



GoodWe Website

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User Manual

Hybrid Inverter

EM Series

V1.3-2024-02-20

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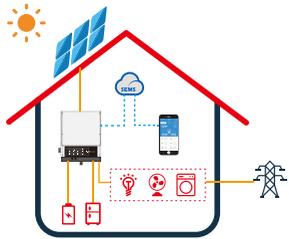
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01 INTRODUCTION

GoodWe EM series, also called hybrid or bidirectional solar inverters, apply to solar system with participation of PV, battery, loads and grid system for energy management.

The energy produced by PV system shall be used to optimize self-consumption, excess power charge battery and the rest power could be exported to the grids.

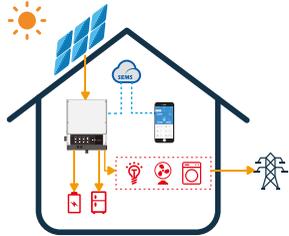
Battery shall discharge to support loads when PV power is insufficient to meet self-consumption. If both PV power and battery power is insufficient, the system will take power from grid to support loads.



Note: The introduction describes a general behavior of EM system. The operation mode can be adjusted on GoodWe SolarGo APP based on the system layout. Below are the general operation modes for EH system.

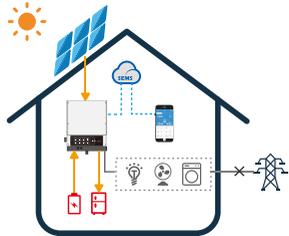
1.1 OPERATION MODES INTRODUCTION

EM system normally has the following operation modes based on your configuration and layout conditions.



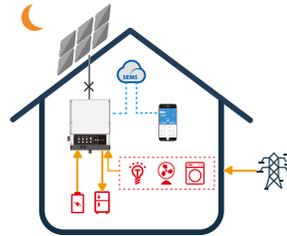
Mode I

The energy produced by the PV system is used to optimize self-consumption. The excess energy is used to charge the batteries, then exported to grid.



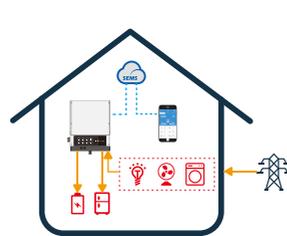
Mode III

When grid fails, the system automatically switches to Back-Up mode, the Back-Up load could be supported by PV and battery.



Mode II

When there is no PV, and the battery is sufficient, it can supply the load with the grid power.



Mode IV

Battery could be charged by grid, and charge time/power could be set flexibly on SolarGo APP.

1.2 SAFETY & WARNING

The EM series hybrid inverter of GoodWe Technologies Co., Ltd. (hereinafter called as GoodWe) strictly comply with related safety rules for product design and testing. Please read and follow all the instructions and cautions on the hybrid inverter or user manual during installation, operation or maintenance, as any improper operation might cause personal or damage.

·SYMBOLS EXPLANATION



Caution!
Failing to observe a warning indicated in this manual may result in injury.



Danger of high voltage and electric shock!



Danger of hot surface!



Components of the product can be recycled.



This side up! The package must always be transported, handled and stored in such a way that the arrows always point upwards.



No more than six (6) identical packages being stacked on each other.



Product should not be disposed as household waste.



The package/product should be handled carefully and never be tipped over or slung.



Refer to the operating instructions.



Keep dry! The package/product must be protected from excessive humidity and must be stored under cover.



Inverter will be touchable or operable after minimum 5 minutes of being turned off or totally disconnected, in case of any electrical shock or injury.



CE Mark

SAFETY WARNING

Any installation and operation on hybrid inverter must be performed by qualified electricians, in compliance with standards, wiring rules or requirements of local grid authorities or companies (like AS 4777 and AS/NZS 3000 in Australia).

- Prohibit to insert or pull the AC and DC terminals when the inverter is running.

Before any wiring connection or electrical operation on inverter, all battery and AC power must be disconnected from inverter for at least 5 minutes to make sure inverter is totally isolated to avoid electric shock.

- The temperature of inverter surface might exceed 60°C during working, so please make sure it is cooled down before touching it, and make sure the inverter is untouchable for children.

Do not open inverter cover or change any components without GoodWe's authorization, otherwise the warranty commitment for the inverter will be invalid.

- Usage and operation of the inverter must follow instructions in this user manual, otherwise the protection design might be useless and warranty for the inverter will be invalid.

Appropriate methods must be adopted to protect inverter from static damage. Any damage caused by static is not warranted by GoodWe.

- PV negative (PV-) and battery negative (BAT-) on inverter side is not grounded as default design. Connecting PV- or BAT- to EARTH are strictly forbidden.

PV modules used on the inverter must have an IEC61730 class A rating, and the total open-circuit voltage of PV string/array is lower than the maximum rated DC input voltage of the inverter. Any damage caused by PV over-voltage is beyond warranty.

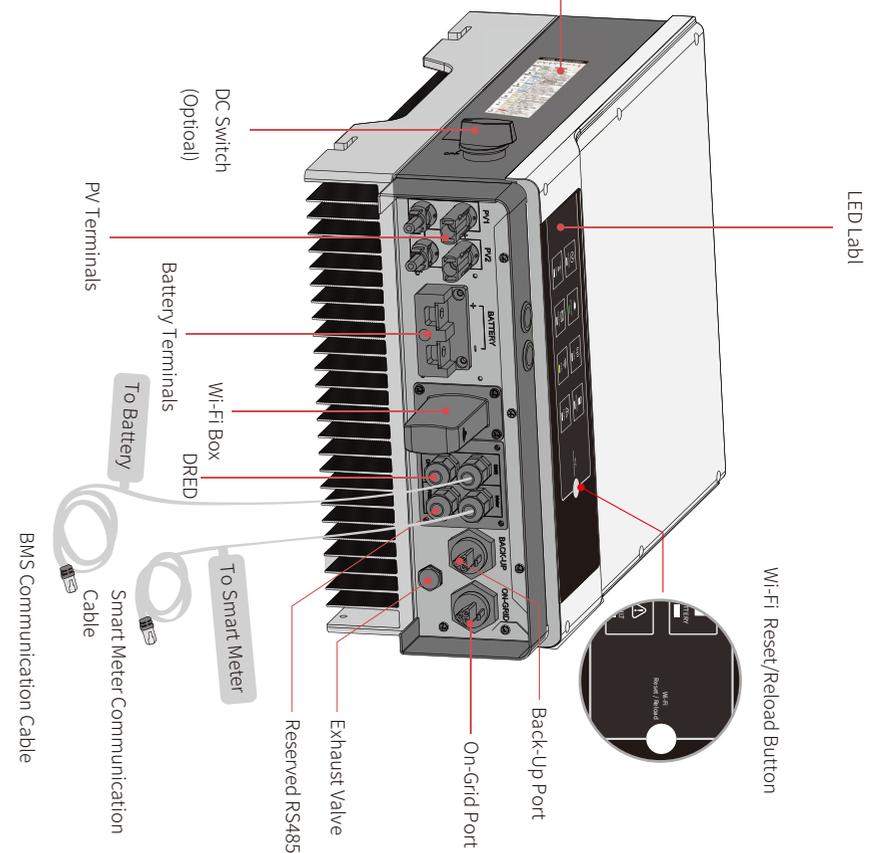
- The inverter, with built-in RCMU, will exclude possibility of DC residual current to 6mA, thus in the system an external RCD (type A) can be used ($\geq 30\text{mA}$).

In Australia, the inverter internal switching does not maintain neutral integrity, which must be addressed by external connection arrangements like in the system connection diagram for Australia on page 16.

- In Australia, output of Back-Up side in switchbox should be labeled 'Main switch UPS supply', the output of normal load side in switch box should be labeled 'main switch inverter supply'.

