

Commercial PV Design Guide for India using the Enphase IQ Microinverter System

The Enphase IQ Microinverter system is easy to install and provides a wide range of new installation options to solar professionals. It is the ideal product for single-phase and three-phase applications. New components available as part of this system provide additional options for reducing balance of system (BOS) costs and installation complexity. This planning guide introduces solar installation professionals to the new components, provides guidance on component selection, and gives tips for various system design and installation scenarios.

The Enphase IQ Microinverter System includes the following:

- Enphase IQ Series microinverters: IQ 7+ and IQ 7X
- Enphase Envoy-S
- Enphase Q Cable and accessories
- Enphase Enlighten and apps



Figure 1: IQ Microinverter



Table of Contents

Best Practices Summary	6
Array Design	8
Information Required for Array Design	8
Site Example	8
Structural Array Design	8
Information Required for Structural Design	8
Structural Design Options and Considerations	9
Design Example	10
Electrical Array Layout	11
Information Required for Electrical Design	11
Electrical Array Design Options and Considerations	11
Solar Design Software	16
AC Circuit Design	17
Voltage Rise Calculations	17
AC Distribution Box (PV load center) Design and Location	17
Key Components of ACDB	17
Location of AC Distribution Board	17
Multiple Switchboards	18
Power Line Communications	19
Envoy-S	19
Design for Reliable PLC	20
Multiple Envoy on Single Site	20
When to Use Multiple Envoys	20
Design Consideration for Multiple Envoys	20
Power Line Filters	21
Design Considerations for Power Line Filters	21
Networking	22
Enlighten Monitoring	22
Power Export Limit	23
Design Considerations for Power Export Limit or Zero Export	23
Design Example for Power Export Limit	23
Appendix A: Enphase Frame Mount Microinverters	24
Appendix B: Calculating AC Line Voltage Rise for IQ-Series Microinverters with Q Cable	25
VRise Calculator Tool	25
Appendix C: Lightning and Surge Suppression in Commercial Systems	26
Lightning Protection	26
Surge Suppression	26
Enphase Recommended Device	26
Appendix D: Phase Loss Protection	27
Phase Loss Scenarios	27
Phase Loss Hardware Solution	27

Third Party Solution27
Appendix E: Internet Speed, Data Calculations, and Illustrative Example29
Appendix F: Design Example of 100kW Rooftop PV System30
Location Examples of AC Distribution Board, PV Array, and Envoy30
Design Example: Single Line Diagrams (SLD) for 100kW System30

List of Figures

Figure 1: IQ Microinverter	1
Figure 2: Enphase India 110kW Site Bengaluru	8
Figure 3: Frame Mount Bracket	9
Figure 4: Rail Mount Bracket	9
Figure 5: Non-Optimized Site Layout.....	10
Figure 6: Optimized Site Layout.....	10
Figure 7: Three Phase Q Cable Phase Changes	13
Figure 8: Cable Clip	14
Figure 9: Female Sealing Caps.....	14
Figure 10: Male Sealing Caps.....	14
Figure 11: Q Terminator	14
Figure 12: End Feeding AC Branch Circuit.....	15
Figure 13: Center Fed AC Branch Circuit	16
Figure 14: AC Distribution Board	18
Figure 15: Envoy-S Terminal Wiring Diagram.....	19
Figure 16: LC Filter and LC Filter Schematic.....	21
Figure 17: LC Filter Dimensions	22
Figure 18: Design Example Power Export Limit	23
Figure 19: Frame Mount Microinverter Bracket	24
Figure 20: Phase Loss Detector	27
Figure 21: Single Line Diagram Phase Loss Protection	28
Figure 22: Design Examples: 100kW System: ACDB, PV Arrays, Envoy-S.....	30
Figure 23: Typical SLD for 100kW Site	31

List of Tables

<i>Table 1: PV Module Compatibility</i>	11
<i>Table 2: Maximum IQ Microinverters per AC Branch Circuit</i>	12
<i>Table 3: Single Phase Q Cable Specifications</i>	12
<i>Table 4: Single Phase Q Cable Types and Ordering Options</i>	12
<i>Table 5: Three Phase Q Cable Specifications</i>	13
<i>Table 6: Three Phase Q Cable Types and Ordering Options</i>	13
<i>Table 7: Q cable Color Codes with Reference to Indian Cable Color Codes in Brackets</i>	13
<i>Table 8: Field Wireable Connectors</i>	14

