ELECTRONIC TEST & POWER SYSTEMS

RENTAL
EAC-ACS-4Q

GRID-TIED FOUR QUADRANT GRID SIMULATOR

POSITIVE PROBLEM SOLVING

The EAC-ACS-4Q is a modular grid emulator with full 4 quadrant operation. Each unit has the ability to sink and source both AC and DC power.

The module's active neutral string allows for any single phase or asymmetric condition to be accurately simulated. All three of the unit's phases are individually programmable for voltage, frequency, phase angles and superimposed harmonics. Current control is also possible via proportional analogue signals. GUIs are available to simulate a variety of grid and impedance conditions. A Fourier tool can create virtually any conceivable periodic waveform, with superimposed harmonics and inter-harmonic voltages up to 5000Hz.

- Mains Regeneration of AC/DC Sink Energy
- Constant Current Amplification Mode
- Frequencies up to 5000Hz
- Simulated RLC Load Mode
- Full 4 Quadrant Operation
- Grid Simulation GUI

CONTENTS

STANDARD MODELS

SELECTION TABLE

Part Number	Maximum Power	Voltage Range	Current Range
EAC-ACS-4Q-50-r	50kVA	3 × 0 to 305Vrms (L - N)	3 × 0 to ±72A

ENCLOSURE

TECHNICAL DATA	
Cabinet Dimensions	600mm × 1100mm × 1000mm (W × H × D) including castors
Cabinet Weight	Approx. 200kg
Basic Construction	IP 20

LINESIDE

STANDARD FEATURES

TECHNICAL DATA	
AC Line Voltage	3 × 360-528VAC_{rms}
Line Frequency	50Hz ± 0.5Hz for UK (48 - 62Hz possible)
Mains Connection Type	CEE125 plug with 5m cable (3L + PE +N)
Input Current	Nominal at 3 × 360VAC_{rms}: 90ARMS Nominal at 3 × 400VAC_{rms}: 81ARMS Nominal at 3 × 440VAC_{rms}: 74ARMS Nominal at 3 × 480VAC_{rms}: 68ARMS
Inrush Current	Built-in precharge circuit (no excessive inrush current)
Powerfactor	1 (at nominal power)
THDi	≤1% at 90%P_{MAX}
Input Filter Discharge to 60V	<20s (standard)

HIGHLIGHTED FEATURE

POWER RECYCLING

When functioning as a load, the EAC-ACS-4Q has an inbuilt monitoring system that synchronises with grid conditions. This recycles the AC/DC sink energy from the loadside back to the three phase mains.

ISOLATION

STANDARD FEATURES

TECHNICAL DATA	
Power to PE (L1/L2/L3)	305VAC$_{RMS}$ (working voltage)
Power to PE (L1/L2/L3)	432VDC (working voltage)
Power to Case/Logic	2120VDC/1s (test voltage)

LOADSIDE

STANDARD FEATURES

TECHNICAL DATA	
Standard Software Modes	Constant Voltage Amplifier Mode, Constant Current Amplifier Mode, ACSControl GUI for voltage/frequency adjustment, Grid Simulation Mode with Fourier Tool, RLC Load Simulation Mode, Load Mode
Connection Type	CEE125 plug with 5m cable (3L + PE +N)
Frequency Range (at Reduced Current)	0 - 5000 Hz (see operational diagram on page 5)
Frequency (P_{MAX})	16 - 1000 Hz (see operational diagram on page 5)
Voltage Slew Rate	≤4V / µs
Voltage Slew Rate (10 - 90% step of full scale)	≤100µs
Harmonic Distortion at 50Hz[1]	≤0.4% (linear), ≤1.6% (non-linear)
Overloadability	≤150% up to 10s every 600s, ≤200% up to 1s every 60s (see operational diagrams)
Modulation Bandwidth	5kHz
DC Offset	≤10mV
DC Ripple and Noise	16Hz - 200kHz: 230mVrms | 9kHz - 20MHz: 700mV$_{p-p}$
Efficiency	90% (at nominal power)
Static Accuracy Voltage (RMS Controller)	0.05% F.S.
Static Accuracy Voltage (General)	<1.5V
Static Accuracy Frequency	2mHz
Static Accuracy Phase Angle	1°
Setpoint Resolution Voltage	0.1V
Setpoint Resolution Frequency	1mHz
Setpoint Resolution Phase	0.1°
Measurement Precision Voltage	±0.7% F.S.
Measurement Precision Current	±1.4% F.S.

[1] (THDu) up to 290Vrms (L-N)

HIGHLIGHTED FEATURES

INDIVIDUALLY PROGRAMMABLE PHASES

All three of the EAC-ACS-4Q's individual phases are independently adjustable. This provides up to three power systems from one unit. Using the GridSim GUI, it is possible to program each phase for: voltage, frequency, phase angle, as well as superimposed harmonic and inter-harmonic voltages up to 5kHz. Different voltage waveforms per phase are also possible in amplifier mode.