1.3 PRODUCT OVERVIEW

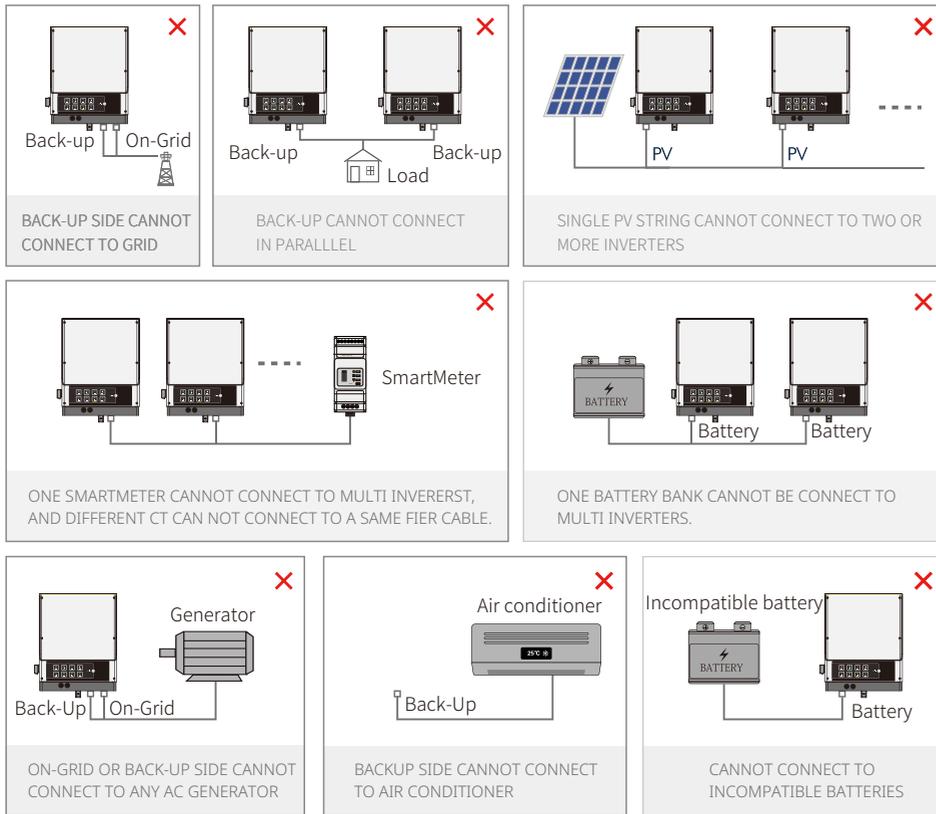
HYBRID LED INDICATORS		
INDICATOR	STATUS	EXPLANATION
SYSTEM	ON = SYSTEM IS READY BLINK = SYSTEM IS STARTING UP OFF = SYSTEM IS NOT OPERATING	ON = SYSTEM IS READY BLINK = SYSTEM IS STARTING UP OFF = SYSTEM IS NOT OPERATING
BACK-UP	ON = BACK-UPS READY / POWER AVAILABLE OFF = BACK-UPS OFF / ON POWER AVAILABLE	ON = BACK-UPS READY / POWER AVAILABLE OFF = BACK-UPS OFF / ON POWER AVAILABLE
COM	ON = BMS AND METER COMMUNICATION OK BLINK 1 = METER COMMUNICATION OK BLINK 2 = BMS COMMUNICATION OK OFF = BMS AND METER COMMUNICATION FAIL	ON = BMS AND METER COMMUNICATION OK BLINK 1 = METER COMMUNICATION OK BLINK 2 = BMS COMMUNICATION OK OFF = BMS AND METER COMMUNICATION FAIL
BATTERY	ON = BATTERY IS CHARGING BLINK 1 = BATTERY IS DISCHARGING BLINK 2 = BATTERY IS LOW / SOC IS LOW OFF = BATTERY IS DISCONNECTED / NOT ACTIVE	ON = BATTERY IS CHARGING BLINK 1 = BATTERY IS DISCHARGING BLINK 2 = BATTERY IS LOW / SOC IS LOW OFF = BATTERY IS DISCONNECTED / NOT ACTIVE
GRID	ON = BATTERY IS ACTIVE AND CONNECTED BLINK = GRID IS ACTIVE BUT NOT CONNECTED OFF = GRID IS NOT ACTIVE	ON = BATTERY IS ACTIVE AND CONNECTED BLINK = GRID IS ACTIVE BUT NOT CONNECTED OFF = GRID IS NOT ACTIVE
ENERGY	BLINK 1 = SUPPLYING ENERGY TO GRID / LEAVING ON = CONSUMING ENERGY FROM GRID / LEAVING OFF = GRID ENERGY CONSUMER OR SYSTEM OUT OF OPERATION	BLINK 1 = SUPPLYING ENERGY TO GRID / LEAVING ON = CONSUMING ENERGY FROM GRID / LEAVING OFF = GRID ENERGY CONSUMER OR SYSTEM OUT OF OPERATION
WiFi	ON = WiFi CONNECTED / ACTIVE BLINK 1 = WiFi SYSTEM RESETTING BLINK 2 = WiFi NOT CONNECT TO ROUTER BLINK 4 = WiFi SERVER PROBLEM OFF = WiFi NOT ACTIVE	ON = WiFi CONNECTED / ACTIVE BLINK 1 = WiFi SYSTEM RESETTING BLINK 2 = WiFi NOT CONNECT TO ROUTER BLINK 4 = WiFi SERVER PROBLEM OFF = WiFi NOT ACTIVE
FAULT	BLINK = OVERLOAD OR BACK-UP OUTPUT / REDUCE LOAD OFF = NO FAULT	BLINK = OVERLOAD OR BACK-UP OUTPUT / REDUCE LOAD OFF = NO FAULT



02 INSTALLATION INSTRUCTIONS

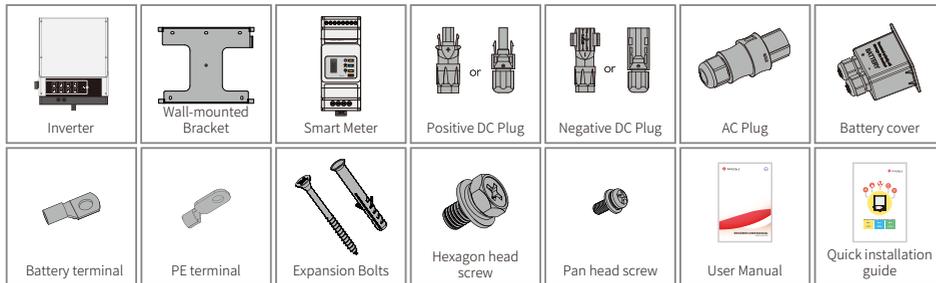
2.1 UNACCEPTABLE INSTALLATIONS

Please avoid the following installations, which will damage the system or the inverter.



2.2 PACKING LIST

On receiving the hybrid inverter, please check to make sure all the components as below are not missing or broken.



2.3 MOUNTING

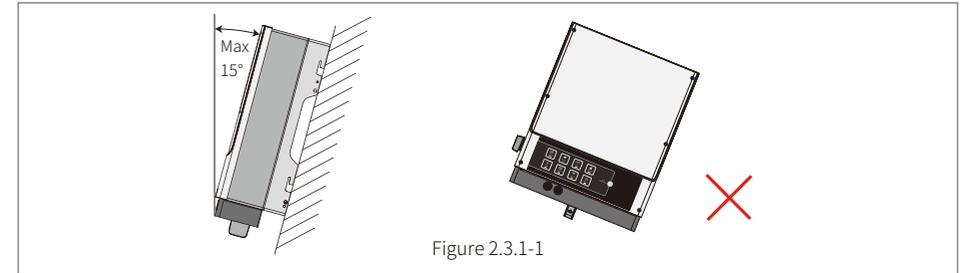
2.3.1 SELECT MOUNTING LOCATION

For inverter's protection and convenient maintenance, mounting location for inverter should be selected carefully based on the following rules:

Any part of this system shouldn't block the switch and breaker to disconnected inverter from DC and AC power.

Rule 1. Inverter should be installed on a solid surface, where is suitable for inverter's dimensions and weight.

Rule 2. Inverter installation should stand vertically or lie on a slop by max 15° (Figure 2.3.1-1)



Rule 3. Ambient temperature should be lower than 45 C

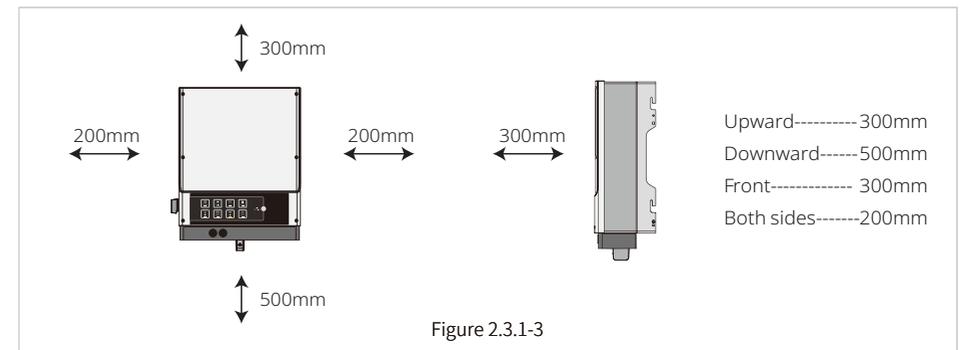
Rule 4. The installation of inverter should be protected under shelter from direct sunlight or bad weather like snow, rain, lightning etc.



Rule 5. Inverter should be installed at eye level for convenient maintenance.

Rule 6. Product label on inverter should be clearly visible after installation.

Rule 7. Leave enough space around inverter following the values on Figure 2.3.1-3.



! Inverter cannot be installed near flammable, explosive or strong electro-magnetic equipment.^[1]

2.3.2 MOUNTING

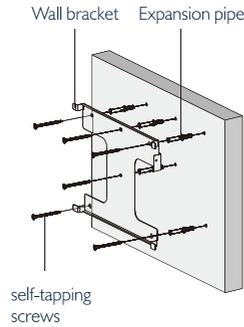
! Remember that this inverter is heavy! Please be careful when lifting out from the package.^[2]

The inverter is suitable for mounting on concrete or other non-combustible surface only

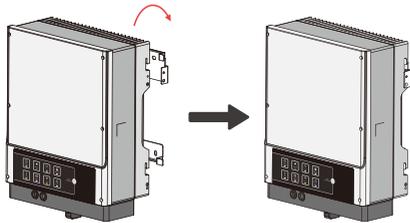
Step 1

- Please use the mounting bracket as a template to drill 4 holes on right positions (10mm in diameter, and 80mm in depth)
- Use expansion bolts in accessory box and fix the mounting bracket onto the wall tightly

Note: Bearing capacity of the wall must be higher than 17kg, otherwise may not be able to keep inverter from dropping.