Best Practices Summary

Enphase System		Best Practices
Array Design	<u>Structural Design</u>	<ul style="list-style-type: none"> Keep enough spacing between module strings for accessibility. Keep modules out of shading zones. Ensure selected PV module junction boxes and/or flying leads are compatible with chosen mounting position of microinverter. Mount the microinverter bracket side up and under the PV module, to protect them from rain and sun.
	<u>Electrical Design</u>	<ul style="list-style-type: none"> Ensure module compatibility with chosen microinverter: module compatibility. Maximum numbers of microinverters per AC branch circuit should be as per Table 2 Each AC branch circuit must be protected with 20A over-current protection device. Install supports (ET-CLIP-100) for Q Cable and raw Q Cable at every 30cm intervals or less. Minimize subbranch lengths to minimize losses in the Q Cable. The total percentage of voltage rise in the AC wiring must be less than 2%, with (an inclusive) less than 1% voltage rise in the Q Cable. Center-feed the branch circuit to minimize voltage rise in a fully populated branch. Limit the total wiring length to 50m between the farthest connected microinverter and AC distribution board. Take care to understand the Q Cable color codes before applying power to equipment. Incorrect terminations can cause damage. Refer Table 7 for Q Cable color codes. Unused Q Connectors must be sealed with a watertight sealing cap. Install a Q Terminator on any cut end of Q Cable that is not terminated with a Field Wireable Q Connector.
	<u>Simulation Software</u>	<ul style="list-style-type: none"> A range of design tools are available to simplify Enphase Commercial design projects like PVSYST, Helioscope etc. PVSYST simulation guidelines for modeling Enphase microinverters is highlighted along with various simulation input parameters.
AC Circuit Design	<u>Voltage Rise and Phase Coupler</u>	<ul style="list-style-type: none"> Improper wire size can result in nuisance tripping due to ACVOOR condition (AC Voltage Out of Range), so the total percentage of voltage rise in AC wiring must be less than 2%. Enphase recommends use of phase coupler required for PLC in multiphase applications.
	<u>AC Distribution Box</u>	<ul style="list-style-type: none"> AC distribution board should be accessible for installation and service. An AC distribution board should be positioned on the rooftop to enable the shortest possible AC cabling run to all microinverters on the branch circuit You must protect your system with lightning and surge suppression devices: UC 275V AC Type I+II SPDs recommended at Main incomer panel of the existing main interconnection panel for residential and commercial system installations. If Type I SPDs are already installed at main incomer electrical panels, then type II SPDs are suitable to handle induced surges.

Power Line Communication	<u>Envoy</u>	<ul style="list-style-type: none"> • AC distribution board should be accessible for installation and service • Do not exceed ~400 IQ microinverters per Envoy. Consult Enphase if this limit needs to be exceeded. • Install the Envoy as close as possible to the microinverters. Consult Enphase if you need to exceed 50 meters conductor length between the Envoy and last microinverter of the circuit • Avoid electrical noise from competing devices or loads by installing Envoy-S Metered on a dedicated AC circuit • For three-phase connections, a phase coupler is required to couple the PLC communication across all phases
	<u>Multiple Envoys</u>	<ul style="list-style-type: none"> • Multiple Envoys can be used only if there are no requirements of zero power export limit on the site and the microinverter count exceeds ~400, or you can use multiple Envoys to create a single system across multiple locations. • For sites with multiple Envoys, the conductors and conduits of each communication domain must be kept physically separated from the conductors and wiring of other communications domains by at least 30 cm.
	<u>Line Filters</u>	<ul style="list-style-type: none"> • Always install a line filter to reduce or eliminate interference on the supply to the AC distribution board.
Networking	<u>Enlighten Monitoring</u>	<ul style="list-style-type: none"> • To enable remote monitoring, the Envoy-S Metered requires Internet access. Provide access this through a standard router or modem as the Internet access point. • Refer to Appendix E for internet speed requirement for each site. • For a commercial installation, Enphase recommends using a direct Ethernet LAN cable connected between the Envoy-S Metered Ethernet port and the Internet access point.
Power Export Limit	<u>Power Export Limit</u>	<ul style="list-style-type: none"> • Export control for a site is managed by a single Envoy-S Metered, as Envoys do not interconnect with other Envoys. • One Envoy-S Metered directly controls export for the associated array or site. • Power Export Limit is recommended for use where the system size is a maximum of 50kW or ~200 microinverters connected to one Envoy. • Install the Envoy as close as possible to microinverters. Do not exceed 50-meter distance between Envoy and the farthest microinverter • Install a line filter to reduce or eliminate interference on the supply to the AC distribution board • Production and consumption CTs must be directly installed into the Envoy-S Metered to enable export control. • CTs must be hard wired to the Envoy-S Metered. The maximum length is 150 meters for a twisted pair cable up to 2.5 sq.mm cross section area.

Array Design

Array design is the physical layout of solar modules and associated electrical cabling. Array design with Enphase allows for flexibility. Because every Enphase Microinverter connected to a solar module forms an array, you can consider any array configuration, module orientation, azimuth, and tilt angle.