HARDWARE IN LOOP COMPATIBILITY

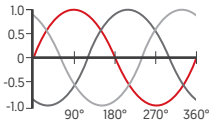
When operating in voltage amplifier mode, the EAC-ACS-4Q operates as a full 4-quadrant three phase amplifier. The drive signals are fed into the power system via analogue inputs from external sources. This is ideal for hardware in the loop (HIL) applications driven by a real time computer. A current amplifier mode is also available.

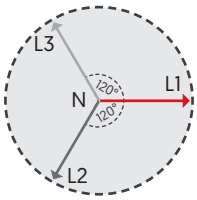
LOADSIDE CONFIGURATIONS

Each of the EAC-ACS-4Q's three phases are individually programmable for voltage, frequency, phase angles and superimposed harmonics. Below are configurations examples:

AC CONFIGURATIONS

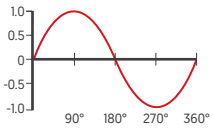
1. 3Φ OUTPUT (3L + N)	
Connection Type	3L + N + PE
EAC-ACS-4Q-50-r Ranges	Each Phase Individually Programmable: + 50kVA / 3× 305Vrms (L-N) / 3× 72A

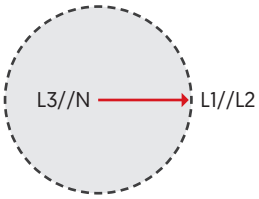




2. 1Φ OUTPUT (1L + N)*	
Connection Type	L1‖L2 + L3‖N + PE
EAC-ACS-4Q-50-r Ranges	+ 20kVA / 305Vrms (L-N) / 144A

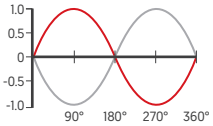
*A firmware update needs to be provided from ETPS to implement this configuration.

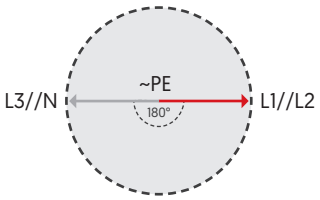




3. 1Φ3W / SPLIT PHASE OUTPUT*	
Connection Type	L1‖L2 + L3‖N + PE
EAC-ACS-4Q-50-r Ranges	+ 50kVA / 610Vrms (L-L) / 144A

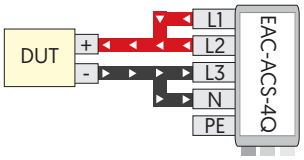
*A firmware update needs to be provided from ETPS to implement this configuration.



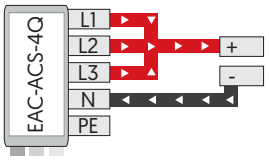


DC CONFIGURATIONS

4. 1× OUTPUT (SYMMETRIC TO PE)	
Connection Type	L1‖L2 + L3‖N
EAC-ACS-4Q-50-r Ranges	+ ±33kW / ±830Vdc / ±40A

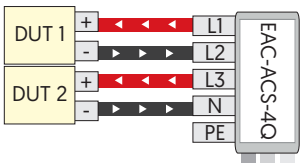


5. 1× OUTPUT (RELATED TO PE)	
Connection Type	L1‖L2‖L3 + N
EAC-ACS-4Q-50-r Ranges	+ ±25kW / ±415Vdc / ±60A



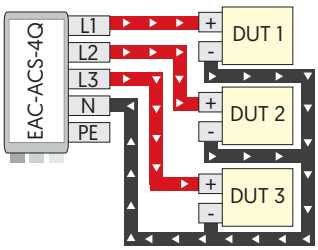
6. 2× INDEPENDENT OUTPUTS	
Connection Type	Output 1: L1 + L2, Output 2: L3 + N
EAC-ACS-4Q-50-r Ranges	+ Output 1: ±16kW / ±830Vdc / ±20A* + Output 2: ±8kW / ±415Vdc / ±20A*

*Total current to neutral limited to ≤20A



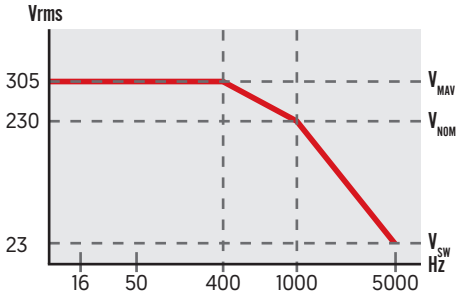
7. 3× INDEPENDENT OUTPUTS (RELATED TO PE)	
Connection Type	L1 + N, L2 + N, L3 + N
EAC-ACS-4Q-50-r Ranges	+ Each independent output: ±8kW / ±415Vdc / ±20A*