Step 2

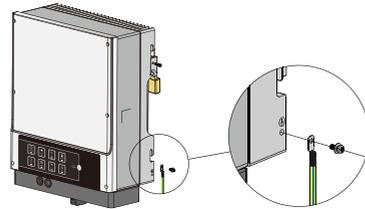


Carry the inverter by holding the heating sink on two sides and Place the inverter on the mounting bracket.

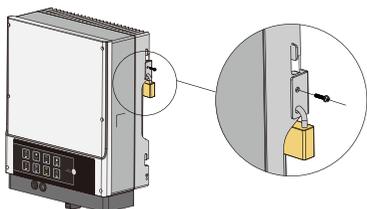
Note: Make sure the heat sink on inverter is right joint with mounting bracket.

Step 3

Ground cable shall be connected to ground plate on grid side



Step 4



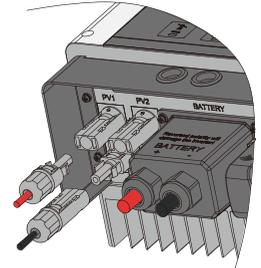
A lock could be used for anti-theft if it is necessary for individual requirement.

2.4 ELECTRICAL WIRING CONNECTION

2.4.1 PV WIRING CONNECTION

Before connecting PV panels/strings to inverter, please make sure requirements are followed as below:

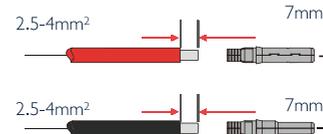
- The total short-circuit current of PV string must not exceed inverter's max DC current
- The minimum isolation resistance to ground of the PV string must exceed 18.33kΩ in case of any shock hazard.
- PV strings could not connect to earth/grounding conductor.
- Use the DC plugs in the accessory box.



Note: There will be MC4 or Amphenol plugs in accessory box, the detailed connection as below:

Step 1

Prepare PV cables and DC plugs

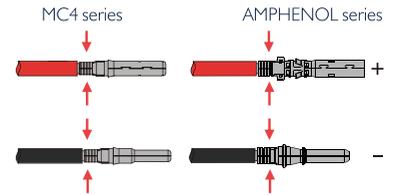


Note:

- Please use DC plugs and connectors in GoodWe accessory box
- PV cable should be standard, 2.5-4mm² PV cable

Step 2

Prepare PV cables and DC connectors

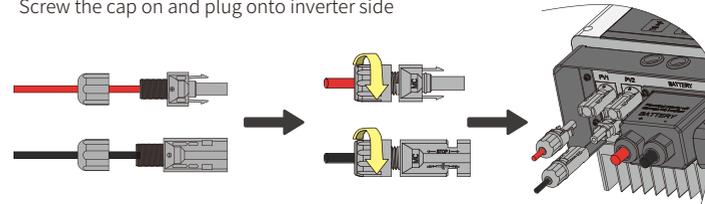


Note:

- PV cable must be tightly crimped into the connectors
- For Amphenol connector, the limit buckle cannot be pressed

Step 3

Screw the cap on and plug onto inverter side



Note:

- There will be a click sound if connectors are inset correctly into DC plugs



The polarity of PV strings or on the inverter cannot be connected by reversely, otherwise inverter could be damaged.^[3]

2.4.2 BATTERY WIRING CONNECTION

- For lithium battery (pack) the capacity should be 50Ah or larger. Lead acid batteries are not allowed to use with GoodWe hybrid inverters without GoodWe's authority. Battery cable requirement as below.(Figure 2.4.2-1)



- Please be careful against any electric shock or chemical hazard.
- Make sure there is an external DC break ($\geq 63A$) connected for battery without attached DC break.

Battery wiring connection process is as below:

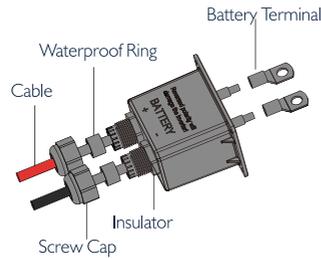
Make sure battery switch is off and battery nominal voltage meet EM specification before connecting battery to inverter make sure inverter is totally isolated from PV and AC power.^[4]

Step 1

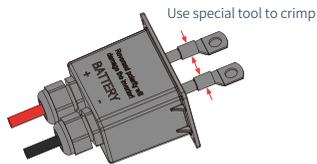
Prepare battery cables and accessories and put battery power cable through battery cover

Note:

- Please use accessories from GoodWe box
- Battery power cable should be 20~25mm²



Step 2



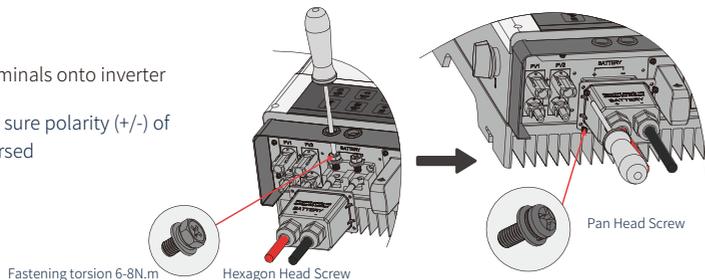
Make battery terminals

- Strip cable coat, revealing 10mm length of metal core
- Use special crimper to compress battery terminal tightly

Step 3

Connect battery terminals onto inverter

Note: Please make sure polarity (+/-) of battery are not reversed



* For the compatible lithium batteries (LG/Pylon/BYD/GCL) connection, please refer to battery connection part in EM QUICK INSTALLATION INSTRUCTIONS.

• BATTERY PROTECTION DESCRIPTION

Battery will act a protective charge/discharge current limitation under any condition as below:

- Battery SOC is lower than I-DOD
- Battery voltage lower than discharge voltage
- Battery over temperature protection
- Battery communication abnormal for lithium battery
- BMS limitation for lithium battery

When charge/discharge current limitation protection happens:

- Under on-grid mode, battery charge/discharge operation could be abnormal
- Under off-grid mode, Back-Up supply will shut down

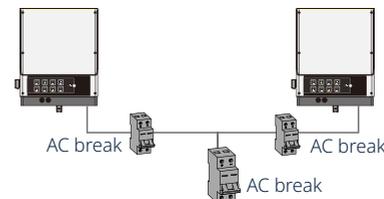
Note:

- Under off-grid mode, if Back-Up supply shuts off because of battery of low battery SOC or voltage, PV power will all be used to charge battery till battery SOC reaches 40% + (I-DOD)/2, then Back-Up supply will be activated up.
- Under on-grid mode, battery is protected from over discharge by DOD and discharge voltage, under off-grid mode, it is protected by only discharge voltage in priority.
- The DOD setting of a battery prevents the inverter from discharging battery reserve power. As soon as the DOD is reached the load of building will only be supported by either PV power or from the grid. If there are continuous days when little or no battery charging occurs, the battery may continue to self-consume energy to support communications with the inverter. This behaviour is different between battery manufactures products, however, if the SOC of the battery reaches a certain level the inverter will boost the SOC back up. This protection mechanism safeguards the battery to falling to 0% SOC.

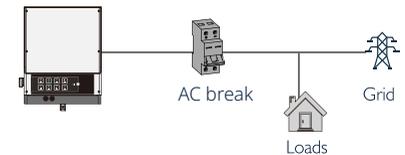
2.4.3 ON-GRID & BACK-UP CONNECTION

When there is no need to connect AC cables, the terminal cover should not be removed from the ON-GRID and Back-UP ports to ensure that the ports are protected and there is no risk of electric shock for personnel.

1. Use a separate AC break for individual inverter



2. On AC side, the individual break should be connected before loads (between inverter and loads)

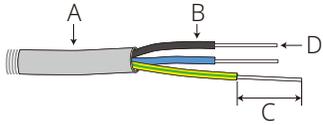


• On-Grid wiring connection process is as below:

Make sure inverter inverter is totally isolated from any DC or AC power before connecting AC cable.^[5]

Step 1

Prepare the AC cable according to the table.



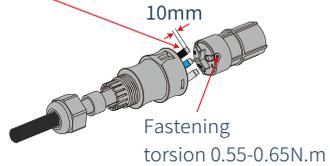
Grade	Description	Value
A	Outside Diameter	13~22mm
B	Separated Wire Length	10~15mm
C	Conduct Wire Length	12~14mm
D	Conduce Core Section	8~10mm ²

Note: If you don't use the back-up function or use on-grid power to charge the battery, the wiring conduct core section can use 4-6mm².

Step 2

1. Prepare the terminals and AC cables.
2. Put AC cable through terminal cover and screw the three cables tightly on the connectors.

4mm² Copper Conductor Material

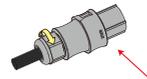


Note:

1. Please use the terminals in GoodWe componets box;
2. Make sure cable jacket is not locked with conductor.

Step 3

Lock terminal cover and screw up the terminal cap.



Make sure terminal cover is locked up here.

Note: Make sure the terminal cover is rightly locked onto the terminal.

Step 4

Connect the assambled AC terminals onto inverter.

Note: Make sure it is connected to "On-Grid" side (other side connected to public grid).

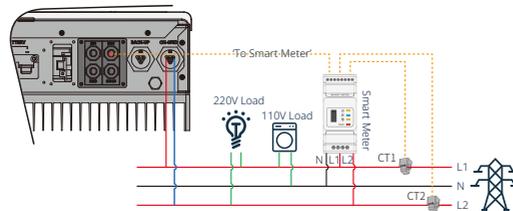


Special Adjustable Settings

The inverter has field adjustable setting like tripping point, tripping time, reconnect time, active and invalid of QU/PU curves etc. by special firmware. Please contact GoodWe after-sales for the special firmware and adjust methods.