The following sections recommend designing the project first for structural design and then for electrical layout.

Information Required for Array Design

- Solar module specifications. Confirm using the Enphase [Module Compatibility](#) calculator
- Available installation area of the proposed location (including shading, pitch, orientation, roof material/type, and access)
- Total number of modules/microinverters to be installed
- Site electrical configuration and layout

Site Example



Figure 2: Enphase India 110kW Site | Bengaluru

Structural Array Design

Structural design is the physical location, orientation, pitch, azimuth of the solar modules and microinverters installed across a site. Every Enphase system installation is modular and can be scaled to suit an installation site. Consider each module separately to optimize your structural design.

Information Required for Structural Design

- Structural mounting integrity
- Site shade paths
- Load bearing capacity of the terrace, rooftop or the structure on which the PV system is mounted
- Typical and maximum wind loads at that location, also factoring the height of the installation
- Site access (access to arrays for maintenance, etc.)

Structural Design Options and Considerations

- The number of solar microinverters is determined by the size of project, available installation area, and locations of arrays.
- Ensure the selected PV module junction box(es) and flying leads are compatible for the chosen mounting position of the microinverter.
- For a portrait mounted structure, locate mounting points for each microinverter within one meter of the solar module junction box to which it is connected. For landscape design, the mounting points should be decided based on length of modules.
- Mount the microinverter bracket side up (as shown figure 5) and under the PV module, protecting them from rain and sun. Allow a minimum of 1.9 cm between the roof and the microinverter. Also allow 1.3 cm between the back of the PV module and the top of the microinverter
- Ensure microinverters are oriented in the correct direction with the correct side facing the solar PV module (bracket side up).
- Maintain correct clearances directly above and below the microinverters. [Refer to relevant microinverter installation guide.](#)
- Consider attachment options for mounting microinverters to solar module framing systems. Solar framing suppliers often have microinverter mounts available.
- Consider using Enphase Microinverter Frame Mounts to support frameless mounting solutions (refer to Figure 4). A frame attach solution makes installation (mounting) easier on the panel itself. When using the Enphase Frame Mount, support the Q Cable to keep it off the roof by attaching it to the module frames using module edge wire clips that work with PV cable and USE-2 cable. Refer [Appendix A.](#)

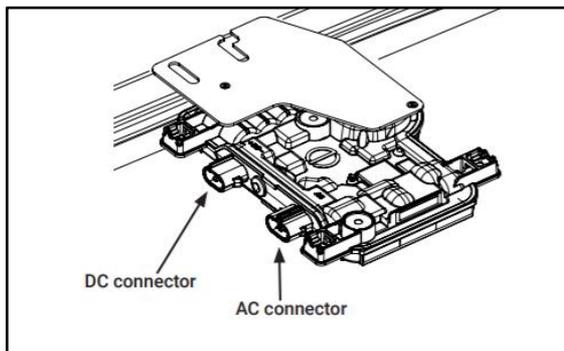


Figure 4: Rail Mount Bracket

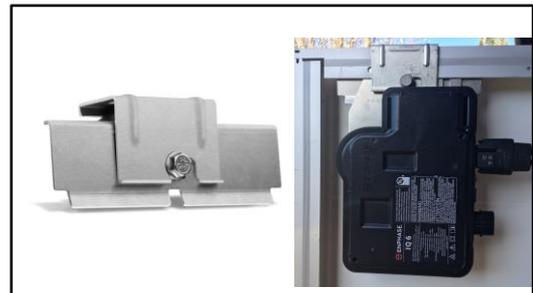


Figure 3: Frame Mount Bracket

Design Example

Layout 1: Non-optimized site layout

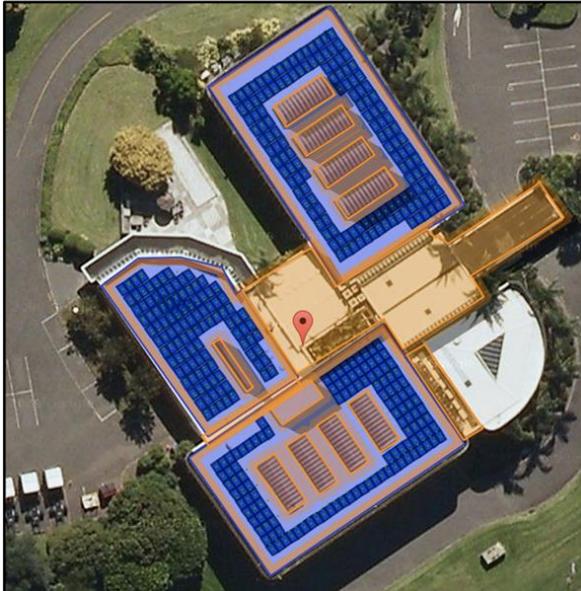


Figure 5: Non-Optimized Site Layout

Non-optimized layout

- No spacing between modules
- No minimum roof edge setbacks
- No allowance for shading path
- Poor site access for maintenance

