Application Note - SolarEdge Inverters, Power Control Options

Version History

- Version 3 (December 2017)
  - Added Active Power ramp up option
  - Added new active power phase balancing feature
- Version 2 (November 2017)
  - Added Demand Response Enabling Device (DRED) connectivity option
  - Clarified correct cosphi(p) setting
  - Removed Active Power phase balance option
  - Removed country defaults list
  - New appendix with explanation of cosphi
- Version 1 (December 2012)

Contents

Introduction

To improve grid stability, many electric utilities are introducing advanced grid limitations, requiring control of the active and reactive power of the inverter by various mechanisms.

All SolarEdge inverters with CPU version 2.337 and later support these requirements. These inverters include default settings per country, based on the specific requirements in that country, as well as the ability to configure these settings (settings may have to be configured according to installation size or utility requirements).

This document details the available power control configuration options in the SolarEdge inverters, and explains how to adjust these settings if such changes are required.

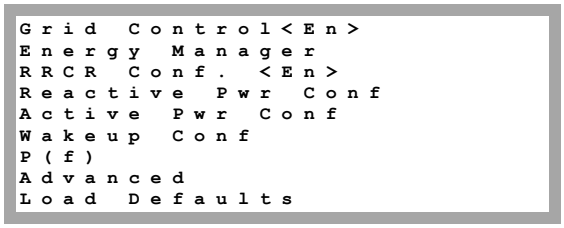
Installation Note for Three Phase Inverters

If power control is enabled, the order of grid lines connection to the inverter is important. A 120deg phase difference between L1 to L2 and between L2 to L3 should be kept (L1-L2-L3 and not, for example L1-L3-L2). If the grid lines are not in this order, the following error will be displayed on the LCD and the inverter will not produce power.

The Power Control Menu

The Power Control menu is accessible from the inverter LCD main menu. Refer to the “Inverter User Interface” chapter in the *SolarEdge installation guide* for LCD navigation instructions.

The Power Control menu includes the following options:



- Grid Control is enabled for Germany and Germany MVGC country settings.

The sections below describe the functionality and configuration of each of these menu options.

Energy Manager

Functionality

SolarEdge offers the Smart Energy Management solution for increasing the self-consumption of a site. One method used for this purpose is limiting the feed-in power: The inverter dynamically adjusts the PV power production in order to ensure that feed-in power does not exceed a preconfigured limit. To enable this functionality, an energy meter that measures feed-in or consumption must be installed at the site.

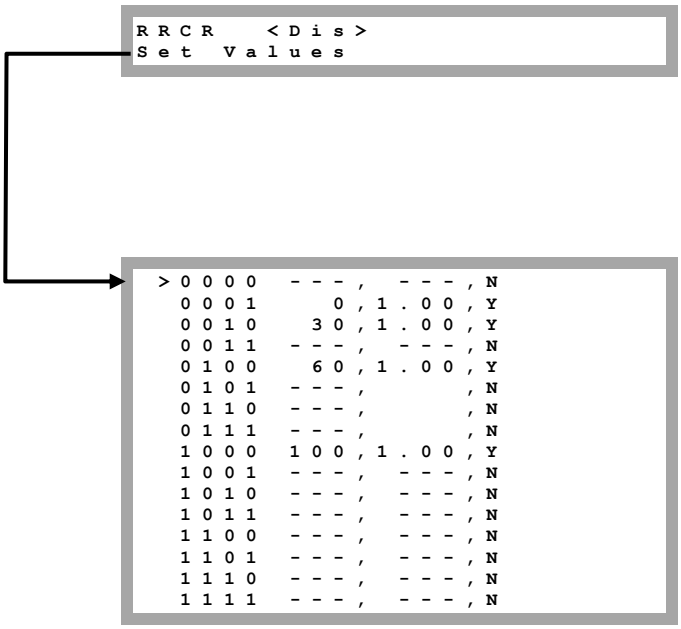
For details on how to use the Feed-in Limitation feature, refer to the Feed-in Limitation application note at https://www.solaredge.com/sites/default/files/feed-in_limitation_application_note.pdf.