Connection for SPLIT Grid System

In SPLIT grid system, there is a solution to allow inverter work under on-grid condition (Figure 2.4.3-1). For details, please check the official application plan on website -GoodWe Hybrid Solution For Split Grid Type.

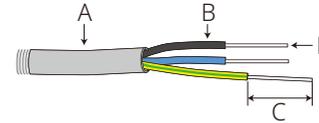


• Back-Up wiring connection process is as below:

An external AC switch ($\geq 32A$) is needed for Back-Up connection to be isolated when necessary.

Note: The absence of AC breaker on Back-Up side will lead to inverter damage if only electrical short-circuit happend on Back-Up side. And Back-Up function cannot turn off under on-grid condition.

Step 1

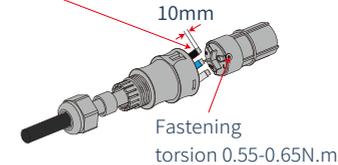


Grade	Description	Value
A	Outside Diameter	10~14mm
B	Separated Wire Length	7~10mm
C	Conduct Wire Length	7~9mm
D	Conduce Core Section	4~6mm ²

Step 2

1. Prepare the terminals and AC cables.
2. Put AC cable through terminal cover and screw the three cables tightly on the connectors.

4mm² Copper Conductor Material

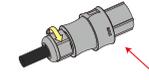


Note:

1. Please use the terminals in GoodWe componets box;
2. Make sure cable jacket is not locked with conductor.

Step 3

Lock terminal cover and screw up the terminal cap.



Make sure terminal cover is locked up here.

Note: Make sure the terminal cover is rightly locked onto the terminal.

Step 4

Connect the assambled AC terminals onto inverter.

Note: Make sure it is connected to "Back-Up" side (other side connected to public grid).



Declaration For Back-Up Function

The below statement lays out GoodWe general policies governing the energy storage inverters of the series ES, EM, SBP, ET, EH and BH.

• For Hybrid inverters (Series ES, EM, EH and ET), the standard PV installation typically consists of the connection of the inverter with both panels and batteries. In case of systems not connected to the batteries, the Back-Up function is strongly not advised to use. GoodWe shall not cover the standard warranty and be liable for any consequences arising from users not following this instruction.

• Under normal circumstances, the Back-Up switching time is less than 10 ms (the minimal condition to be considered as the UPS level). However, some external factors may cause the system to fail on Back-Up mode. As such, we recommend the users to be aware of conditions and follow the instructions as below:

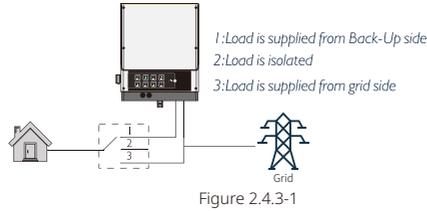
1. Do not connect loads if they are dependent on a stable energy supply for a reliable operation.
2. Do not connect the loads which may in total exceed the maximum Back-Up capacity.
3. Try to avoid those loads which may create very high start-up current surges such as Inverter Air-conditioner, high-power pump etc.
4. Due to the condition of battery itself, battery current might be limited by some factors including but not limited to the temperature, weather etc.

Declaration For Back-Up Loads

GoodWe EM inverter is able to supply a continuous 2300VA output or max 3500VA in less than 10 seconds on Back-Up side to support Back-Up loads. And the inverter has self-protection derating at high ambient temperature.

- Accepted Back-Up loads: Television, computer, fridge, Fan, Illumination Lamps, Microwave Oven, Electrical Rice Cooker and router etc.
- Unacceptable Back-Up loads: Air Conditioner, Water Pump, Heaters, Washing Machine, Electromagnetic Oven, Compression Engine, Hair drier and Dust Cleaner etc. and other loads with high inrush current at start-up.

For a convenient maintenance, an SP3T switch could be installed on Back-Up and On-Grid side. Then it is adjustable to support load by Back-Up or by grid or just leave it there. (Figure 2.4.3-1)



Declaration For Back-Up Loads

Inverter will restart itself as overload protection happens. The preparation time for restarting will be longer and longer (max one hour) if overload protection repeats. Take following steps to restart inverter immediately:

- Decrease Back-Up load power within max limitation.
- On SolarGo → Advanced Setting → Click “Reset Back-Up Overload History”

2.4.4 SMART METER & CT CONNECTION

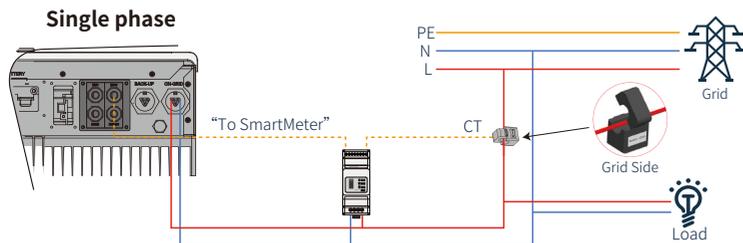
! Make sure AC cable is totally isolated from AC power before connecting SmartMeter and CT[6]

The SmartMeter with CT in GoodWe product box is compulsory for EM system installation, used to detect grid voltage and current direction and magnitude, further to instruct the operation condition of EM inverter via RS485 communication.

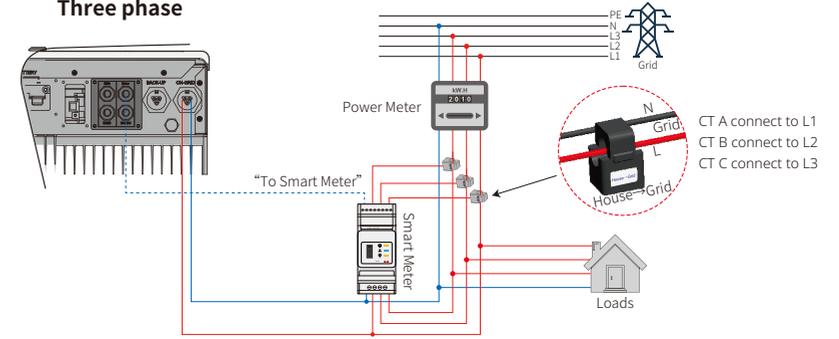
NOTE:

1. The SmartMeter and CT is well configured, please do not change any setting on SmartMeter;
2. One SmartMeter & CT can only be used for one EM inverter;
3. Three CTs must be used for one Smart Meter, and must be connected on the same phase with Smart Meter power cable.

Single-Phase SmartMeter & CT Connection Diagram



Three phase



NOTE:

1. Please use the SmartMeter and CT in GoodWe product box;
2. CT cable is 3m as default, could be extended to max 5m
3. SmartMeter communication cable (RJ45) is attached on the inverter (“To SmartMeter” cable), could be extended to max 100m, and must use standard RJ45 cable and plug, as below:

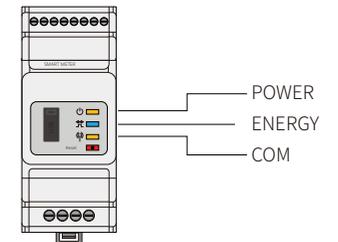


Position	Color	BMS Function	SmartMeter Function	RS485
1	Orange&white	485_A2	NC	485_A
2	Orange	NC	NC	485_B
3	Green&white	485_B2	485_B1	485_A
4	Blue	CAN_H	NC	NC
5	Blue&white	CAN_L	NC	NC
6	Green	NC	485_A1	485_B
7	Brown&white	NC	485_B1	NC
8	Brown	NC	485_A1	NC

BMS: Forbidden to change the BMS cable if no issues! CAN communication is configured by default. RS485 Port has signal with standard communication cable.

• Single-Phase SmartMeter LED Indications

	OFF	ON	Blinking
POWER	Not working	Working	/
ENERGY	/	Importing	Exporting
COM	Blink one time when it transfer data to inverter		



NOTE:

1. For 3-phase SmartMeter please check on LCD left-down side, a phone signal blinking means communication OK
2. For both SmartMeter, customer can also check on SolarGo App

2.5 DRED&REMOTE SHUTDOWN CONNECTION

DRED is only for Australian and New Zealand installations, in compliance with Australian and New Zealand safety requirements. And DRED device is not provided by GoodWe.

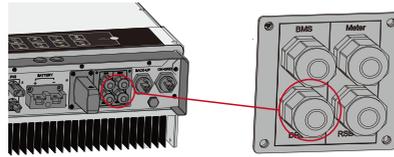
Remote shutdown is only for Europe installations, in compliance with Europe safety requirements. And Remote shutdown device is not provided by GoodWe.

Detailed connection of DRED/Remote Shutdown device is shown below:

Step 1

Screw this plate off from inverter.

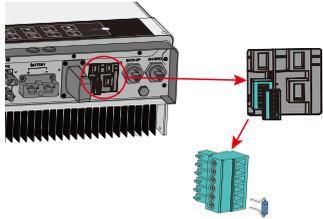
Note:
DRED/Remote Shutdown device should be connected through "DRED port" as the figure shows.



Step 2

1. Plug out the 6-pin terminal and dismantle the resistor on it.
2. Plug the resistor out, leave the 6-pin terminal for next step.