*Total current to neutral limited to ≤20A

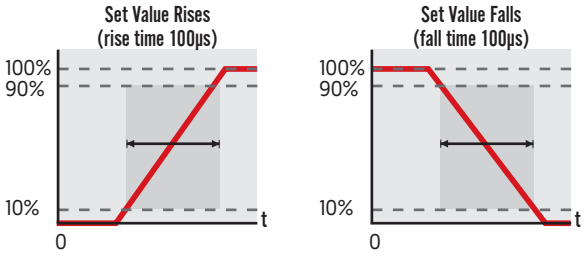


OPERATIONAL DIAGRAMS

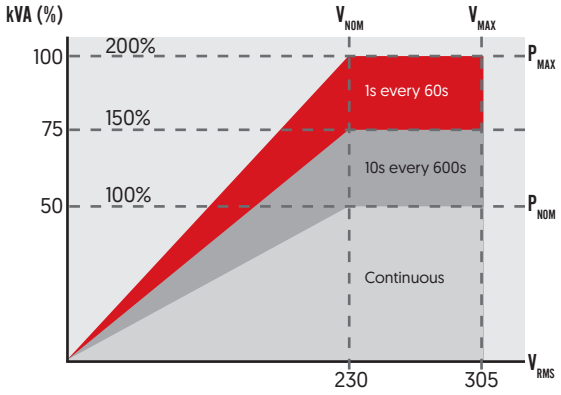
OUTPUT VOLTAGE VERSUS FREQUENCY



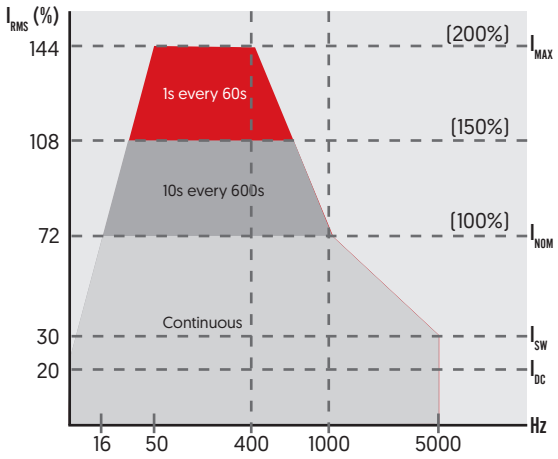
SLEW RATE AT A RESISTIVE LOAD



OVERLOADABILITY VERSUS VOLTAGE



OVERLOADABILITY VERSUS FREQUENCY



SOFTWARE/SOFT TOOLS

ACSCONTROL GUI

All EAC-ACS-4Q units come with a simple and intuitive ACSControl operating GUI as standard. The module is connected to a PC via the standard Ethernet or USB interface. Live values of the power supply are displayed graphically along with any warning and error messages. Input values to the EAC-ACS-4Q from the local grid are also displayed, including: input current, reactive power, active power and Cosϕ (Figure 8.1). The software allows protection levels to be set on both the lineside and loadside of the system.

FIGURE 8.1

As standard, ACSControl comes with a basic waveform generator mode (Figure 8.2). This allows users to implement sinewaves and edit parameters such as frequency and voltage (either L-N or L-L), as well as choosing the number of output phases (two or three). For more complex programming requirements, the GridSim GUI provides users with much greater functionality than standard ACSControl.

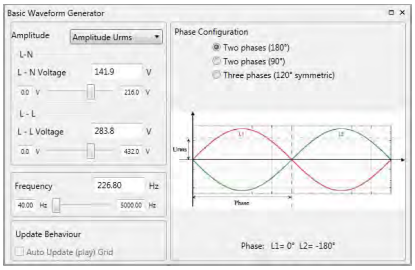


FIGURE 8.2

HIGHLIGHTED FEATURES

VOLTAGE AMPLIFIER MODE

ACSControl also features a voltage amplifier mode as standard. The module receives external signals via an analogue input for each phase. To achieve a desired output on the loadside of the module, the signals can be either amplified or reduced by a user defined scaling factor. Different waveforms are possible per phase.

Any device which creates -10 to +10V can be used as an external signal generator. This functionality is particularly useful for hardware in the loop applications. Users also have the ability to discharge the EAC-ACS-4Q module through the amplifier mode.