Layout 2: Optimized site layout

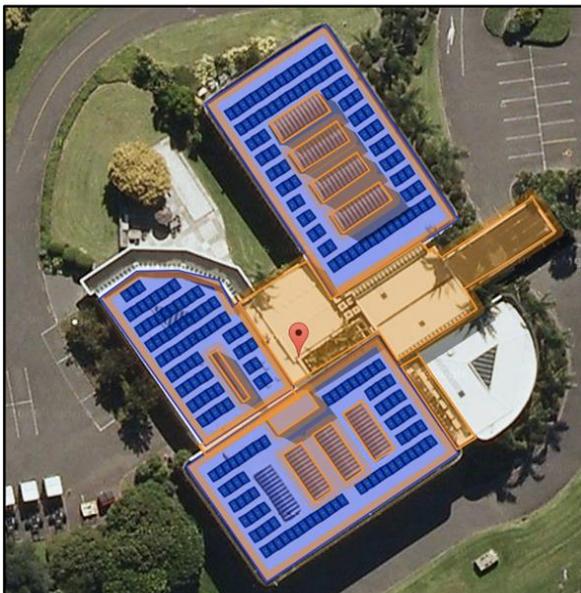


Figure 6: Optimized Site Layout

Optimized layout

- Site access zones
- Setbacks from roof edges
- Shading zones
- Keep out zones for adjacent obstacles

Electrical Array Layout

Electrical Array Design is the specification of the cabling system connecting the microinverters together and connecting back to the AC distribution boards(s). Designing array cabling successfully can simplify a design, increase performance, and reduce costs. Note the following when working your design:

- Design only for 230/415V AC cabling. DC string sizing is not required for Enphase installations.
- AC distribution board(s) are required on multiphase installations. These are used as a marshalling point for the cabling of the microinverter circuits/branches, Envoy-S Metered, solar production CTs, consumption CT connections (where applicable) and line filter.
- Export Limiting requirements may require specific design. Also refer to [Power Export Limiting](#) for more information.

Information Required for Electrical Design

- PV module specifications
- Structural layout of the solar arrays
- Electrical switchboard layout at the site
- Export Limit Requirements for site

Electrical Array Design Options and Considerations

PV Module Compatibility

The Enphase IQ Series Microinverters are electrically compatible with PV modules as listed in the following table. Refer to the Enphase Compatibility Calculator at: [module-compatibility](#) to verify PV module electrical compatibility. To ensure mechanical compatibility, be sure to order the correct connector type for both microinverter and PV module from your distributor.

Microinverter Model	Connector Type	PV Module Cell Count
IQ7+-72-2-INT	MC-4 locking type	Pair with 60 or 72-cell modules
IQ7X-96-2-INT	MC-4 locking type	Pair only with 96-cell modules

Table 1: PV Module Compatibility

Number of Microinverters per Branch Circuit

IQ microinverters connect Line to Neutral, and three phase generation can be achieved by connecting the same number of microinverters between phase pairs (L1-N, L2-N and L3-N).

The IQ 7+ and IQ 7X Microinverters have a 96.5% EN 50530 (EU) efficiency for single-phase applications and are available at peak output power ratings of 295 watts and 320 Watts, respectively. See the IQ product data sheet for complete product specifications at [enphase.com](#)

Plan your AC branch circuits to meet the following limits for maximum number of microinverters per branch when protected with a 20A over-current protection device (OCPD). For three phase installations, use a 4-pole 20A OCPD.

Refer to the following table for maximum IQ microinverters per AC branch circuit.

Maximum* IQ microinverters per AC branch circuit		
	IQ 7+ (1Ø 230 VAC)	IQ 7X (1Ø 230 VAC)
Single Phase	12	12
Three Phase	12 X 3 (36)	12 X 3 (36)

**Low Grid AC voltage scenarios and high AC voltage to be considered*

Table 2: Maximum IQ Microinverters per AC Branch Circuit

Grounding Considerations

The IQ Series Microinverters do not require grounding electrode conductors (GEC) or equipment grounding conductors (EGC). CEA/State Distribution Companies may require you to bond the mounting bracket to the racking. If so, use earthing hardware or star washers. The microinverter itself has a Class II double-insulated rating, which includes ground fault protection (GFP). To support GFP, use only PV modules equipped with DC cables labeled PV Wire or PV Cable.

