



Sunny Island
3324/4248/4248U FC

Sunny Island Inverters in Fuel Cell Applications

Revision History

Document number SI-WR_FUEL CELL	Edition and type of revision ¹⁾		Remarks	Author
-11:FE4806	1.0	A	First edition	Alireza Mehrdash
-11:FE0607	1.1	A	Revision	Alireza Mehrdash

¹⁾ A: Correction of errors in or improvement of manual

B: Changes assuring complete or forward compatibility

C: Changes restricting or removing compatibility

	Name	Date	Signature
Checked	Claus Allert		
Approved	Volker Wachenfeld		

Explanation of Symbols Used

In order to guarantee optimum use of this handbook and to ensure the safe use of the device during the commissioning, operational and maintenance phases, please pay attention to the following explanations of the symbols used.



This symbol indicates a fact that is important for optimum operation of the product. For this reason, read these sections carefully.



This symbol indicates a fact which, if not observed, could result in damage to components or represent a danger to persons. Please read these sections especially carefully.



This symbol indicates an example.

Contents

1	Introduction	5
2	System Description	6
3	Connecting the Inverter to the System Control.....	8
4	System Management and Control	9
4.1	Connecting, Enabling.....	9
4.2	“Ready for Operation” Response Signal	10
4.3	Error Confirmation	10
4.4	Stand-alone Operation.....	11
4.5	Grid Operation	12
5	SI3324/4248/4248U FC – Difference to SI3324/4248 (U)	14
6	Technical Data.....	16
7	Contact.....	18

1 Introduction

The inverters are based on a system from the SMA Sunny Island product family and have thus been primarily developed for grid-independent operation. Grid-parallel operation mode has been added to the integrated system software for fuel cell applications. This additional feature allows the electrical energy generated to be fed into the public grid.

Due to the application-specific modification, the system is to be considered a prototype. Another complete type testing will not be performed by an accredited testing institute for this system.



The system is not equipped with a grid monitoring function, i.e. an automatic disconnection device (Mains monitoring with allocated Switching Devices, MSD), in accordance with DIN VDE 0126. The operator must test the application regarding the extent in which the technical connection requirements (TCR) demand grid monitoring or if necessary, he must install a readily accessible disconnection unit. For more detailed specifications concerning this, please refer to the TCR of the grid operator. In particular, when using the system under conditions similar to the field test, such an isolator is generally already installed.

2 System Description

The inverters can be used with the following configurations for providing AC voltage from a fuel cell system:

Inverter type	Output voltage/ Output frequency	Input voltage	Maximum DC output of the fuel cell system
SI3324 FC	230 V / 50 Hz	24 V _{DC}	3300 W
SI4248 FC	230 V / 50 Hz	48 V _{DC}	4200 W
SI4248U FC	120 V / 60 Hz	48 V _{DC}	4200 W

The input voltage of the inverters must be decoupled using corresponding system components (DC/DC inverter, battery or double layer capacitors) according to the fuel cell curve. A virtually constant operational voltage was assumed as the system was designed.

The inverters are especially designed for extremely low input voltages. In this case, despite the comparably high currents, an efficiency of up to 90 % is reached.

The inverters are made of a DC input filter, a power module in a MOSFET full bridge circuit, a grid frequency transformer and a grid-side EMC filter. The devices are not equipped with a pre-charging device for limiting the starting current of the DC input capacitors.

In grid operation, the inverters operate with regulated voltage. This means that the nominal value for the DC input current can be specified using a serial interface (RS232, optional RS485). A grid frequency transformer provides the galvanic isolation, thus ensuring that no DC components can be fed into the grid current.

Using a digital input, the higher-level process control enables the system for operation. During operation, the system monitors the DC input voltage at an adjustable upper and lower limit. If the DC input voltage falls below or exceeds these limits, the system switches off and signals the disconnection using a dry contact.