Note:
The 6-Pin terminal in the inverter has the same function of DRED device. Please leave it on the inverter if no external device connected.

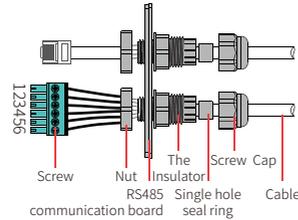


Step 3-1 For DRED

1. Put the cable through the plate.
2. Connect DRED cable on the 6-pin terminal.

The function of each connection position as below:

NO	1	2	3	4	5	6
Function	DRM1/5	DRM2/6	DRM3/7	DRM4/8	REFGEN	COM/DRMO

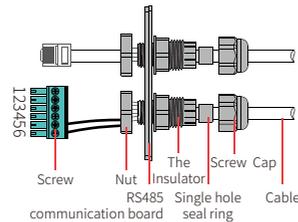


Step 3-2 For Remote Shutdown

1. Put the cable through the plate.
2. Connect DRED cable on the 6-pin terminal. (Wiring from the No. 5 and 6 holes respectively.)

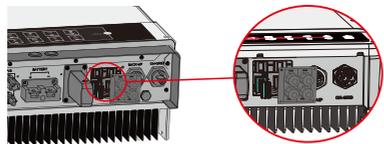
The function of each connection position as below:

NO	5	6
Function	REFGEN	COM/DRMO



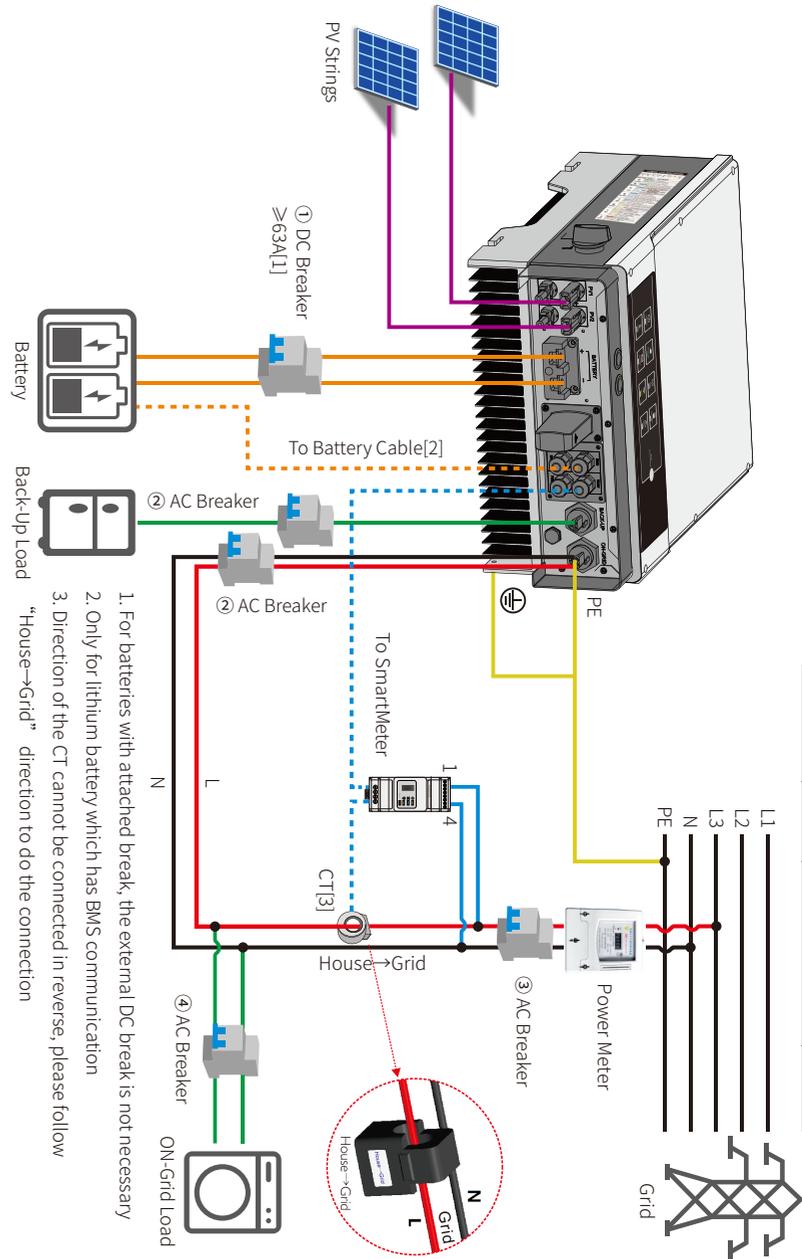
Step 4

Connect "DRED" or "Remote shutdown" terminal to the right position onto the inverter.



2.6 EARTH FAULT ALARM CONNECTION

GoodWe EM series inverter complies with IEC 62109-2 13.9. Fault indicator LED on inverter cover will light up and the system will email the fault information to customer.



1. For batteries with attached break, the external DC break is not necessary
2. Only for lithium battery which has BMS communication
3. Direction of the CT cannot be connected in reverse, please follow "House→Grid" direction to do the connection

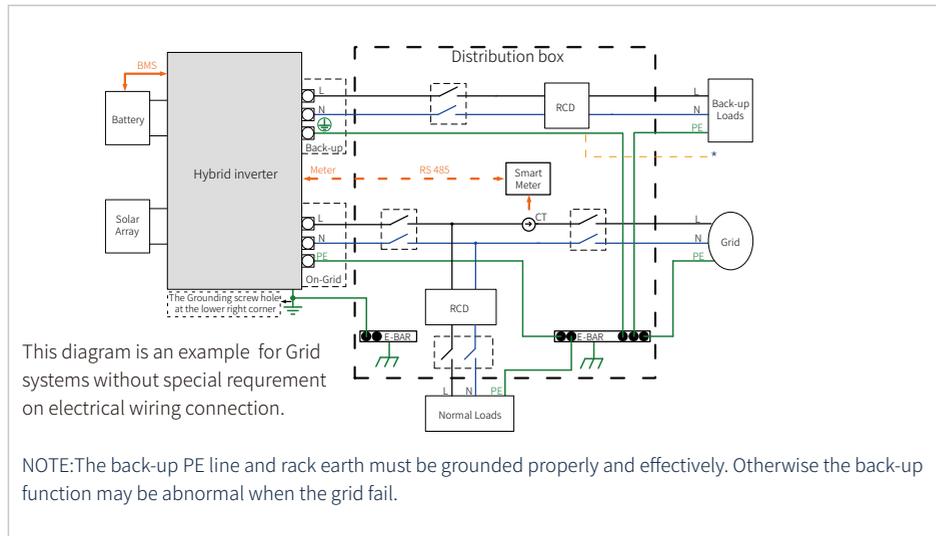
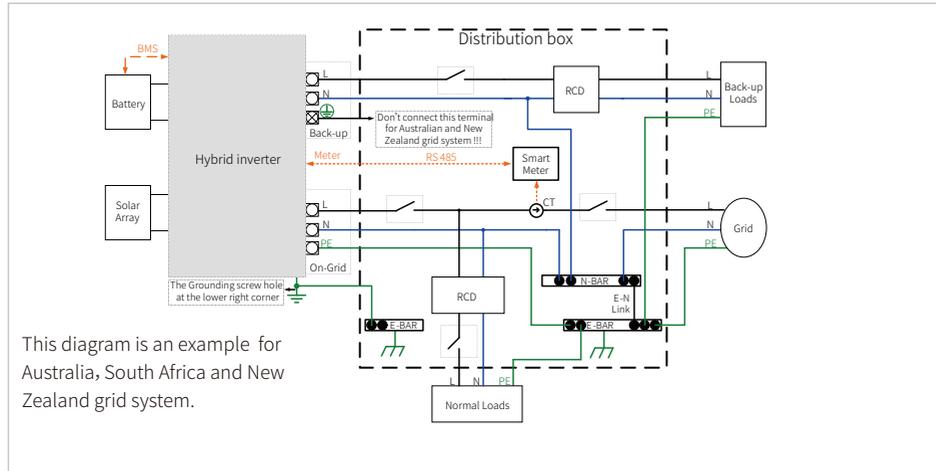
• WIRING SYSTEM FOR EM SERIES HYBRID INVERTER

Please select Breaker according to the specification below

	①	②	③	④
GW3000-EM	63A/60V DC breaker	32A/230V AC breaker	Depends on household loads	
GW3680-EM	63A/60V DC breaker	32A/230V AC breaker	Depends on household loads	
GW5000-EM	63A/60V DC breaker	32A/230V AC breaker	Depends on household loads	

• SYSTEM CONNECTION DIAGRAMS

NOTE: For Australian safety country, the neutral cable of On-Grid side and Back-Up side must be connected together, Otherwise Back-Up function will not work.



03 MANUAL OPERATION

3.1 WI-FI CONFIGURATION

• This part shows configuration on web page.

• Wi-Fi configuration is absolutely necessary for online monitoring and after-sales maintenance.

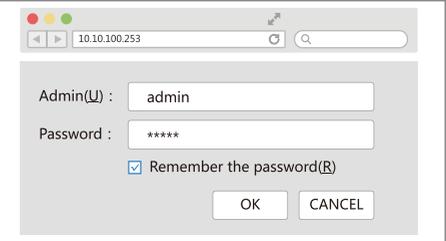
PREPARATION:

1. Inverter must be powered up with only PV power.

2. Need a router with available internet access to GoodWe portal <http://www.semsportal.com/>.

Step 1

1. Connect Solar-WiFi* to your PC or smart phone (* means the last 8 characters of the inverter serial No.).
2. Open browser and login 10.10.100.253 Admin (User): admin; Password: admin.
3. Then click "OK".