Microinverter AC Cabling

The IQ Microinverter system uses Q Cable system which is lighter than previous generation cabling systems and easier to manage, thus driving down overall system costs. Q Cable is a purpose-built cable containing two 12 AWG conductors for single phase and four 2.5mm² conductors for three phase applications, with integrated AC connectors. The Q Cable male connectors plug directly into the IQ Microinverters, whose double insulated rating requires no neutral or ground conductors.

Single Phase Q Cable Specifications, Cable Types and Ordering Options

Q CABLE SPECIFICATIONS	
Certification	UL3003 (raw cable), UL 9703 (cable assemblies), DG cable
Flame test rating	FT4
Compliance	RoHS, OIL RES I, CE, UV resistant, combined UL
Conductor type	THHN/THWN-2 dry/wet

Table 3: Single Phase Q Cable Specifications

Following are single-phase Q Cable types and order options as per PV module orientation

Q CABLE TYPES / ORDERING OPTIONS					
Model Number	Max Nominal Voltage	Size	Connector Spacing	PV Module Orientation	Connector Count per Box
Q-12-10-240 (Single Phase)	277 VAC	12 AWG	1.3 m	Portrait	240
Q-12-17-240 (Single Phase)	277 VAC	12 AWG	2.0 m	Landscape (60 Cells)	240
Q-12-20-200 (Single Phase)	277 VAC	12 AWG	2.3 m	Landscape (72 Cells)	200
Q-12-RAW-300	Raw Q Cable (single-phase) 300 meters cable with no connectors				

Table 4: Single Phase Q Cable Types and Ordering Options

Three-Phase Q Cable Specifications, Cable Types, and Ordering Options

Q CABLE SPECIFICATIONS	
Voltage rating	600V (connector rating up to 250 V)
Cable temperature rating	90° C wet/dry
UV exposure rating	EN ISO 492-2
Environmental protection rating	IEC 60529 IP67
Compliance	RoHS, OIL RES I, CE, UV resistant
Cable Insulator Rating	H07BQ-F
Flame Rating	IEC 60332-1-2

Table 5: Three Phase Q Cable Specifications

Following are three-phase Q Cable types and order options as per PV module orientation

CABLE TYPES / ORDERING OPTIONS					
Model Number	Max Nominal Voltage	Ampacity Rating	Connector Spacing	PV Module Orientation	Connector Count per Box
Q-25-10-3P-200 (Three Phase)	250 VAC	25 A	1.3 m	Portrait	200
Q-25-17-3P-160 (Three Phase)	250 VAC	25 A	2.0 m	Landscape (60 Cells)	160
Q-25-20-3P-160 (Three Phase)	250 VAC	25 A	2.3 m	Landscape (72 Cells)	160
Q-25-RAW-3P-300	Raw Q Cable (Three-phase) 300 meters cable with no connectors				

Table 6: Three Phase Q Cable Types and Ordering Options

In the three-phase cable, each connector changes phase within the cabling (auto phase balancing). Each connector supplies 230VAC L-N. See figure 7.

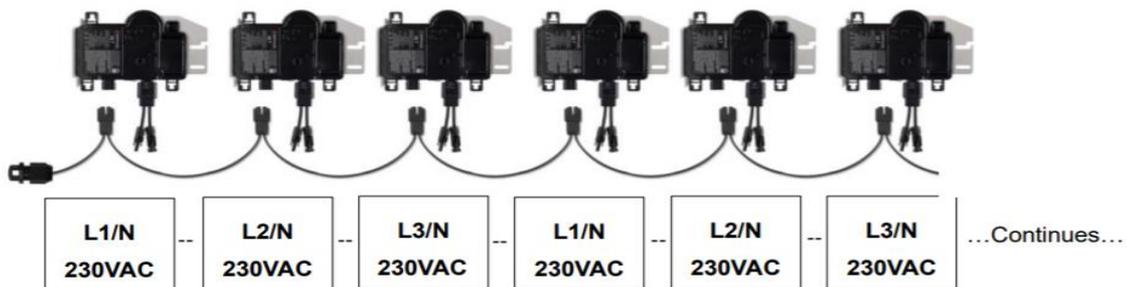


Figure 7: Three Phase Q Cable Phase Changes

NOTE: Take care to understand the Q Cable color codes before applying power to equipment. Incorrect terminations of the cable can present phase-to-phase voltage, rather than phase-to-neutral voltages. Phase-to-phase voltages can be in excess of 415V and cause irreversible damage to the connected microinverters, a situation not covered by warranty. Refer to Table 7 for Q Cable color codes with reference to Indian cable color codes in brackets.