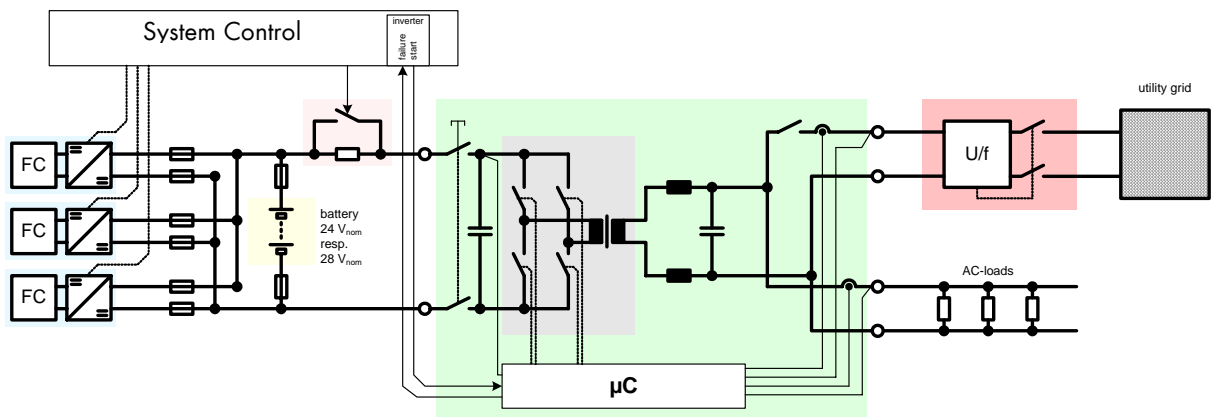


Figure 2.1: General structure

3 Connecting the Inverter to the System Control

In order to connect the inverter to the system control, the connections listed below are used (compare with figure 3.1):

The "G_REQ+" and "G_REQ-" connection terminals serve as the output in the form of a dry contact. They are connected to the system control accordingly. In this case, the ready for operation status of the inverter is indicated.

The "G_RUN+" and "G_RUN-" connection terminals serve as the digital input and are connected to the system control accordingly. The system control sends the enabling signal to the digital input.

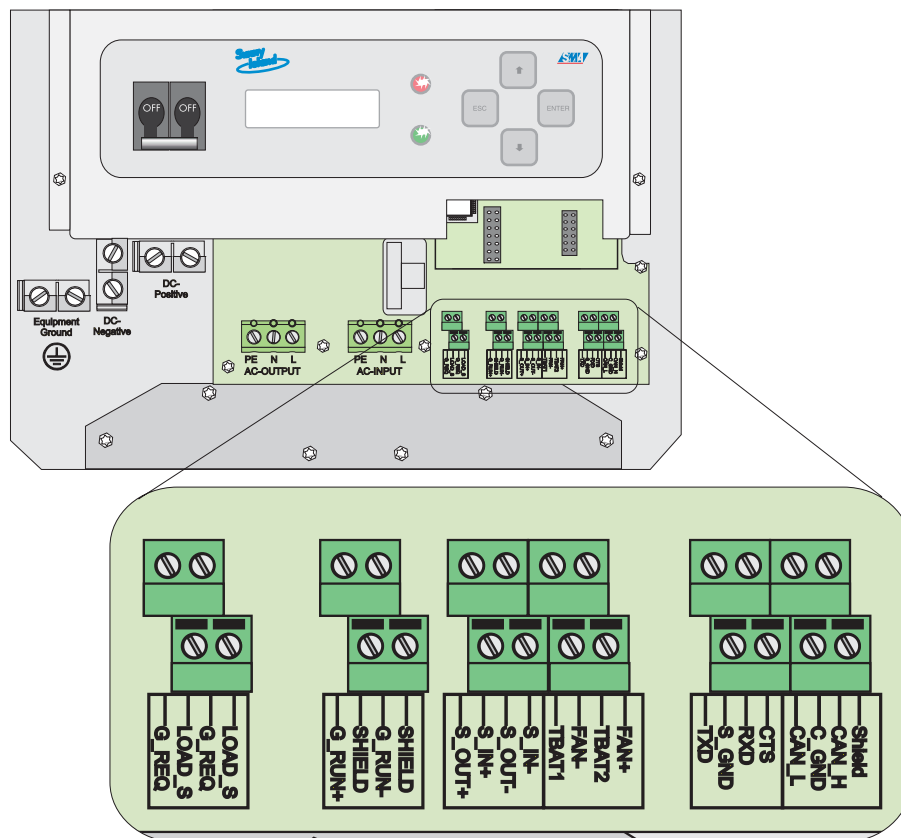


Figure 3.1: Additional inverter connections

4 System Management and Control

The inverter is designed as a battery power inverter for supplying connected off-grid loads (stand-alone operation) as well as for battery management tasks. The latter characteristics are not required in this application. However, they are optionally available and can be used if required.