Step 2

1. Click "Start Setup" to choose your router.
2. Then click "Next".

Device information

Firmware version	1.6.9.3.38.2.1.38
MAC address	60:C5:A8:60:33:E1
Wireless AP mode	Enable
SSID	Solar-WiFi
IP address	10.10.100.253
Wireless STA mode	Disable
Router SSID	WiFi_Bum-in
Encryption method	WAP/WAP2-PSK
Encryption algorithm	AES
Router Password	WiFi_Bum-in

Cannot join the network, may be caused by:

No router / weak WiFi signal / password is not correct

★ **Help:** Wizard will help you to complete setting with one minute.

Start Setup

Please select your current wireless network:

SSID	Sec mode	Enc type	Channel	RSSI
WiFi Test	WAP2-PSK	AES	6	54%

★ **Note:** When RSSI of the selected WiFi Network is fewer than 10%, the connection maybe unstable, please select other available network or shorten the distance between the device and the router.
If your wireless router does not broadcast SSID, please click "Next" and add a wireless network manually.

Back Next

Step 3

1. Fill in the password of their router, then click "Next".
2. Click "Complete".

Add wireless network manually

Network name (SSID)	WiFi-Test
Encryption method	WPA/WPA2-PSK
Encryption algorithm	AES

Please enter the wireless network password:

Password (8-63 bytes)
show psk

Note: Case sensitive for SSID and password, Please make sure all parameters of wireless network are matched with router, including password

Back Next

Save success!

Click "Complete", the current configuration will take effect after restart.

If you still need to configure the other pages of information, please go to complete your required configuration.

Configuration is completed, you can log on the Management page to restart device by Click on "OK" button.

Confirm to complete?

Back Complete

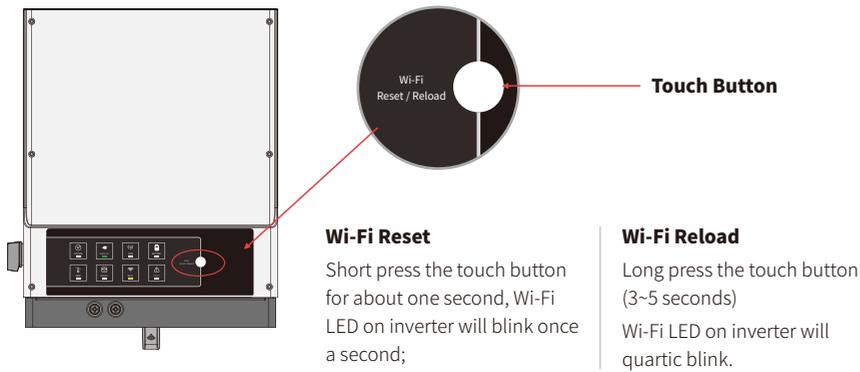
NOTE:

1. Please make sure the password, Encryption Method / Algorithm is right the same with the router's.
2. If everything is right well, the Wi-fi LED on inverter will change from double blink to quartic blink then to solid status, which means Wi-fi is connected to GoodWe icloud successfully.
3. Wi-Fi configuration could also be done on SolarGo details please check on SolarGo APP.

- Wi-Fi Reset & Reload

Wi-Fi Reset means restarting Wi-Fi module, Wi-Fi settings will be reprocessed and saved.

Wi-Fi Reload means setting Wi-Fi module settings back to default factory setting.



NOTE:

1. Wi-Fi losses connection to internet or cannot connect to SolarGo App successfully.
2. Cannot find “Solar-WiFi signal” or have other Wi-Fi configuration problem.
3. Please do not use this button if wi-Fi monitoring work well.

3.2 SolarGo APP OPERATION

SolarGo is an external configuration application for GoodWe hybrid inverters, used on smart phones or pad for both Android and iOS system, main functions as below:

1. Edit system configuration to make the system work as customer needs.
2. Wi-Fi configuration.

Please download **SolarGo User Manual** from www.goodwe.com



3.3 CEI AUTO-TEST FUNCTION

PV Auto-Test function of CEI is integrated in SolarGo App for Italy safety country requirements. For detailed instruction of this function please refer to **SolarGo User Manual**

4.1 DISCLAIMER

The EM series hybrid inverters are transported, used and operated under environmental and electrical conditions. GoodWe has the right not providing after-sales services or assistance under following conditions:

- Inverter is damaged during transferring.
- Inverter is out of warranty year and extended warranty is not bought.
- Inverter is installed, refitted or operated in improper ways without authority from GoodWe.
- Inverter is installed or used under improper environment or technical condition mentioned in this user manual, without authority from GoodWe.
- Installation or configuration of the inverter does not follow requirements mentioned in this user manual.
- The inverter is installed or operated against the requirements or warnings that are mentioned in this user manual.
- Inverter is broken or damaged by any force majeure like lightning, earthquake, fire hazard, storm and volcanic eruption etc.
- Inverter is disassembled, changed or updated on software or hardware without authority from GoodWe.
- Inverter is installed, used or operated against any related items in international or local policies or regulations.
- Any non-compatible batteries, loads or other devices connected to EM system.
- Obtain the Battery-Ready inverter activation code through illegal channels.

Note:

GoodWe will keep right to explain all the contents in this user manual. To insure IP65, inverter must be sealed well, please install the inverters in one day after unpacking, otherwise please seal all unused terminals/holes, not allowed to keep any terminals/holes open, confirm there is no risk to have water & dust in.

* Maintenance

The inverter requires periodically maintenance, details as below:

- Make sure inverter is totally isolated from all DC and AC power for at least 5 mins before maintenance.
- Heat sink: Please use clean towel to clean up heat sink once a year.
- Torque: Please use torque wrench to tighten AC and DC wiring connection once a year.
- DC breaker: Check DC breaker regularly, active the DC breaker 10 times in a row once a year.
- Operating DC breaker will clean contacts and extend lifespan of DC breaker.
- Water-proof covers: Check if water-proof covers of RS485 and other part are fastend once a year.

4.2 ERROR MESSAGE AND TROUBLESHOOTINGS

• ERROR MESSAGE

The error messages below will be displayed on SolarGo App or report by Email if the error really happen.

ERROR MESSAGE	EXPLANATION	REASON	SOLUTIONS
Utility Loss	Not available of public grid power (power lost or on-grid connection fails)	Inverter does not detect the connection of grid	<ol style="list-style-type: none"> 1. Check (use multi-meter) if AC side has voltage. Make sure grid power is available. 2. Make sure AC cables are connected tightly and right well. 3. If all is well, please try to turn off AC breaker and turn on again after 5 mins.
VAC Failure	Grid voltage is not within permissible range	Inverter detects that AC voltage is beyond the normal range required by the safety country	<ol style="list-style-type: none"> 1. Make sure safety country of the inverter is set right. 2. Check (use multi-meter) if AC voltage (Between L & N) is within a normal range (Also on AC breaker side) <ol style="list-style-type: none"> a. if AC voltage is high, then make sure AC cable complies with that required on user manual and AC cable is not too long b. if voltage is low, make sure AC cable is connected well and the jacket of AC cable is not compressed into AC terminal 3. Make sure the grid voltage of your area is stable and within normal range.
FAC Failure	Grid Efficiency is not within permissible range	Inverter detects that Grid frequency is beyond the normal range required by the safety country	<ol style="list-style-type: none"> 1. Make sure safety country of the inverter is set right. 2. If safety country is right, then please check on inverter display if AC frequency (Fac) is within a normal range. 3. If FAC failure only appear a few times and resolved soon, it should be caused by occasional grid frequency instability.
PV Over Voltage	DC total voltage of PV string is too high	The total voltage (short-circuit voltage) of each PV string is higher than the max DC input voltage of the inverter.	<p>Check PV string VOC is lower than Max PV Input Voltage of the inverter</p> <p>If VOC of PV string is high, please decrease panels to make sure VOC is with the max DC input voltage of the inverter.</p>
Over Temperature	Temperature inside of the inverter is too high	Inverter working environment leads to a high temperature condition	<ol style="list-style-type: none"> 1. Try to decrease surrounding temperature. 2. Make sure the installation complies with the instruction on inverter user manual. 3. Try to close inverter for 15 mins, then start up again.
Isolation Failure	Ground insulation impedance of PV string is too low	Isolation failure could be caused by multi reasons like PV panels are not grounded well, DC cable is broken, PV panels are aged or surrounding humidity is comparatively heavy, etc.	<ol style="list-style-type: none"> 1. Use multi meter to check if the resistance between earth & inverter frame is about zero. If it's not, Please make the connection between earth & inverter frame well. 2. If the humidity is very high, there maybe Isolation Failure occur. 3. Check the resistance between PV1+/PV2+/BAT+/PV- to earth, if the resistance is lower than 33.3k, check the system wiring connection. 4. Try to restart the inverter, check if the fault is still happens, if not, means it is just an occasional situation, or contact GoodWe.
Ground I Failure	Ground leakage current is over-high	Ground I failure could be caused by multi reasons like neutral cable on AC side is not connected well or surrounding humidity is comparative heavy, etc.	<p>Check use multi-meter if there is voltage (normally should be close to 0V) between earth & inverter frame.</p> <p>If there is a voltage, it means the neutral & ground cable are not connected well on AC side. If it happened only at early morning, dawn or on rainy days with higher air humidity, and recover soon, it should be normal.</p>
Relay Check Failure	Self checking of relay fails	Neutral & ground cable are not connected well on AC side or just occasional failure	<p>Check use multi-meter if there is high voltage (normally should be lower than 10V) between N & PE cable on AC side.</p> <p>If the voltage higher than 10V, it means the Neutral & ground cable are not connected well on AC side or restart inverter.</p>
DC Injection High	/	Inverter detects a higher DC component in AC output	Try to restart inverter, check if it still happens, if not, means it is just an occasional situation or contact GoodWe.
EEPROM R/W Failure	/	Caused by a strong external magnetic field etc.	Try to restart inverter, check if it still happens, if not, means it is just an occasional situation or contact GoodWe.
SPI Failure	Internal communication fails	Caused by a strong external magnetic field etc.	Try to restart inverter, check if it still happens, if not, means it is just an occasional situation or contact GoodWe.
DC Bus High	BUS voltage is over-high	/	Try to restart inverter, check if it still happens, if not, means it is just an occasional situation or contact GoodWe.
Back-Up Over Load	Back-up side is over loaded	Total Back-Up load power is higher than the nominal backup output power	Decrease Back-Up loads to make sure the total load power is lower than Back-Up nominal output power (please refer to page 12).