Single-phase service		Three-phase service	
Red – L1 (Red) Black – Neutral (Black)	L1-N: 195.5 to 276 VAC	Brown – L1 (Red), Black – L2 (Yellow) Grey – L3 (Blue), Blue – Neutral (Black)	L1-L2-L3: 360 to 440 VAC L1, L2, L3 – N: 195.5 to 276 VAC

Table 7: Q cable Color Codes with Reference to Indian Cable Color Codes in Brackets

Q Cable Supports

- You must install supports (clip: ET-Clip-100) for the Q Cable and raw Q Cable at 30 cm intervals or less to ensure that the cable does not sag and does not touch the roof.
- Installation requirements for wet-rated cable allow Q Cable and raw Q Cable to be installed in conduits, cable trays, and other raceways.
- Dress any excess cabling in loops so that it does not contact the roof. Do not form loops smaller than 12 cm in diameter.

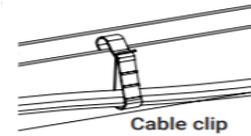


Figure 8: Cable Clip

Field Wireable Q Connectors

You can use the male or female Field Wireable Q Connectors to extend the Q Cable (with connectors) or the raw Q Cable (without connectors). Installers assemble the Field Wireable Q Connectors using a crimp tool and the provided terminals.

When the microinverters are located some distance from the roof top junction box, it may be most economical to use raw Q Cable (without connectors) to run across an array or to run through raceway, conduit and connected using Field Wireable Q connectors.

Description	Model Number	Usage
Field-wireable connector (male)	Q-CONN-10M	Make connections using single-phase cable
Field-wireable connector (male)	Q-CONN-3P-10M	Make connections using three-phase cable
Field-wireable connector (female)	Q-CONN-10F	Make connections from any Q Cable (single-phase) open connector
Field-wireable connector (female)	Q-CONN-3P-10F	Make connections from any Q Cable (three-phase) open connector

Table 8: Field Wireable Connectors

Note:

- **Use only the provided terminals, and do NOT use the Field Wireable Q Connectors with other types of terminals.**
- **Use the Field Wireable Q Connectors only with Enphase Q Cable, and do NOT use other types of cables or conductors**

Sealing Caps

Unused Q Cable connectors must be sealed with a watertight sealing cap (Q-SEAL-10). Refer to Figures 9 and 10.

Use male sealing caps to temporarily seal any exposed IQ Microinverter connectors not connected to the Q Cable to protect against moisture or water damage at the exposed connector during construction.

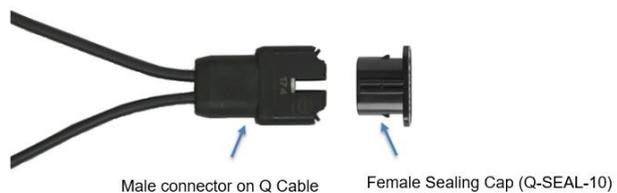


Figure 9: Female Sealing Caps



Figure 10: Male Sealing Caps

Q Terminator

Install a terminator (Single Phase: Q-TERM-10 and Three Phase: Q-TERM-3P-10) on any cut end of Q Cable that is not terminated with a Field Wireable Q Connector.



Figure 11: Q Terminator

Wire Management Clips for Attaching Q Cable to Module Frames for Rail-less and AC Modules

There are a variety of products available for supporting DC module leads off the roof. Most of the wire clips available for PV cable and for USE-2 cable can also be used to attach Q Cable to module frames. Attaching Q Cable to module frames can be useful for rail-less racking systems since there is no rail on which to support the cabling. Also, for AC Module installations, it is often more convenient to clip the Q Cable to the module frame than to clip the Q Cable to the racking system (if available).

Best Practices for Electrical Array Design

- Minimize sub-branch lengths to minimize losses in the Q Cable.
- Locate solar array AC isolating devices as close to the AC distribution board as possible to reduce voltage rise calculations.
- Limit the total wiring length to 50m between the furthest connected microinverter and the Envoy.
- Locate AC the distribution board as close to the array as possible to increase power line communication levels.
- Ensure that cable sizing voltage drop/rise requirements meet Indian standards.
- Regardless of the application, Enphase recommends that the total percentage of voltage rise in the AC wiring be less than 2%, with (an inclusive) less than 1% voltage rise in the Q Cable. Although the Q Cable is optimized for minimal VRise, it is still important to calculate total VRise for the entire system for the array from the last microinverter on each branch of sub-branch to the PCC.
- Center-feed the branch circuit to minimize voltage rise in a fully populated branch. This practice greatly reduces the voltage rise as compared with an end-fed branch. To center-feed a branch, divide the circuit into two sub-branch circuits protected by a single OCPD. Refer to Advantages of Center-Feeding the AC Branch Circuits over End Feeding.