4.1 Connecting, Enabling

The inverter has an integrated DC disconnecting switch that can be manually operated. This disconnecting switch must be switched on before commissioning.



Due to the large capacities on the DC side, high charging currents occur when the DC disconnecter is switched on. Such charging currents can trigger the connected protection devices to protect the batteries or the fuel cell module. Using a pre-charging device made of a charging resistor and a bypass contactor can prevent such protection devices from being triggered.

The system computer is started by activating the disconnecting switch. The system performs a self-test and goes into "Standby" mode.



Switching off the DC disconnecting switch while the system is in operation interrupts the inverter's power supply. Once the DC disconnecting switch is switched back on, the system must be rebooted!

In Standby mode, the inverter begins to monitor the voltages present. If the DC voltage is in a $V_{DCmin} < V_{DC} < V_{DCmax}$ permissible range, the dry contact (G_REQ+ / G_REQ-) will close. This output sends the ready for operation signal to the system control.

If the system control now sets the start signal ($4V_{DC}$ to $28V_{DC}$) at the digital input to "Enable" (G_RUN+ / G_RUN-), the inverter first checks whether there is any voltage at the grid connection. If there is any voltage present, the device automatically goes into grid operation; otherwise, Stand-alone mode is started.

4.2 “Ready for Operation” Response Signal

The “Ready for operation” feedback contact is designed as a digital output and relay (maximum 250 V/1 A). In order to ensure fail-safe functionality, the level assignment must be performed as follows:

Operating mode	Relay contact
Device off	open
Device is on, no error, $V_{DCmin} < V_{DC} < V_{DCmax}$	closed
Device is on, no error, $V_{DC} < V_{DCmin}$ or $V_{DC} > V_{DCmax}$	open
Device is on, there is an internal device fault	open

4.3 Error Confirmation

If an error occurs, for example

- DC overvoltage,
- DC undervoltage,
- short circuit at the output,
- internal device fault,



In principle, the system can be automatically restarted following an error, but it is not permitted for operating safety reasons.

the ready for operation signal is disabled. In order to restart the device, the error must first be confirmed. The error is confirmed by disabling and re-enabling the start signal (minimum interruption: 2 seconds).

4.4 Stand-alone Operation

Provided that the inverter is not connected to a higher-level grid on the AC side, it provides a voltage of 230 V/50 Hz for powering connected AC loads if the enable signal (start signal) is present at the output.

The output is monitored for short circuits and overloading. In the event of temporary overloading, for example, due to a connected motorized load, the control limits the output current until the load is started up to nominal speed. The inverter is not disconnected during this phase. If, however, the current does not drop below the maximum value within a few seconds, a highly resistive short circuit is detected, the inverter switches off and the "Ready for operation" signal is disabled.

The inverter still switches off and disables the "Ready for operation" signal if

- due to the permanent battery load, the battery voltage drops below the V_{DCmin} limit or
- the battery – possibly due to a system error – is overcharged by the fuel cells ($V_{DC} > V_{DCmax}$) without the energy being fed to a load (no or insufficient load).

If the higher-level supply grid is connected in stand-alone operation, this grid is detected by the internal voltage value at the grid connection. The inverter synchronizes its output voltage with the grid voltage, closes the internal grid connecting relay and goes into grid operation without interruption. The connected AC loads are also still powered from the grid.



The internal grid connecting relay has only one pole and generally cannot be used as an interconnection circuit breaker according to TCR/feed-in directives.

4.5 Grid Operation

Starting with the fundamental concept for grid operation, the battery power inverter was developed for charging system batteries. The battery management functions are not required in this application; however, they are available if needed.

If the grid is connected and the start signal is present, the power inverter synchronizes with the grid voltage and closes the grid relay. The connected AC loads are powered from the grid. The inverter's operating mode can be specified by giving the V_{DCNom} nominal battery charging voltage. This is preferably accomplished using the parameter settings for the battery management.