RRCR Conf.

Functionality

SolarEdge inverters can connect to an external device which can control active and reactive power according to commands sent by the grid operator (examples, RRCR – Radio Ripple Control Receiver, DRED – Demand Response Enabling Device).

The RRCR menu includes the following options:



Use the RRCR Conf. menu to enable this control and to configure up to 16 control states. Each control state is a combination of the following three fields:

- **AC output power limit** – limits the inverter's output power to a certain percentage of its rated power with the range of 0 to 100 (% of nominal active power).
- **CosPhi** – sets the ratio of active to reactive power. The Reactive Power Conf. Mode must be set to RRCR when using this control mode. The CosPhi range is from 0.8 leading to 0.8 lagging (a negative value indicates a lagging CosPhi). For further information, see *Appendix C – CosPhi Calculation*.
- **Enable/Disable** – enables or disables control according to the specific state.

To enable/disable RRCR control:

Select **RRCR** ➔ Choose **Enable** or **Disable** ➔ Press Enter

In addition to enabling this option, the inverter must be connected to a power reduction device.

For RRCR connectivity, refer to the *Power Reduction Control application note* for details: http://www.solaredge.com/sites/default/files/power-reduction-control-application-note.pdf.

For DRED connection in Australia, refer to the application note, *Connecting a Demand Response Enabling Device (DRED) to a SolarEdge Inverter*: https://www.solaredge.com/sites/default/files/dred-connection-application-note.pdf.

To enable/disable any of the 16 states:

When you select a disabled state, only one line is displayed. After you enable it, three lines are displayed: `enable <yes>`, `pwr reduce` and `cosphi`.

Select **Set Values** ➔ Scroll to the relevant state ➔ Press Enter ➔ Select **Enable** ➔ Choose **Yes** or **No** ➔ Press Enter

Now you can select either cosphi or power reduce and set their value.

To set the values of an enabled state:

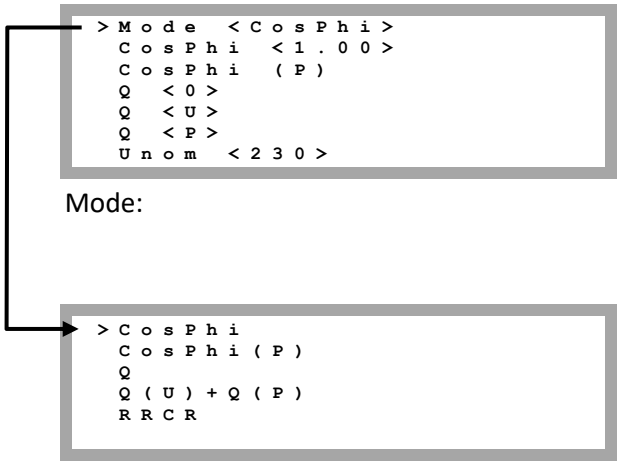
Select **Set Values** ➔ Scroll to the relevant state ➔ Press Enter ➔ Scroll to the relevant value ➔ Input the required setting ➔ Press Enter

When setting CosPhi values, use the minus symbol (-) for a lagging value.

Reactive Power Conf.

Functionality

The Reactive Power menu includes the following options:



Use the Reactive Power menu to select one of several reactive power control modes listed below, and to configure the various modes:

- **CosPhi** – sets a constant CosPhi, regardless of other parameters. Range: from 0.8 leading to 0.8 lagging (a negative value indicates a lagging CosPhi).
- **CosPhi(P)** – sets a graph of CosPhi to active power (P). CosPhi(P) has a 6-point graph setup. P can be set to any value between 0 and 100 [% of nominal active power], and should increase from P(0) to P(5). CosPhi can be set to any value between "0.8 leading" and "0.8 lagging" (a negative value indicates a lagging CosPhi). Each point includes the following fields: < % of nominal active power, CosPhi >.
- **Q** – sets constant reactive power (Q).
  Range: -100 to 100 (% of nominal reactive power. A negative value indicates a lagging reactive power).
- **Q(U)+Q(P)** – sets a graph of reactive power (Q) to grid voltage (U) and to active power (P); this mode can be used when Q(U) control is required, by setting Q(P) to zero, and vice versa. Q(U) and Q(P) have 6-point graph setups. Refer to *Appendix A – Q Configuration* on page 10 for additional configuration instructions.
  - U: 0 to 200 [% of nominal voltage].
  - P: 0 to 100 [% of nominal active power]
- **RRCR** – enables CosPhi control through the RRCR. RRCR must be enabled, as described above, when using this control mode.
- **Unom** - The Reactive Power menu is also used to set Unom, a reference grid voltage, when required for installation testing. Range: 0 to 500 [V].

Configuration Options

▶ To select a reactive power control-mode:

Enter the Mode menu ➔ Scroll to the required mode ➔ Press Enter

▶ To set the values of a reactive power control-mode:

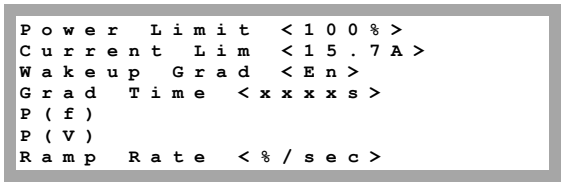
Scroll to the relevant mode ➔Press Enter ➔ Input the required setting ➔ Press Enter

When setting CosPhi or Q values, use the minus symbol (–) for a lagging value.

Active Power Conf.

Functionality

The Active Power menu includes the following options:



Use the Active Power menu to control the inverter active power:

- **Power Limit** - limits the inverter maximum output power. The power limit can be set to any value between 0-100 [% of nominal active power].
- **Current Lim** – **Current Limit**: limits the inverter's maximum output current (available from inverter CPU version 2.549). The current limit can be set to any value between 0 and the inverter's max AC current [A] (the LCD will allow setting to a higher value but the inverter will never exceed its maximum AC current).
- **Wakeup Grad** – **Wakeup Gradient**: enables gradual power production when it begins operation after a fault or an inverter reset. For gradual power production during normal operation, use the Ramp Rate option.
- **Grad Time** – **Gradient Time**: The wakeup time setting. This line is displayed only if the Wakeup Gradient is enabled. Can be set to any value between 1 and 9999 seconds.
- **P(f)** – **Power Frequency:** This is used when frequency-based power reduction is required. This defines a linear graph set by two points. The inverter de-rates power according to the defined graph, until the frequency reaches the trip value and the inverter disconnects (the trip point is preset per country therefore does not need to be defined as one of the two points).
- **P(V)** – **Power Voltage**: This is used when voltage-based power reduction is required. This defines a linear graph set by six points (available from inverter CPU version 3.1808). The inverter de-rates power according to the defined graph, until the voltage reaches the trip value and the inverter disconnects.
- **Ramp Rate:** enables gradual power production during normal operation (available from inverter CPU version 3.22xx). Can be set to any value between 0-100%/sec with 0.1% resolution. Ramp rate of 0 means production increase is immediate.

Configuration Options

▶ To change the power or current limit:

Select **Power Limit** or **Current Lim** ➔ Press Enter ➔ Input the required setting ➔ Press Enter

▶ To set gradual power production:

1. Select **Wakeup Gradient** ➔ Select Enable ➔ Press Enter
2. Select **Grad Time** ➔ Press Enter ➔ Input the required setting ➔ Press Enter

To set P(f) and change the P or f values:

Each point includes the following fields: <frequency, % of nominal active power>.

```
P 0 < 5 0 . 2 0 , 1 0 0 . 0 >
P 1 < 5 1 . 2 0 , 6 0 . 0 0 >
```

The ranges for P(f) parameters are:

- Frequency: 0 to 100 [Hz]
- P: 0 to 100 [% of nominal active power].