Advantages of Center-Feeding the AC Branch Circuits Over End Feeding

The following diagram represents a 230VAC system with a fully populated end-fed branch circuit of IQ7+ Microinverters with 1.3-meter portrait cable. As the number of microinverters in a branch circuit increase, the voltage at each microinverter rises in a non-linear manner

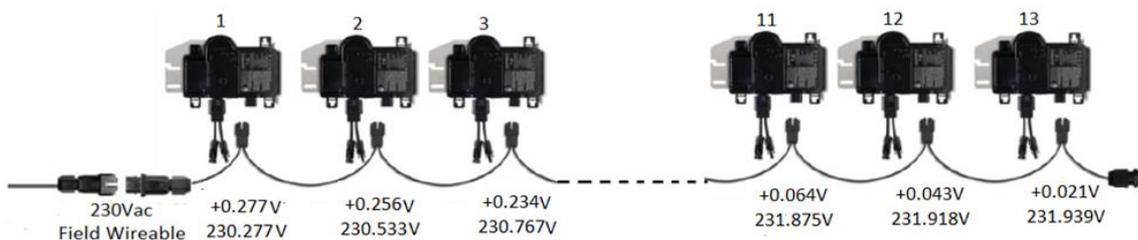


Figure 12: End Feeding AC Branch Circuit

The top row of numbers is the cumulative voltage rise from first microinverter, and the bottom row is the cumulative line-to-line voltage overall. VRise of 0.84% for 13th microinverter with end-fed branch circuit with center feed branch circuit VRise max is 0.25%.

See [Appendix B](#) for detailed calculations of Q Cable VRise and VRise table for Enphase Microinverters.

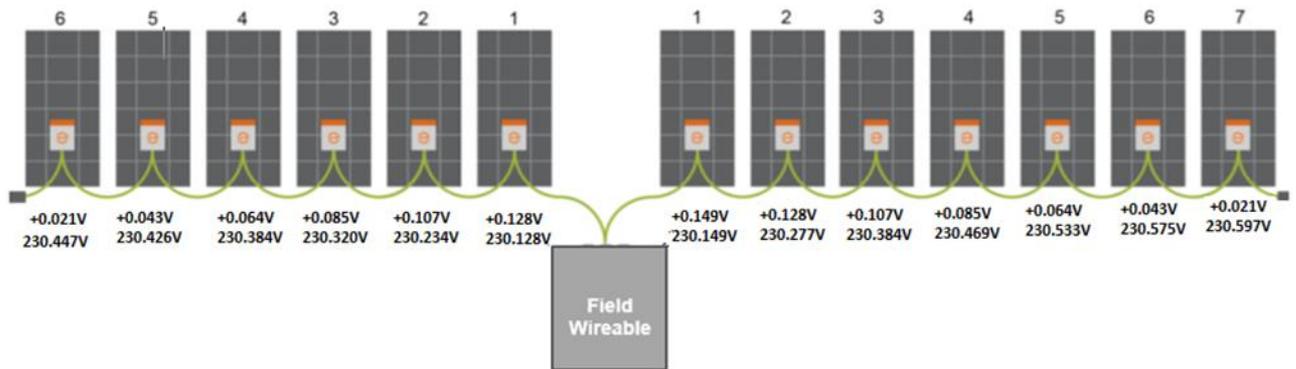


Figure 13: Center Fed AC Branch Circuit

Solar Design Software

A range of design tools are available to simplify your Enphase Commercial design project. Enphase is compatible with Helioscope, PVSyst tools, which should be used to assist in your design. Following is the guide to modeling Enphase microinverter systems with PVsyst.

[Guide to Modeling Enphase Microinverter Systems with PVsyst](#)

AC Circuit Design

AC circuit design is the specification of electrical cabling and its protection from the main switch of the property to the AC distribution box (PV load center) This section covers the following topics to assist the system designer to complete the AC circuit design for the site:

- Voltage rise calculations
- PV circuit design
- AC distribution box (PV load center) design and location
- Multiple switchboards

Voltage Rise Calculations

Regardless of the application, Enphase recommends that the total percentage of voltage rise in the AC wiring be less than 2%, with (an inclusive) less than 1% voltage rise in the Q Cable. Although the Q Cable is optimized for minimal VRise, it is still important to calculate total VRise for the entire system for the array from the last microinverter on each branch of sub-branch to the Point of common coupling.

Improper wire size can result in nuisance tripping of the utility-protective functions in the microinverter. Undersized conductors can cause the voltage measured at the microinverter to fall outside of the limits, triggering an ACVOOR condition (AC Voltage Out of Range)

AC Distribution Box (PV load center) Design and Location

An AC distribution box (ACDB) enables dedicated isolation of the microinverter installation and provides a simple installation platform for reliable Envoy-S Metered power line communications. As the examples in this guide indicate, the AC distribution box is installed considering both cable route and distance to the microinverters. You can install the AC distribution box indoors or outdoors depending on the electrical layout across the site.