NOTE: All the errors about battery happen only on Lithium battery with BMS communication.

• TROUBLESHOOTINGS

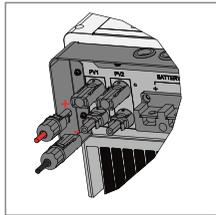
Checking Before Starting EM Up

PV Input Connection: Confirm the connection between EM inverter and PV panels : polarity (+/-) not reversed, refer to 4.2-1.

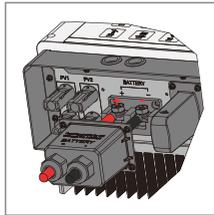
Battery Connection: Confirm the connection between EM inverter and battery : polarities (+/-) not reversed, refer to 4.2-2.

On-Grid & Back-Up Connection: Confirm On-Grid connected to public grid and Back-Up to loads :polarity (L/N) not reversed, refer to 4.2-3.

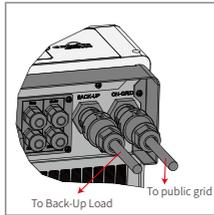
SmartMeter & CT Connection: Make sure CT are connected between house loads and grid, and follow the House→Grid direction sign on CT. (4.2-4)



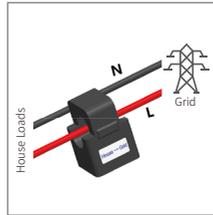
4.2-1



4.2-2



4.2-3



4.2-4

Checking as Start EM Up and Turn On AC Power

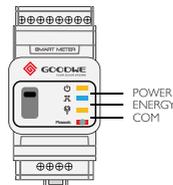
SmartMeter Communication: Turn off PV and battery, turn on Loads, check if R-P led is solid or not (4.2-5). If “R-P” is not solid, means CT connected by reversed or on a wrong phase, please check:

- 1.if connection between SmartMeter and CT (port 1 and 4 on SmartMeter) is OK
- 2.Make sure CT connected between house loads and grid, follow the House→Grid direction on CT(4.2-5).
3. Make sure CT is connected on the same phase with the power cable of SmartMeter.

Battery Settings, BMS Communication and Safety Country: After connecting Solar-WiFi* (* means the last 8 characters of the inverter serial No.), check on SolarGo App Param to make sure battery type is right what you have installed, and Safety Country is right. If not right, please set it right in “Set”

NOTE:

- 1.For lead-acid battery: All the settings should comply with the parameter of the battery, and please contact GoodWe for advices
- 2.For lithium batteries, BMS status is “Communication OK”
If APP BMS Status on APP says “NG” or “NA”, please check if battery wiring and settings are all right following battery connection SOP in EM QUICK INSTALLATION INSTRUCTIONS
3. Make sure CT is connected on the same phase with the power cable of SmartMeter.



4.2-5



4.2-6

Problems during operation

EM not start up with only battery

Solution:

Make sure the voltage of battery is higher than 180V, otherwise battery cannot start BT up.

EM not start up with only PV

Solution:

1. Make sure the voltage of PV is higher than 150V (need 200V to enter on-grid mode);
2. Make sure that connection between EM and PV panels: polarities (+/-) not reversed.

No discharge or output from EM at night without PV or PV power lower than load power:

Solution:

1. Communication between EM and SmartMeter is OK or not;
2. Make sure load power is higher than 150W;
 - a. Battery will not discharge continuously unless load power is higher than 150W;
 - b. If battery still not discharge when Meter power is higher than 150W, then please check SmartMeter & CT connection and direction;
3. Make sure SOC is higher than I-DOD. Or if battery discharged to below I-DOD, than battery will only discharge again when SOC charged to 20%+ (I-DOD)/ 2 and SOC>105%-DOD (if need battery discharge immediately, battery should be restarted);
4. Check on App if ti is set as charge time, during charge time, battery will not discharge (battery will charge in priority during coincident time of charge/ discharge).

Battery not charge when PV power higher than load power:

Solution:

1. Check if charge voltage on App (Set→Basic Setting) is properly set (for lead-acid battery) as battery cannot charge if battery voltage reaches charge voltage;
2. Check if it is during discharge time set on App;
3. Check if battery is fully charged or not, or battery voltage reach “charge voltage” or not.

High power fluctuation on battery charge or discharge:

Solution:

1. Check if there is a fluctuation on load power;
2. Check if there is a fluctuation on PV power.

Battery does not charge:

Solution:

1. Make sure BMS communication is OK on SolarGo (for lithium batteries);
2. Check if CT connected in the right position and to right direction as on the user manual page 13;
3. Check if the total load power is much higher than PV power.

About Wi-Fi Configuration

Q: Why cannot see Solar-WiFi* signal on mobile devices

A: Normally Solar-WiFi* signal could be searched right after inverter powered up. But Solar-WiFi signal will disappear when BT connected to internet. If need to change settings, can connect to the router to change. If cannot see Wi-Fi signal even not connect to router, then please try to reload Wi-Fi (please refer to EM user manual page 19).

About Battery Operation

Q: Why battery does not discharge when grid is not available, while it discharges normally when grid is available?

A: On APP, Off-Grid output and Back-Up function should be turned on to make battery discharge under Off-Grid mode.

Q: Why there is no output on Back-Up side?

A: For Back-Up supply, the “Back-Up Supply” on SolarGo App must be turned on. Under Off-Grid mode or grid power is disconnected, “Off-Grid Output Switch” function must be turned on as well.

Note: As turn “Off-Grid Output Switch” on, don't restart inverter or battery, otherwise the function will switch off automatically.

Q: Why battery switch always trip when starts it up (Lithium battery)?

A: The switch of lithium battery normally trips for following reasons:

1. BMS communication fails.
2. Battery SOC is too low, battery trips to protect itself.
3. An electrical short-cut happened on battery connection side. Or other reasons please contact GoodWe for details.

Q: Which battery should I use for EM?

A: For BT series inverter, it could connect lithium batteries which have compatibility with BT series inverter with nominal voltage from 180V to 600V. Compatible lithium batteries can see on battery list in SolarGo APP.

About SolarGo Operation and Monitoring

Q: Why Cannot save settings on SolarGo App

A: This could be caused by losing connection to Solar-WiFi*.

1. Make sure you connected Solar-WiFi* (make sure no other devices connected) or router (if connected Solar-WiFi* to router) and on APP home page shows connection well.
2. Make sure EM Under waiting mode (on App) before you change any settings on SolarGo App disconnect grid/load/battery, only leave PV connected and then restart EM till see work as “wait” on App.

Q: On the App, why the data on the homepage and Param page is different, like charge/discharge, PV value, load value or grid value?

A: As the data on App is from inverter and on home page and Param page, the data refresh frequency is different, so there will be a data inconformity between different pages on APP as well as between that on portal and APP.

Q: On App, some columns show NA, like battery SOH, etc. why is that?

A: NA means App does not receive data from inverter or server, normally it is because communication problem, such as battery communication, and communication between inverter and the APP.

About Smart Meter and Power Limit Function

Q: How to Act Output Power Limit function?

A: For EM system, the function could be realized by:

1. Make sure Smart Meter connection and communication well.
2. Turn on Export Power Limit function and set the max output power to grid on APP.

Note: If out-put power limit set as 0W, then there might still have deviation max 100W exporting to grid.

Q: Why there is still power exporting to grid after 1 set power limit as 0W?

A: Export limit could theoretically to minimum 0W, but there will have a deviation of around 50-100W for EM system.

Q: What is the max current allowed going through CT on SmartMeter?

A: The max current for CT is 120A.

Other Questions

Q: Is there a quick way to make the system work?

A: The shortest way, please refer to EM QUICK INSTALLATION INSTRUCTIONS and SolarGo User Manual.

Q: What kind of load can I connect on Back-Up side?

A: Please refer to user manual on page 12.

Q: Whether the warranty of the inverter still valid if the installation or operation does not follow the user manual instructions, for some special conditions when we cannot 100% follow them?