When changing values, scroll to the relevant point ➔ Press Enter ➔ Input the required value ➔ Press Enter

To set P(V) and change the P or f values:

Each point includes the following fields: <voltage, % of nominal active power>.

```
S e t   P o i n t
   < V , P % >
```

The ranges for P(V) parameters are:

- Voltage: 0 to 200 [% of 230V].
- P: 0 to 100 [% of nominal active power].

```
P 0   < 2 0 0 . 0 , 1 0 0 . 0 >
P 1   < 1 0 0 . 0 , 1 0 0 . 0 >
P 2   < 1 0 0 . 0 , 1 0 0 . 0 >
P 3   < 1 2 0 . 4 , 1 0 0 . 0 >
P 4   < 1 0 0 . 0 , 1 0 0 . 0 >
P 5   < 1 0 0 . 0 , 1 0 0 . 0 >
```

When changing values, scroll to the relevant point ➔ Press Enter ➔ Input the required value ➔ Press Enter

To set a ramp rate:

1 Select : **PowerControl ➔ Active Pwr Conf. ➔ Ramp Rate ➔** Input the required settings ➔ Press Enter

- Resolution 0.1%
- Range 0-100%/sec
- 0 = disable (transition is immediate)

Phase Balancing

Functionality

The phase balancing feature is used to connect up to 3 *single phase inverters* to a *three phase grid* in cases where phase balancing is required by the utility.

- Supported by inverters with a maximum 21.7A AC output current
- Supported from inverter CPU version 3.22xx.

When phase balancing is enabled, if any inverter in the system disconnects, the other inverters disconnect within 2 seconds. Disconnect occurs under the following conditions:

- Loss of communications between any of the inverters
- Grid protection trip
- Inverter receives a zero-production command from an external device

In the event of a communications loss, the following message is displayed:

In the event of a grid protection trip or zero-production command, the following message is displayed:

Configuration Options

NOTE:
The configuration must be performed on *all* inverters.

NOTE:
In addition to enabling this option, the inverters must be connected on an RS485 bus.

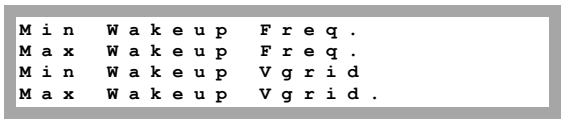
▶ To enable/disable phase balancing:

1. Select **Power Control ➔ Grid Control: Enable**
2. Select **Power Control ➔ Phase Balance: Enable**
3. Select **Connection: RS485**

Wakeup Conf.

Functionality

The Wakeup menu includes the following options:



Use the Wakeup menu to set the minimum and maximum grid frequencies and grid voltages between which the inverter can begin power production. This menu does not set the inverter disconnection values, which are pre-set per country.

The ranges for Wakeup parameters are:

- Frequency: 0 to 100 [Hz]
- Voltage 0 to 500 [V]

Configuration Options

▶ To change the frequency or voltage values:

Scroll to the relevant setting ➔ Press Enter ➔ Input the required value ➔ Press Enter

Advanced

Functionality

Use the Advanced menu to configure the K-Factor for the BDEW-MVGC certification in Germany. It is set to a default value of 2.

The range for the FRT-K parameter is 0 to 16.

Configuration Options

▶ To enable/disable FRT-K:

Select **Set FRT** ➔ Select **Enable** or **Disable** ➔ Press Enter

▶ To change the value after enabling the K-Factor:

Select **FRT-K** ➔ Input the required value ➔ Press Enter

Load Defaults

Use the Load Defaults menu to restore the default Power Control settings of the country to which the inverter is set, according to the settings detailed below. The only parameter that is *not* reset when using the Load Defaults option is Active Power Conf. ➔ Power Limit.

Power Control Hierarchy

Reactive Power Control

The following describe reactive power control conditions:

- If RRCR is disabled, and "Reactive Pwr. Conf ➔ Mode" is not set to RRCR, the RRCR points will be ignored.
- If RRCR is enabled, and "Reactive Pwr. Conf ➔ Mode" is set to RRCR, the RRCR points will control active power and reactive power.
- If RRCR is enabled, and "Reactive Pwr. Conf ➔ Mode" is not set to RRCR, the RRCR points will control only active power, and reactive power will be controlled by the selected mode.

