V (DC or AC peak)
Common-mode voltage range		±1200 V (DC or AC peak)
Voltage measurement accuracy		±1 V (0.1% of measurement range)
Current measurement range		±250 A (DC or AC peak)
Current measurement accuracy		±1,4 A (0,56% of measurement range)
Measurement resolution		16 bit
Measurement sample rate		1 MS/s (per channel)
Measurement bandwidth		0,1 Hz–100 kHz (-3 dB)

[3] Only the AC component of the output voltage is considered, as the CDA output voltage has a DC offset of 420 V. The values characterizing AC operation are valid for all AC modes.

COMMUNICATION ARCHITECTURE & INTERFACES

The basic properties of the communication protocols and interfaces supported by the CSU100-1GAMP4-HV are presented in Table 3, and the communication architecture is illustrated in Figure 9. Supported HIL platforms are listed in Table 3.

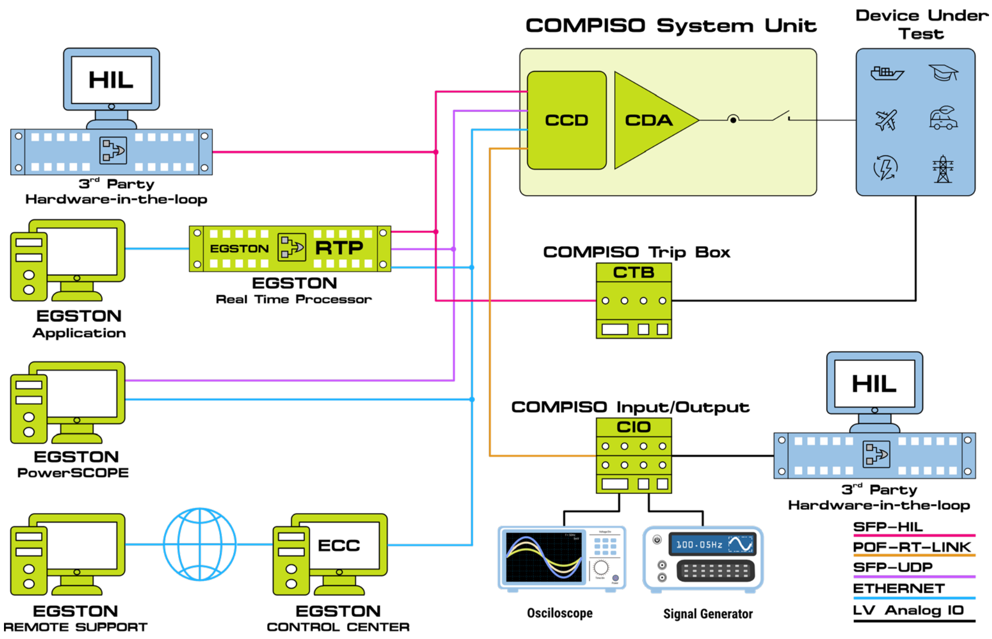


Figure 9. COMPISO communication architecture.

Table 3. Communication protocols and interfaces supported by the CSU100-1GAMP4-HV

Supported commercial HIL platforms			
SFP interface	OPAL-RT National Instruments RTDS Speedgoat Typhoon HIL dSPACE		
Analog interface	Any HIL system with low-voltage analog input/output signals		
Programming interfaces			
Modbus, Mathlab, Python, Java, C/C++			
SFP–HIL ultra-high-speed interface			
Digital RT communication between each GAMP within the CSU and an external HIL RT processor (or an EGSTON Power RT Processor) over optic-fibre cable. Receives voltage or current setpoints and transmits measured voltages and currents.			
Data rate	5 Gbps		
Latency	≤ 1 µs		
Setpoint time step	4 µs		
Setpoint update frequency	250 kHz		
SFP–UDP			
Digital RT data transfer from the GAMPs within the CSU to the EGSTON PowerSCOPE, transmitting measured voltages, currents and setpoints set via the SFP–HIL to the CCD.			
Data rate	1 Gbps (1000BASE-T)		