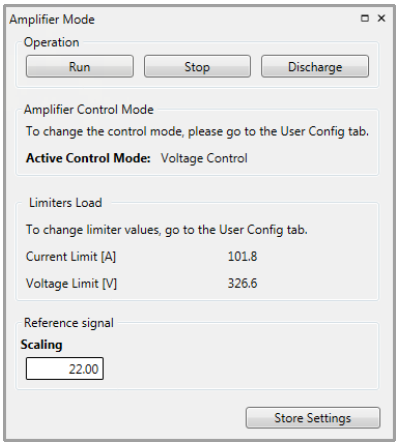


FIGURE 8.3

CURRENT CONTROL MODE

For applications where you need to actively control the output current of the EAC-ACS-4Q, an additional current controlled amplifier mode is provided. For example, a 10V input is equal to 124A for the 50kVA module. So if you want an output of 62A, then a factor of 0.5 (62/124) is entered into the scaling field.

RLC LOAD MODE

The RLC load mode {Resistance (R), Inductance (L), Capacitance (C)} enables the user to set apparent (VA) and reactive power (VAR). It also allows the power factor (cos phi) to be adjusted. The simulated impedance is particularly useful for users who design, research and develop renewable systems which feed energy to the public grid.

ANTI-ISLANDING TESTING

The software allows the EAC-ACS-4Q to test against anti-islanding regulations for grid-tied power systems. These regulations prevent safety risks and define the operating limits at which power equipment goes out of tolerance. If the equipment exceeds these tolerance levels, it needs to detect the condition and disconnect from the grid.

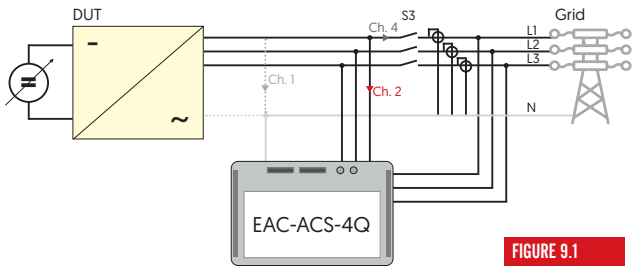


FIGURE 9.1

As the EAC-ACS-4Q simulates impedance for these regulatory tests, users do not have to use real components. This drastically reduces set up time and minimises the possibility of human error within the setup of the test circuit. It also eliminates the need to buy lots of different high power components for multiple tests, which can often prove very expensive. The difference between using real components and the EAC-ACS-4Q is illustrated in Figure 9.2.

Figure 9.1 illustrates a test set-up using the EAC-ACS-4Q's simulated impedance. For the detection of islanding, the switch S3 is closed and the module is operated in RLC simulation mode. The S3 switch is reopened again to test the DUT's behaviour while in an islanding condition.

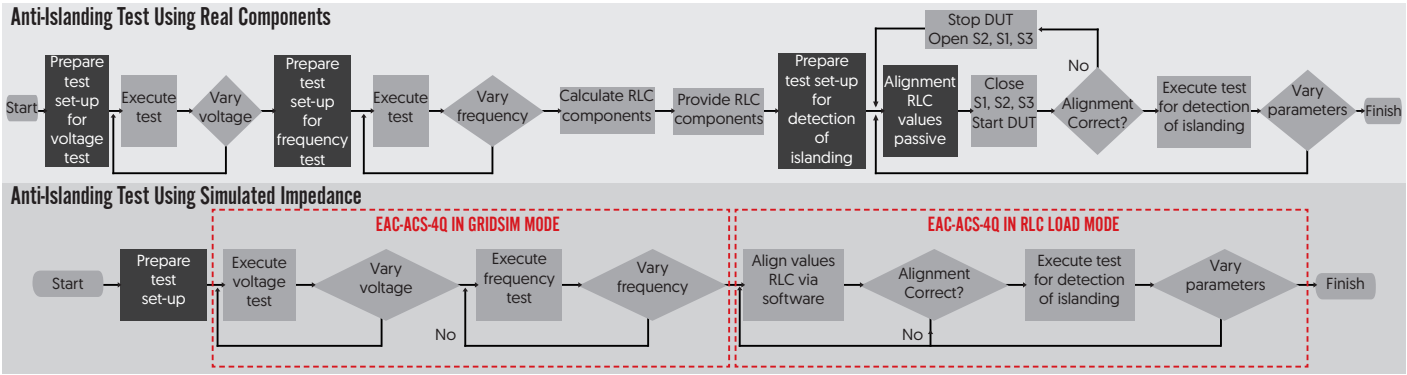


FIGURE 9.2

CONFIGURING AN RLC CIRCUIT

Users can select between 12 different types of topology within the software (Figure 9.4). Each loadside phase can have its own RLC topology, as shown in Figure 9.3.

Individual parameters of each topology circuit can be set to customise the test to your specific requirements. The settable values are listed in Figure 9.5.