Provided that

- the actual value is greater than the nominal value ($V_{DC} > V_{DCNom}$), the power is fed into the supply grid. The quantity of the power fed into the grid can be set using a parameter (I_{ACmax}). If the drawn power is greater than the power subsequently provided by the fuel cells, the grid current drops to zero once the nominal voltage is reached. This prevents the batteries from being subsequently discharged.
- the actual value is less than (or at most equal to) the nominal value ($V_{DC} \leq V_{DCNom}$), the inverter recharges the batteries from the grid (current limit based on I_{ACmax}). Once the nominal value is reached, the inverter goes into Float charge mode. The battery voltage is continuously monitored and recharged in cycles.



If the inverter is to prevent the batteries from being recharged, the nominal battery voltage value can be set lower than the V_{DCmin} undervoltage limit. The inverter operating mode on the grid is then limited to Working mode only.

If, due to the permanent battery load, the battery voltage drops below the V_{DCmin} limit, the inverter switches off and disables the "Ready for operation" signal.



Using the float charge function allows the customer to operate the batteries over an extended period of time without feeding the grid and without additional monitoring being performed on the inverter.

This prevents manual maintenance/recharging or any damage to the batteries.

We recommend using the Sunny Island internal battery management system, which keeps the battery in good working condition.

For this purpose, all fuel cell batteries should always be operated on the Sunny Island so that they all have the identical charge state (this prevents equalization currents when connecting batteries with different charge states). The battery capacity to be set on the Sunny Island is the sum of the individual capacities.

Furthermore, reasonable charging voltages should be used.



The V_{DCmin} , V_{DCmax} , V_{DCNom} and I_{ACmax} parameters can be specified using service software (Sunny Data Control). This software can be found on the Internet at <http://www2.sma.de/de/solartechnik/downloads/index.html>. The changed parameter settings are saved in the device so that they are available after the system is restarted.

In principle, the nominal value can be constantly specified using the interface.

If the grid fails due to a temporary interruption, an upstream protection device being activated or the external grid monitoring, the inverter automatically goes into Stand-alone operation if the start signal is still active. Due to the switching of the control mode, voltage distortions ranging from one to two half-waves may occur.

If the battery – possibly due to a system error – is overcharged by the fuel cells ($V_{DC} > V_{DCmax}$) without the energy being fed into the grid (I_{ACmax} set too low), the inverter switches off and disables the “Ready for operation” signal.

5 SI3324/4248/4248U FC — Difference to SI3324/4248 (U)

(Installation guide, version SI3324-SI4248-14:SD2406)

In this section, the parameters that must be changed to operate the inverters in a fuel cell application are listed. The installer password is required to obtain the required access rights for changing these parameters.

Battery Settings #23

No.	Name	Range		Default		Setting	
		SI3324 FC	SI4248 FC (U)	SI3324 FC	SI4248 FC (U)	SI3324 FC	SI4248 FC (U)
7	VchargeBoost	27...31.2 V	44...62.4 V	28.8 V (VRLA) 30.6 V (FLLA)	56.8 V (VRLA) 60 V (FLLA)	27 V (VRLA) 27 V (FLLA)	54 V (VRLA) 54 V (FLLA)
4	AmpdcBatMax	0...140 A	0...100 A	10 A	10 A	140 A	70 A
9	VchargeEqual	27...31.2 V	44...62.4 V	28.8 V (VRLA) 30 V (FLLA)	56.8 V (VRLA) 60 V (FLLA)	27 V (VRLA) 27 V (FLLA)	54 V (VRLA) 54 V (FLLA)
11	VchargeFull	27...31.2 V	44...62.4 V	28.8 V (VRLA) 30 V (FLLA)	56.8 V (VRLA) 60 V (FLLA)	27 V (VRLA) 27 V (FLLA)	54 V (VRLA) 54 V (FLLA)
12	VchargeFloat	27...31.2 V	44...62.4 V	27 V (VRLA) 27 V (FLLA)	54 V (VRLA) 54 V (FLLA)	27 V (VRLA) 27 V (FLLA)	54 V (VRLA) 54 V (FLLA)

The V_{DCNom} value can be set using parameters seven, nine, eleven and twelve.