Active Power Control

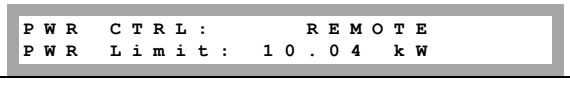
The following modes can control the active output power of the inverter:

- RRCR
- Power Limit <%>
- Current Limit <A>
- Wakeup Gradient
- P(f)
- P(V)

If several control modes are active, the output power of the inverter will be the minimum power. For example, if an RRCR point is configured to "Pwr Reduce=60%" and "Active Power Conf. ➔ Power Limit=70%", the output power will be limited to 60% of Pnom.

The Power Control Status Window

Short-press the external LCD button at the bottom of the inverter until the following screen appears:



- **PWR CTRL**: The power control status:
  - **REMOTE** - Communication with the smart energy manager is confirmed/validated or the inverter power is controlled by an RRCR device.
  - **LOCAL** - The power is controlled locally (e.g. by a fixed limit), or this inverter limits the PV power production to its relative portion of the feed-in power limit, as a result of disconnected communication with the smart energy manager. If this status appears, check the communication to the smart energy manager or the communication to the meter.
- **PWR Limit**: The inverter maximum output power set by the smart energy manager
- **Cos Phi**: The ratio between active to reactive power
- **Power Prod**: The power produced by the inverter

Appendix A – Q Configuration

If the utility requires Q(U) control of the inverter, it will typically provide a linear graph including Umin, Umax, Q(Umin) and Q(Umax) values.

If the utility requires Q(U)+Q(P) control of the inverter, it will typically provide a linear Q(U) graph for P=0 and for P=Pnom.

NOTE:
Q controls are also for 1ph with Digital J.

To translate this graph into values to be configured in the inverter, follow the definitions and instructions below; **Bolded face Q** and **U** are the values that should be set in the inverter:

- $Q_{max} = 0.6 * S_{max}$

  NOTE:
  $Q_{max} = sin\varphi * S_{max} = \sin(\cos^{-1}\frac{P}{S}) * S_{max}$; optimally CosPhi is set to a min/max value of -0.8/0.8 and therefore $\sin(\cos^{-1} 0.8) = 0.6$

- $\boldsymbol{U}_{min} = {}^{U_{min}}/_{U_{nom}}$; $\boldsymbol{U}_{max} = {}^{U_{max}}/_{U_{nom}}$ (between 0 and 200)

- $\boldsymbol{Q}(\boldsymbol{U}_{min}) = -{}^{Q(U_{min})}/_{Q_{nom}}$; $\boldsymbol{Q}(\boldsymbol{U}_{max}) = -{}^{Q(U_{max})}/_{Q_{nom}}$

  NOTE:
  SolarEdge inverters use the convention of inductive power being positive and capacitive power being negative; since most graphs are supplied with the opposite convention, i.e. with Q decreasing as U increases, the minus sign was inserted into the above definitions. When supplied with a graph where Q increases as U increases, ignore the minus sign.

- Set the 6 points that create the linear Q(U) graph to the following:

P0	**U**min	**Q**(**U**min)
P1	**U**min	**Q**(**U**min)
P2	**U**min	**Q**(**U**min)
P3	**U**max	**Q**(**U**max)
P4	**U**max	**Q**(**U**max)
P5	**U**max	**Q**(**U**max)

  NOTE:
  If the graph comprizes several linear sections, use points 1-4 for the Q(U) values of the break points in the graph.

  NOTE:
  Do not enter identical $Q(U_{min})$ or $Q(U_{max})$ values for different U points.