FIGURE 9.3

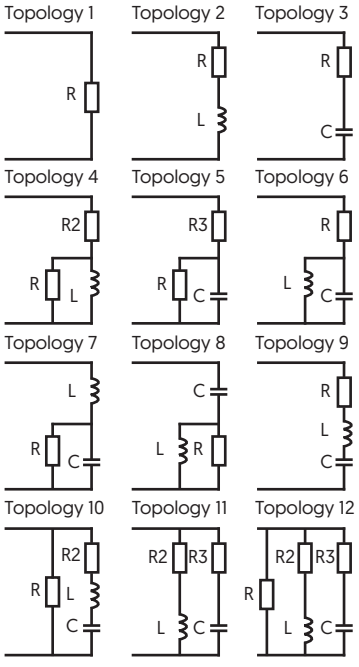


FIGURE 9.4

POSSIBLE VALUE RANGES OF RLC CIRCUIT

Topology	Range of Values	Topology	Range of Values
1	R: 0.001Ω to 10000Ω	7	R: 0.001Ω to 100Ω L: 1µH to 100mH C: 1µF to 100mF
2	R: 0.01Ω to 100Ω L: 1µH to 1000mH	8	R: 0.1Ω to 100Ω L: 1µH to 50mH C: 1µF to 50mF
3	R: 0.001Ω to 100Ω C: 1µF to 1000mF	9	R: 0.001Ω to 100Ω L: 1µH to 100mH C: 1µF to 100mF
4	R: 0.1Ω to 100Ω R2: 0.1Ω to 100Ω L: 1µH to 1000mH	10	R: 1Ω to 50Ω R2: 0.001Ω to 5Ω L: 10µH to 10mH C: 10µF to 5mF
5	R: 0.001Ω to 100Ω R3: 0.001Ω to 10Ω C: 1µF to 100mF	11	R2: 0.1Ω to 1Ω R3: 0.001Ω to 1Ω L: 1µH to 50mH C: 1µF to 10mF
6	R: 0.001Ω to 3.2Ω L: 1µH to 10mH C: 1µF to 10mF	12	R: 1Ω to 100Ω R2: 0.1Ω to 1Ω R3: 0.2Ω to 1Ω L: 10µH to 50mH C: 10µF to 10mF

FIGURE 9.5

FULL WAVEFORM GENERATOR MODE (GRIDSIM)

Where more advanced testing is required, the GridSim GUI provides users with a selection of advanced features. The software allows for manual operation and programming, as well as automated test runs to be configured with ease. A set of predefined periodic waveforms are available including sine, clipped sine, square, triangle, sawtooth. User defined waveforms are also possible.

FOURIER TOOL

A Fourier tool is provided that can create virtually any conceivable periodic waveform. Superimposed harmonic and inter-harmonic voltages are programmable up to 5000Hz. The Fourier mathematics required to generate such waveforms is already built into the tool, meaning there is no need to manually figure out the complex equations that are required for advanced waveforms. This saves time when configuring a test setup, as well as reducing the possibility of any human errors.

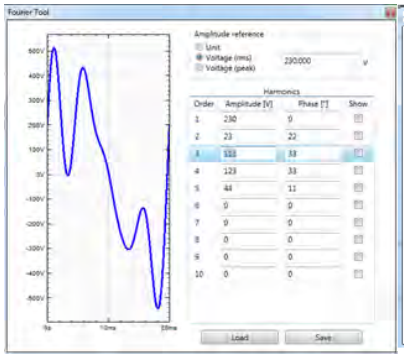


FIGURE 10.1

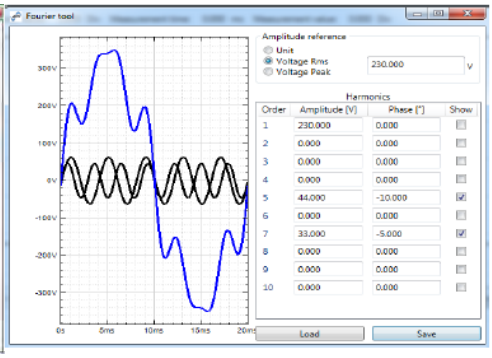


FIGURE 10.2

Individual waveforms, as well as the final synthesised waveform, are represented graphically within the software. As shown above, the synthesised waveform is shown in blue and the individual waveforms are shown in black.

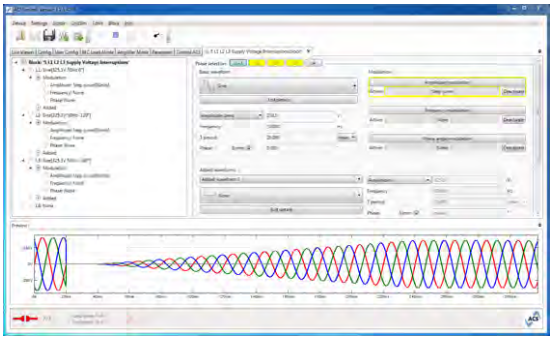


FIGURE 10.3

GRID SIMULATION

A bidirectional circuit can be formed between the DUT(s) and the EAC-ACS-4Q to emulate a grid network. Typical grid conditions can be created in the GUI to investigate how changes to the mains voltage affect a power system's behaviour.