Ethernet interface (non-RT communication between CSU, ECC and EGSTON Power applications PC)			
Transmission protocol	TCP		
Data rate	100 Mbps		
Recommended cable category	CAT 6a or better		
POF–RT-link–high–speed RT interface (RT communication between the CSU and external COMPISO Input/Output Boxes (CIOs))			
RT-link interface to connect CIOs is optional and not part of the product delivery.			
Number of CIOs connected to CSU	3. Each CIO provides 4 analog input and 4 analog output channels.		
Cable	2,2 mm jacketed plastic optic-fibre cable		
Upload (CIO to CSU)	Sample rate	1 MS/s per channel (there are 4 channels in one CIO)	
	Latency	≤ 45,5 µs (from the analog input of CIO to the CSU output)	
Download (CSU to CIO)	Sample rate	256 kS/s per channel (there are 4 channels in one CIO)	
	Latency	≤ 5 µs (from the CSU output to the analog output of the CIO)	

Table 3. (continued)

Low-voltage analog interface between CIOs and external HIL platforms			
Analog input signals	Drives amplifier output voltages or currents.		
Analog output signals	Analog low-voltage outputs that transmit high-power voltage and current measurements from the CDAs.		
Input/output voltage range	-10 V to 10 V		
Input impedance	50 kΩ		
Sampling rate	250 kHz		
ADC resolution	16 bit		
Low-voltage digital interface (digital interface between the CIOs and external HIL platforms)			
Digital input signals	Can be transmitted from CIO over POF–RT-link to the CCD. CCD sends the digital values over POF– or SFP–RT-link to external HIL or EGSTON RT Processor for further processing.		
Digital output signals	External HIL or EGSTON RT Processor can send digital values via SFP to the CSU control to drive the digital output signal of the CIOs.		
Logic levels (3,3 V LVCMOS)	Input voltage levels:	2 V ≤ V_{IN_HIGH} ≤ 3,6 V	-0,3 V≤ V_{IN_LOW} ≤ 0,8 V
	Output voltage levels:	3,1 V ≤ V_{OUT_HIGH}	V_{OUT_LOW} ≤ 0,2 V
Maximum currents (3,3 V LVCMOS)	Input current:	I_{IN_MIN} = -5 µA	I_{IN_MAX} = 5 µA
	Output current:	I_{OUT_MIN} = -100 µA	I_{OUT_MAX} = 100 µA

COOLING REQUIREMENTS

Table 4. Cooling requirements

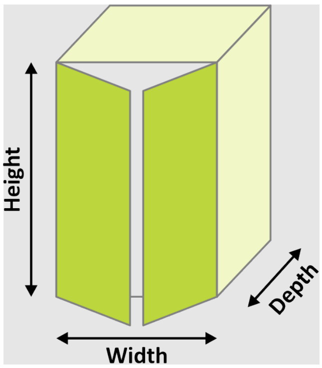
Liquid cooling (CDAs)	
Cooling media	Water, ethylene glycol, propylene glycol, glycol–water solutions
Minimum required cooling power	4,0 kW_{th} (for all 4 CDAs operating at full power)
Coolant pressure range	2,5–3 bar
Coolant flow rate	14l/min (for all 4 CDAs, using water with an inlet temperature of 20°C)
To avoid condensation, temperature of the cooling liquid must be kept higher than the ambient temperature.	
Forced-air cooling (cabinets)	
Maximum heat dissipation per CSU100-1GAMP4-HV at full power	6,5 kW_{th}

TECHNICAL DATA: MECHANICAL PROPERTIES

The CSU100-1GAMP4-HV system consists of two fixed free-standing cabinets. The dimensions and weight of each cabinet are listed in Table 5.

Table 5. Dimensions and weight of CSU100-1GAMP4-HV cabinets

Mechanical data (cabinet dimensions)								
	Width		Depth		Height		Weight	
	mm	ft	mm	ft	mm	ft	Kg	lb
Cabinet 1 1GAMP4	800	2,63	1200	3,94	2110	6,92	570	1256,60
Cabinet 2 AFE & Transformer	800	2,63	1200	3,94	2200	7,22	1100	2425,10
Total	1600	5,26	1200	3,94	2200	7,22	1670	3681,70



TESTING CAPABILITIES ACCORDING TO STANDARDS

Power grid:

- IEEE Std. 1547.1; usable as simulated area electric power systems source
- IEC 61000-3-12; meets requirements for power sources

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