- $dQ = -[Q(U, P = P_{nom}) - Q(U, P = 0)]$

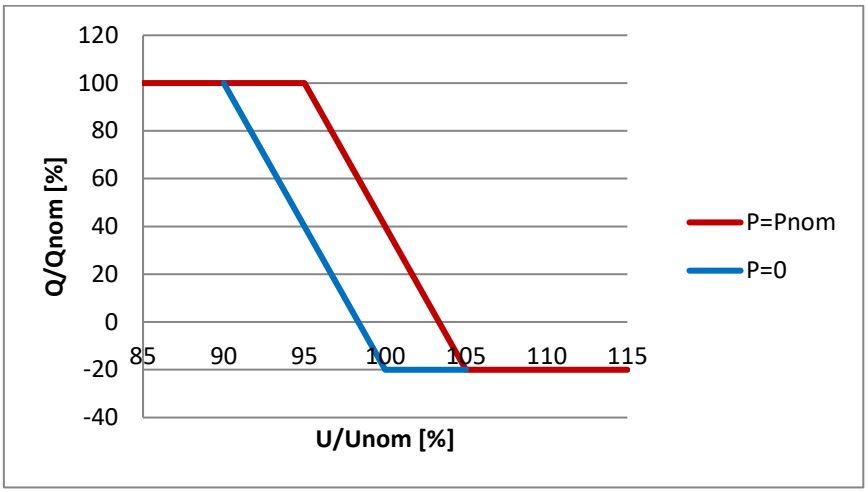
See above note regarding the minus sign.

- Set the 6 points that create the linear Q(P) graph to the following:

P0	0	0
P1	0	0
P2	0	0
P3	100	dQ/Qmax
P4	100	dQ/Qmax
P5	100	dQ/Qmax

Example

The following Q(U,P) graph has been provided by the utility:



The inverter being configured is SE10k, which has a maximum AC power of 10kVA. Following the above steps result in the following values:

- $Q_{max} = 0.6 * 10 = 6kVAR$
- $\boldsymbol{U}_{min} = 90\%$; $\boldsymbol{U}_{max} = 100\%$
  [if U is provided in Volts, divide by Unom to get the percentage value]
- $\boldsymbol{Q}(\boldsymbol{U}_{min}) = -100\%$; $\boldsymbol{Q}(\boldsymbol{U}_{max}) = 20\%$
  [if Q is provided in kVAR, divide by Qnom to obtain the percentage value]
- Set the 6 points that create the Q(U) graph to the following:

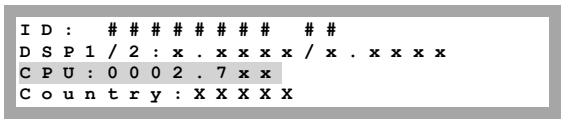
P0	90	-100
P1	90	-100
P2	90	-100
P3	100	20
P4	100	20
P5	100	20

- $dQ = -[40 - (-20)] = -60\%$
  In this case dQ is already normalized by Qmax. Therefore, the 6 points that create the Q(P) graph should be the following:

P0	0	0
P1	0	0
P2	0	0
P3	100	-60
P4	100	-60
P5	100	-60

Appendix B – How to Identify the Inverter's CPU Version

Once the inverter is connected to the AC grid, the CPU version can be verified by pressing the inverter LCD button several times until the ID Status window appears:



Most inverters with previous CPU versions can be upgraded to the new version:

- All three phase inverters can be upgraded
- All single phase inverters with DSP2 version 1.027 and above can be upgraded.

For upgrade files please contact support@solaredge.com.

For upgrade instructions, refer to the following document:
http://www.solaredge.com/sites/default/files/application-note-upgrading-solaredge-inverter-fw.pdf.

Appendix C – CosPhi Calculation

CosPhi (cos Ø) is a measurement used in *Power Factor* computing, representing the ratio of the real power flowing to the load divided by the apparent power in the circuit, and whose value ranges between -1 and +1. Phi (Ø) represents the angular measurement between the real power and the apparent power vectors, in which:

- P = active power, measured in kW, and is computed as the expression: cos Ø
- Q = reactive power, measured in VAr (volt-ampere reactive)
- S = apparent power, measured in VA (volt amperes)