Common conditions such as voltage dips, short interruptions and voltage spikes can be recreated. An example of a voltage interruption is shown in Figure 10.3. Each of the system's three output phases can be used independently to simulate the balancing of a grid to meet changing demands.

Both user defined and automated tests can be implemented, with the ability to record and recall data. Relevant grid feed-in regulations can be programmed into the software. This is particularly useful for testing renewable energy generation devices.

ADDITIONAL FUNCTIONALITY

Non-periodic waveforms such as voltage ramps, DC straight lines (either positive or negative), step curves and exponential curves can also be programmed within GridSim. This allows virtually any conceivable waveform to be generated that is within the unit's dynamic capabilities.

Specific phase imbalance conditions can be user programmed, which is particularly useful when testing three phase induction AC motors under various conditions.

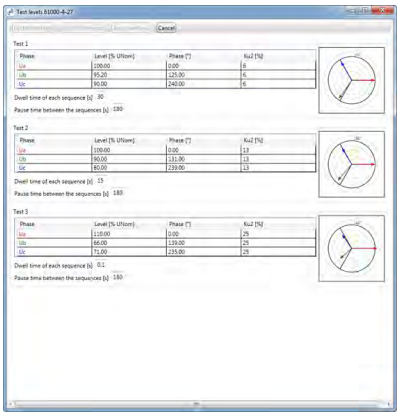


FIGURE 10.4

INTERFACES & CONTROL

STANDARD INTERFACES

1. SAFETY AND MULTI-MODULE OPERATION	
X112-2	ISR interface (must be terminated with the dummy plug X112, if not used)
X601/X602	Preset distribution interfaces, only used for multi-module systems (NOTE: In single device use one of these interfaces must be terminated with 100 ohms)

2. CONTROL PORT OUTPUT FUNCTIONS	
X603	EtherCAT input interface (only used for multi-module systems)
X604	EtherCAT output interface (only used for multi-module systems)
X605	LAN interface for remote control through ACSControl/API; 200Vrms isolation to electronics and earth
X607	USB type B interface for remote control through ACSControl/API; 250Vrms isolation to electronics and earth
X608	Micro SD card slot (for service only)
X609	Analogue input and output for general usage, 12 pin flush-type, mating connector: Phoenix Contact (1430048) 4 Inputs for general usage, ±9.5V reference voltage; 4 Outputs for general usage, ±9.5V reference voltage Time delay power output to analogue output: <50µs; 80kHz Sampling rate; 250Vrms isolation to electronics and earth; 330kΩ input pins input impedance; 2kΩ output pins min. load impedance
X620	Trigger input port BNC (start) TTL; 250Vrms isolation to electronics and earth; 10kΩ input impedance
X621	Trigger output port BNC (programmable) TTL; 250Vrms isolation to electronics and earth; 560Ω output impedance (short circuit proof)

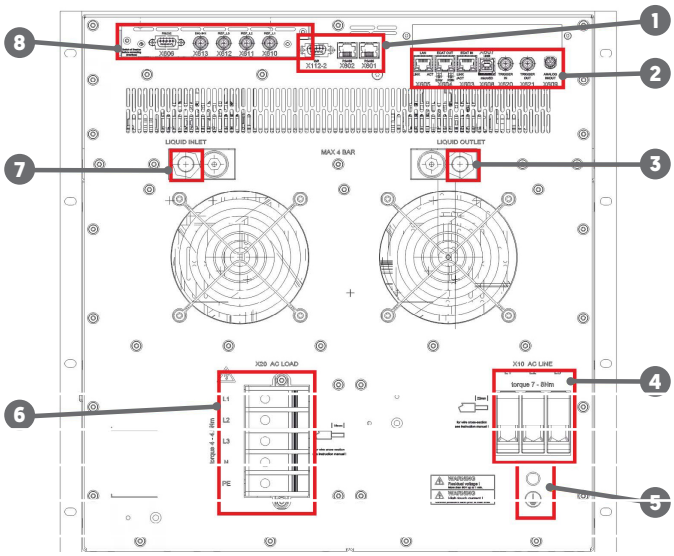
3. OUTPUT INTERFACE FOR COOLING CIRCUIT	
Thread	G½" with connection fitting