Battery Settings #23

No.	Name	Range		Default		Setting	
		SI3324 FC	SI4248 FC (U)	SI3324 FC	SI4248 FC (U)	SI3324 FC	SI4248 FC (U)
6	VdcBatMin	18...24 V	30...48 V	18 V	35 V	18 V	35 V
7	VdcBatMax	24...35 V	48...70 V	34.5 V	67.2 V	34.5 V	67.2 V

You require an additional access permission for the upper two menu subitems. Please consult our Sunny Island customer service for this access permission.

The V_{DCmin} value can be set using parameter six.

The V_{max} value can be set using parameter seven.

Generator Setting #24

No.	Name	Range		Default		Setting	
		SI3324 FC	SI4248 FC (U)	SI3324 FC	SI4248 FC (U)	SI3324 FC	SI4248 FC (U)
2	AmpacGenMax	2...56 A	2...56 A (2...60 A)	10 A	10 A	14.5 A	18 A (35 A)
8	GridConnected	GridNone GridCharge GridFeedPV	GridNone GridCharge GridFeedPV	GridNone	GridNone	GridCharge	GridCharge

The I_{ACmin} value can be set using parameter two.

6 Technical Data

		SI3324 FC	SI4248 FC	SI4248U FC
Output data				
Rated AC voltage (adjustable)	U_{AC}	230 V (202...253 V)	230 V (202...253 V)	120 V (105...132 V)
Grid frequency (adjustable)	f_{AC}	50 Hz (45...55 Hz)	50 Hz (45...55 Hz)	60 Hz (55...65 Hz)
Continuous AC Output at 25 °C/45 °C	P_{nom}	3300/2300 W	4200/3400 W	4200/3400 W
Continuous AC Output at 25 °C for 30/5/1 min	$P_{30/5/1}$	4200/4600/ 5000 W	5400/6200/ 7000 W	5400/6200/ 7000 W
Rated AC current	$I_{AC,nom}$	14.5 A	18 A	35 A
Max. current (peak value) for 100 ms		100 A	100 A	140 A
Output voltage harmonic distortion factor	K_{VAC}	< 3 %	< 3 %	< 3 %
Power factor	$\cos\varphi$	-1...+1	-1...+1	-1...+ 1
Input data				
DC voltage	U_{DC}	24 V (21...32 V)	48 (41...63 V)	48 (41...63 V)
Max. DC current	$I_{DC,max}$	140 A	100 A	100 A
Rated DC current	$I_{DC,nom}$	104 A	80 A	80 A
Max. DC power	$P_{DC,max}$	4480 W	6300 W	6300 W
DC voltage ripple	U_{SS}	< 10 %	< 10 %	< 10 %
Pole confusion protection		short circuite diode	short circuite diode	short circuite diode
Efficiency / Leistungsaufnahme				
Max. efficiency	η_{max}	94.5 %	95 %	95 %
Own consumption (no load/standby)		22 W (< 4 W)	22 W (< 4 W)	22 W (< 4 W)
Protection type acc. to DIN EN 60529		IP30	IP30	IP30
Device protection		short circuite, overload, overtemperature	short circuite, overload, overtemperature	short circuite, overload, overtemperature

		SI3324 FC	SI4248 FC	SI4248U FC
Interfaces		two LEDs, four buttons, two-line display, one relay for load shedding, one relay for diesel- generator- controlling, RS485/RS232 galvanically isolated (opt.)	two LEDs, four buttons, two-line display, one relay for load shedding, one relay for diesel-generator- controlling, RS485/RS232 galvanically isolated (opt.)	two LEDs, four buttons, two-line display, one relay for load shedding, one relay for die- sel-generator- controlling, RS485/RS232 galvanically iso- lated (opt.)
Mechanical data				
Width/Height/Depth		390 x 590 x 245 mm	390 x 590 x 245 mm	390 x 590 x 245 mm
Weight		ca. 39 kg	ca. 39 kg	ca. 39 kg
Ambient conditions				
Ambient temperature		von -25 °C... + 50 °C	von -25 °C... + 50 °C	von -25 °C...+ 50 °C

7 Contact

If you have any questions or queries, please contact us.

A team of qualified engineers and technicians is at your disposal.



Address:

SMA Technologie AG

Hannoversche Straße 1-5

34266 Niestetal

Germany

Tel. (+49) 561 9522 - 933

Fax. (+49) 561 9522 - 4697

SunnyIsland.hotline@SMA.de

www.SMA.de