A: Normally if any problem caused by disobeys the instructions on user manual, we can provide technical support to help to solve the problem, but cannot guarantee a replacement or returns. So if there is any special conditions when you cannot 100% follow the instructions, please contact GoodWe for suggestions.

4.3 TECHNICAL PARAMETERS AND CERTIFICATES

Technical Data	GW3048-EM	GW3648-EM	GW5048-EM
Battery Input Data			
Battery Type	Li-Ion		
Nominal Battery Voltage (V)	48		
Battery Voltage Range (V)	40~60		
Max. Continuous Charging Current (A) ^{*1}	50		
Max. Continuous Discharging Current (A) ^{*1}	50		
Max. Charge Power (W)	2,500		
Max. Discharge Power (W)	2,500		
PV String Input Data			
Max. Input Power (W)	3,900	4,600	6,500
Max. Input Voltage (V) ^{*2}	550		
MPPT Operating Voltage Range (V)	100~500		
MPPT Voltage Range at Nominal Power (V)	280~500	170~500	230~500
Start-up Voltage (V)	125		
Nominal Input Voltage (V)	360		
Max. Input Current per MPPT (A)	11		
Max. Short Circuit Current per MPPT (A)	13.8		
Max. Backfeed Current to The Array (A)	0		
Number of MPP Trackers	1	2	2
Number of Strings per MPPT	1		
AC Output Data (On-grid)			
Nominal Apparent Power Output to Utility Grid (VA)	3,000	3,680	5,000
Max. Apparent Power Output to Utility Grid (VA) ^{*3}	3,000	3,680	5,000
Nominal Apparent Power from Utility Grid (VA)	5,300		
Max. Apparent Power from Utility Grid (VA)	5,300		
Nominal Output Voltage (V)	230		
Nominal AC Grid Frequency (Hz)	50/60		
Max. AC Current Output to Utility Grid (A) ^{*7}	13.6	16.0	22.8
Max. AC Current From Utility Grid (A)	23.6		
Max. Output Fault Current (Peak and Duration) (A)	43A@0.2μs		
Inrush Current (Peak and Duration) (A)	55A@5μs		
Power Factor	~1 (Adjustable from 0.8 leading to 0.8 lagging)		
Max. Total Harmonic Distortion	<3%		
Maximum Output Overcurrent Protection (A)	30		
AC Output Data (Back-up)			
Back-up Nominal Apparent Power (VA)	2,300		
Max. Output Apparent Power (VA) ^{*4}	2,300 (3,500@10sec)		
Max. Output Current (A)	10.0		
Max. Output Fault Current (Peak and Duration) (A)	43A@10s		
Maximum Output Overcurrent Protection (A)	30		
Nominal Output Voltage (V)	230 (±2%)		
Nominal Output Frequency (Hz)	50/60 (±0.2%)		
Output THDv (@Linear Load)	<3%		
Efficiency			
Max. Efficiency	97.6%		
European Efficiency	97.0%		
Max. Battery to AC Efficiency	94.5%		

Technical Data	GW3048-EM	GW3648-EM	GW5048-EM
MPPT Efficiency	99.9%		
Protection			
PV Insulation Resistance Detection	Integrated		
Residual Current Monitoring	Integrated		
PV Reverse Polarity Protection	Integrated		
Anti-islanding Protection	Integrated		
AC Overcurrent Protection	Integrated		
AC Short Circuit Protection	Integrated		
AC Overvoltage Protection	Integrated		
General Data			
Operating Temperature Range (°C)	-25~+60		
Relative Humidity	0~95%		
Max. Operating Altitude (m)	4000		
Cooling Method	Natural Convection		
User Interface	LED, APP		
Communication with BMS ^{*5}	RS485, CAN		
Communication with Meter	RS485		
Communication with Portal	WiFi		
Weight (kg)	16.0	17.0	17.0
Dimension (W×H×D mm)	347×432×175		
Noise Emission (dB)	<25		
Topology	Non-isolated		
Self-consumption at Night (W)	<13		
Ingress Protection Rating	IP65		
Environmental Category	4K4H		
Overvoltage Category	DC II / AC III		
Protective Class	I		
Storage Temperature (°C)	-30~+65		
Mounting Method	Wall Mounted		
Active Anti-islanding Method	AFDPF + AQDPF ^{*8}		
Country of Manufacture	China		
Certification^{*6}			
Grid Standards	VDE-AR-N 4105, VDE 0126-1-1, EN 50549-1, G98, G100, CEI 0-21, AS/NZS 4777.2, NRS 097-2-1		
Safety Regulation	IEC/EN62109-1&2, IEC62040-1		
EMC	EN61000-6-1, EN61000-6-2, EN61000-6-3, EN61000-6-4, EN 61000-4-16, EN 61000-4-18, EN 61000-4-29		
<p>*1: The actual charge and discharge current also depends on the battery. *2: Maximum operating dc voltage is 530V. *3: For CEI 0-21 GW3048-EM is 3300, GW3648-EM is 4050, GW5048-EM is 5100; for VDE-AR-N4105&NRS 097-2-1, GW5048-EM is 4600. *4: Can be reached only if PV and battery power is enough. *5: CAN communication is configured by default. If 485 communication is used, please replace the corresponding communication line. *6: Not all certifications & standards listed, check the official website for details. *7: For CEI 0-21 GW3048-EM is 14.5, GW3648-EM is 18. *8: AFDPF: Active Frequency Drift with Positive Feedback, AQDPF: Active Q Drift with Positive Feedback.</p>			

Technical Data	GW3048-EM	GW3648-EM	GW5048-EM
Protection			
Anti-islanding Protection		Integrated	
PV String Input Polarity Reverse Protection		Integrated	
Isolation resistor Detection		Integrated	
Residual Current Monitoring Unit		Integrated	
Output Over-current Protection		Integrated	
Output Short Protection		Integrated	
Output Over-Voltage Protection		Integrated	
Certifications & Standards			
Grid Regulation	RD1699, UNE206006, EN50438, AS/NZS 4777.2:2015, G98/1, G100, CEI 0-21, VDE-AR-N4105, VDE0126-1-1, NRS 097-2-1		RD1699, UNE206006, EN50438, AS/NZS 4777.2:2015, G99/1, G100, CEI 0-21, VDE-AR-N4105, VDE0126-1-1, NRS 097-2-1
Safety Regulation	IEC / EN62109-1 & 2		
EMC	EN61000-6-1, EN61000-6-2, EN61000-6-3, EN61000-6-4, EN61000-4-16, EN61000-4-18, EN61000-4-29		

[8] GW3048-EM: 14.5A for CEI 0-21(Italy), GW3648-EM: 18A for CEI 0-21(Italy), GW5048EM: 21.7A for AS4777.2 (Australia & New Zealand).

[9] Default communication with BMS is CAN, requirement RS485 needs special configuration process.

• OTHER TEST

For Australian requirements, in the THDi test, there should add Zref between inverter and mains.

RA, XA for Line conductor

RN, XN for Neutral conductor

Zref:

RA=0, 24; XA=j0, 15 at 50Hz;

RN=0, 16; XN=j0, 10 at 50Hz.

4.4 WARNING QUICK CHECK LIST

[1] Inverter cannot be installed near flammable, explosive or strong electro-magnetic equipment, page 06

[2] Remember that this inverter is heavy! Please be careful when lifting out from the package, page 07

[3] The polarity of PV strings or on the inverter cannot be connected by reverse, otherwise inverter could be damaged, page 08

[4] Make sure battery switch is off and battery nominal voltage meet EM specification before connecting battery to inverter make sure inverter is totally isolated from PV and AC power, page 09

[5] Make sure inverter is totally isolated from any DC or AC power before connecting AC cable, page 11

[6] Make sure AC cable is totally isolated from AC power before connecting SmartMeter and CT, page 13

Appendix Protection Category Definition

Overvoltage Category Definition

Category I	Applies to equipment connected to a circuit where measures have been taken to reduce transient overvoltage to a low level.
Category II	Applies to equipment not permanently connected to the installation. Examples are appliances, portables tools and other plug-connected equipment.
Category III	Applies to a fixed equipment downstream and including the main distribution board. Examples are switchgear and other equipment in an industrial installation.
Category IV	Applies to equipment permanently connected at the origin of an installation (upstream of the main distribution board). Examples are electricity meters, primary over-current protection equipment and other equipment connected directly to outdoor open lines.

Moisture Location Category Definition

Moisture Parameters	Level		
	3K3	4K3	4K4H
Temperature Range	0~+40°C	-33~+40°C	-20~+55°C
Moisture Parameters	5%~85%	15%~100%	4%~100%

Environment Category Definition

Environment Condition	Ambient Temperature	Relative Humidity	Applied to
Outdoor	-20~50°C	4%~100%	PD3
Indoor Unconditioned	-20~50°C	5%~95%	PD3
Indoor conditioned	0~40°C	5%~85%	PD2

Pollution Degree Definition

Pollution Degree I	No pollution or only dry, non-conductive pollution occurs. The pollution has no influence.
Pollution Degree II	Normally only non-conductive pollution occurs. Occasionally, however, a temporary conductivity caused by condensation must be expected.
Pollution Degree III	Conductive pollution occurs, or dry, non-conductive pollution occurs, which becomes conductive due to condensation, which is expected.
Pollution Degree IV	Persistent conductive pollution occurs, for example, the pollution caused by conductive dust, rain and snow.