4. AC LINE INPUT TERMINAL	
X10	L1, L2, L3

5. EARTHING STUD FOR ADDITIONAL EARTH CONNECTION	
Diameter and Thread	Diameter: M10, thread length: 28mm

6. AC LOAD OUTPUT TERMINAL	
X20	L1, L2, L3, N, PE

7. INPUT INTERFACE FOR LIQUID COOLING CIRCUIT*	
Thread	G½" with connection fitting
Material	Aluminium
Liquid Temperature	15 - 50°C
Flow Rate	2.5l/min (min), 5l/min (recommended)
Max. Inlet Temperature	25°C at 2.5l/min, 40°C at 5l/min, 50°C at 8l/min
Maximum Pressure	4 bar
Pressure Drop	70mbar at 5l/min



*Use cooling liquid with a 30% share of Antifrogen N® within a closed circuit

8. CONTROL PORT INPUT FUNCTIONS FOR AMPLIFIER MODE (X610 - X612)	
X606	RS-232 interface (for service only); 125Vrms isolation to electronics and earth
X610	Signal input for phase L1 on the load side; voltage setting -432V to +432V (-10V to +10V)
X611	Signal input for phase L2 on the load side; voltage setting -432V to +432V (-10V to +10V)
X612	Signal input for phase L3 on the load side; voltage setting -432V to +432V (-10V to +10V)
Maximum Input Voltage	±30V
Sampling Rate	80kHz
Time Delay Input to Output	Typically <70µs
Isolation to Electronics and Earth	125 Vrms
Input Impedance	20.5kΩ

SAFETY & PROTECTION

STANDARD FEATURES

TECHNICAL DATA	
Overvoltage and Overcurrent Protection	Programmable
Ingress Protection (According to EN 60529)	Basic construction to IP20
Safety Interfaces	The energy transfer between the line side and the load side will be disconnected via integrated safety relays. The interface provides a connection to an external safety circuit.
Internal Diagnostics	Line input conditions, internal current conditions, temperature conditions, system configuration, system communication, power semiconductor temperatures
Protection Class	1
Degree of Pollution	2
Overvoltage Category	III
Low Voltage Directive 2014/35/EU	EN 62477-1:2012 + A11:2014 + A1:2017 + A12:2021
Electrical Equipment (Safety) Regulations 2016	BS EN 62477-1:2012+ A11:2014 + A1:2017 + A12:2021
Directive 2014/30/EU EMC Immunity (Industrial)	EN 61000-6-2:2005
Directive 2014/30/EU EMC Emission (Industrial)	EN 61000-6-4:2007+A1:2011
Electromagnetic Compatibility Regulations 2016 EMC Immunity (Industrial)	BS EN 61000-6-2:2005
Electromagnetic Compatibility Regulations 2016 EMC Emission (Industrial)	BS EN 61000-6-4:2007+A1:2011
RoHS Directive 2011/65/EU	EN IEC 63000:2018
The Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2012	BS EN IEC 63000:2018

HIGHLIGHTED FEATURE

INTEGRATED SAFETY RELAY (/ISR)

For additional safety, contactors are provided on both the lineside and the loadside of the EAC-ACS-4Q. These integrated safety relays provide a safe shutdown according to EN 13849-1 category 2/3. The ISR is connected to the external safety switch loop. If the external loop is opened, the EAC-ACS-4Q is powered down immediately.

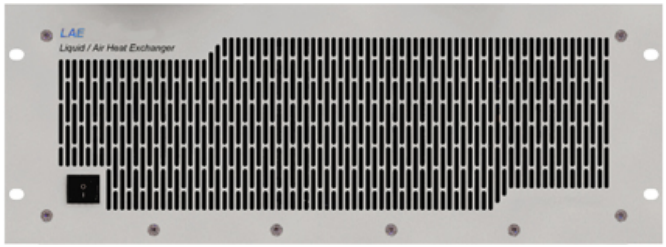
MECHANICAL

STANDARD FEATURES

TECHNICAL DATA	
AC Lineside Terminals	Screw terminals 6 to 35 mm^2 wires, diameter ≤8.5mm (3L + PE)
AC Loadside Terminals	Screw terminals 6 to 35 mm^2 wires, diameter ≤8.5mm (3LN + PE)
Noise	≤74dB at 1m
Cooling	Air cooled via liquid to air heat exchanger (liquid cooling also possible)
Operating Temperature	5 to 40°C (when a liquid to air heat exchanger is installed, then the module's maximum power is limited to 45kVA between 32 to 35°C and 35kVA between 35 to 40°C)
Storage Temperature	-18 to 70°C
Relative Air Humidity	0 to 95% (non-condensing)
Installation Altitude	0 - 2000m above sea level (slight temperature derating possible above 1000m)
Vibration	IEC 60068-2-6 (Test Fc)

LIQUID TO AIR HEAT EXCHANGER

As standard the 50kVA module has the below liquid to air heat exchanger installed, to allow air cooling of the module. If preferred, users can connect the unit to an external cooling loop instead. Please advise ETPS beforehand if you intend to do this.



/LAE SPECIFICATIONS

TECHNICAL DATA	
Line Voltage	380 - 480VAC
Voltage Tolerance	± 10%
Line Frequency	48 - 62Hz
Input Power	200VA
Mains Connection Type	2x L + PE
Power Factor	≥0.98
Current	0.5A
Leakage Current L to PE	<10mA
Heat Exchanger Material	Aluminium
Inlet / Outlet on Rear Size	G½"
Storage Temperature[1]	-18 to 70°C
Cooling Air Temperature in Operation	0 to 40°C
Atmospheric Humidity	0 to 90%, non-condensing
Cooling Power[2]	5kW at 20°C
Flow Rate (Max)	10 l/min
Pressure Difference $\Delta P = P_{OUT} - P_{IN}$	250mbar
Additional Weight Added to Cabinet	25kg
Dimensions in Cabinet (W × H × D)	19" × 4U × 649mm

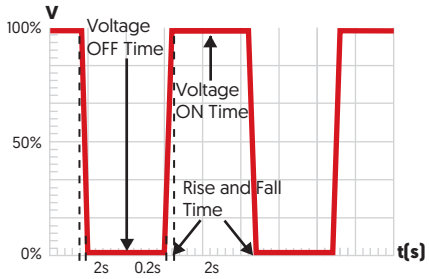
[1] With full filled ethylene glycol based coolant in a mixture of 30%

[2] Cooling power at ambient temperature

COMMON EAC-ACS-4Q APPLICATIONS

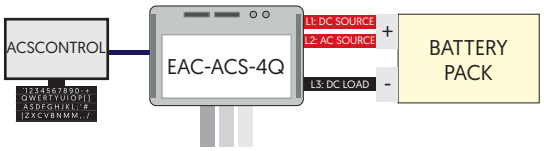
SMART GRID RESEARCH

A bidirectional circuit can be formed between devices under test and the EAC-ACS-4Q. By using each of the unit's phases as an AC source, the balancing of a smart grid to meet demand can be accurately simulated. The grid feed-in regulations can be programmed into the GridSim GUI, to ensure any device which generates energy to the mains is compliant to local standards.



AC RIPPLE ON BATTERY LINK

A potential side effect of charger circuits that contain both AC and DC components is electrical noise. The AC ripple causes unwanted fluctuations in battery temperature, which results in deterioration of the battery's performance. Two separate phases of the EAC-ACS-4Q can be used to emulate a high frequency AC ripple over a DC battery link. By charging the battery with one phase, another phase can be used to superimpose an AC ripple of up to 5kHz on the battery link.

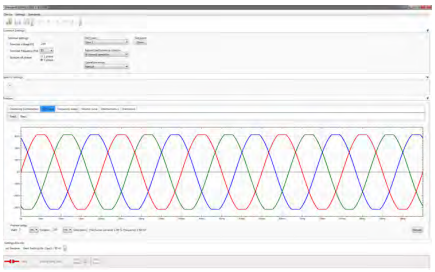


AC MOTOR IMBALANCES

The EAC-ACS-4Q can be used to simulate three phase motor imbalances. Using the GridSim GUI, each of the unit's output phases are individually programmable for phase angle, voltage, current and frequency. The GridSim GUI provides users with a convenient way to program specific phase imbalance conditions.

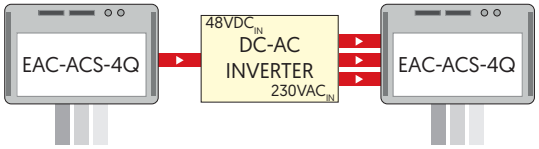
EMC TESTING

On request, a trial of Automated EMC tests can be activated via the GridSim GUI. The power system is capable of testing against standards for voltage fluctuations, power frequency variations and short interruptions among others. Each EAC-ACS-4Q has an incredibly high peak current capability.



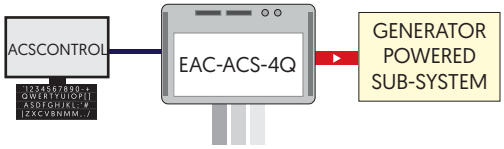
INVERTER/CONVERTER TESTING

The AC or DC input/output of virtually any power conversion device can be replicated. The influence that variables such as line voltage variation have on performance can be isolated and tested. This allows optimum operating conditions to be characterised to improve efficiency and performance.



TESTING MORE ELECTRIC AIRCRAFT

The EAC-ACS-4Q is able to provide frequencies up to 1kHz, with superimposed harmonics up to 5kHz. This allows virtually any conceivable power condition to be recreated, such as the wide frequency range required for replicating an aircraft's variable frequency generator.



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