Key Components of ACDB

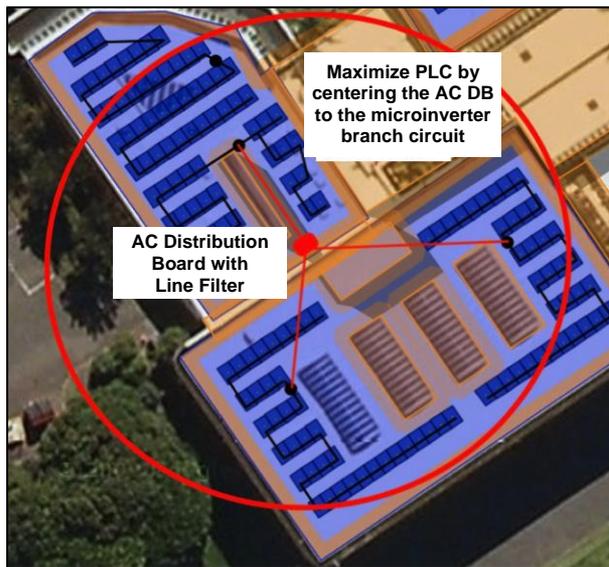
- Envoy-S Metered
- Dedicated Envoy-S Metered circuit
- Current transformers: Production CTs required for solar production circuit
- Phase coupler: Required for multiphase installations for powerline communications.
- Line filter: Always install a line filter to reduce or eliminate interference. See [Power Line Filters](#).
- Surge protection device: Enphase requires that you protect your system with lightning and surge suppression devices. Enphase recommend UC 275V AC Type I+II SPDs at main incomer panel of the existing main interconnection panel for residential and commercial system installations. If already Type I SPDs installed at main incomer electrical panels, then Type II SPDs are suitable to handle induced surges. See [Appendix C](#) on lightning and surge suppression for Enphase systems.
- Switchboard enclosure: The switchboard enclosure may be indoor or outdoor rated, depending on the installation location of the ACDB onsite.

Location of AC Distribution Board

Install an AC distribution board (ACDB) between the solar PV array and the existing distribution boards on site. The ACDB location can be anywhere across the site. However, consider the following when planning the location:

- Distance from the switchboard to which the ACDB is connected. (Note Vrise and PLC considerations.)
- Distance from PV arrays to location of the solar supply main switch
- Conductor sizing of the installed cabling system between the PV array isolator(s) and the ACDB
- Route length distance on the same circuit between the first microinverter and the Envoy-S Metered:
 - No more than 50 meters between farthest microinverter on the branch circuit and the Envoy
- Accessibility for installers and for servicing
- Available space for installation

Design Example AC Distribution Board



- AC distribution board positioned on rooftop to enable shortest possible AC cabling run to all microinverter branch circuit
- AC power line communication benefits from centralized position of the ACDB
- Line filter protects AC power line from electrical noise from external AC loads

Multiple Switchboards

You can use multiple switchboards for interconnection of the solar AC cabling system on a site. This allows for flexibility when running the solar AC cabling across a site. Connect the solar AC cabling to multiple distribution boards. This eliminates the expense to connect solar AC cabling back to a central distribution board and saves cabling and installation costs.

NOTE: Using multiple switchboards and multiple Envoys is conditional on the power export requirements for a site. Multiple switchboards have design limitations and should not be used in case of zero power export limitations.

Power Line Communications

Installing the Envoy-S Metered in a commercial environment has the same considerations as any residential installation. However, there are some additional factors to consider when locating the Envoy-S Metered for a large site.

It is essential to correctly locate and install the Envoy-S Metered on commercial installation. For reliable data reporting and power export limiting control, the power line communications (PLC) from the Envoy-S Metered to the microinverters must have a robust signal.

Topics covered in the following sections:

- Envoy-S
- Designs for reliable PLC
- Multiple Envoys
- Power line filters
- Networking

Envoy-S

When designing a three-phase, commercial scale system, it is critical to install an Envoy. Envoy-S Metered (model ENV-S-WM-230) should be used to communicate with up to ~400 IQ Series microinverters in a three-phase application. The Envoy-S Metered also provides integrated PV production metering (+/- 1.0%) with included two 200A continuous rated split core CTs, one for production and one for consumption metering. You must order additional CTs (CT-200-SPLIT) to separately monitor multiple phases. Check that there is enough space in the switchboard to install CTs. Do not install the CTs in a panel where they exceed 75% of the wiring space of any cross-sectional area within the panel.

Depending on the number of phases you will wire, use a one-, two-, or three-pole (20 A) circuit breaker for the supply wiring and connect Line 1 to L1, Line 2 to L2, Line 3 to L3, and Neutral to N, as required.

Refer to the [Envoy-S Metered Quick Install Guide](#). The following diagram shows how to properly wire the Envoy ENV-S-WM-230 into a three-phase system

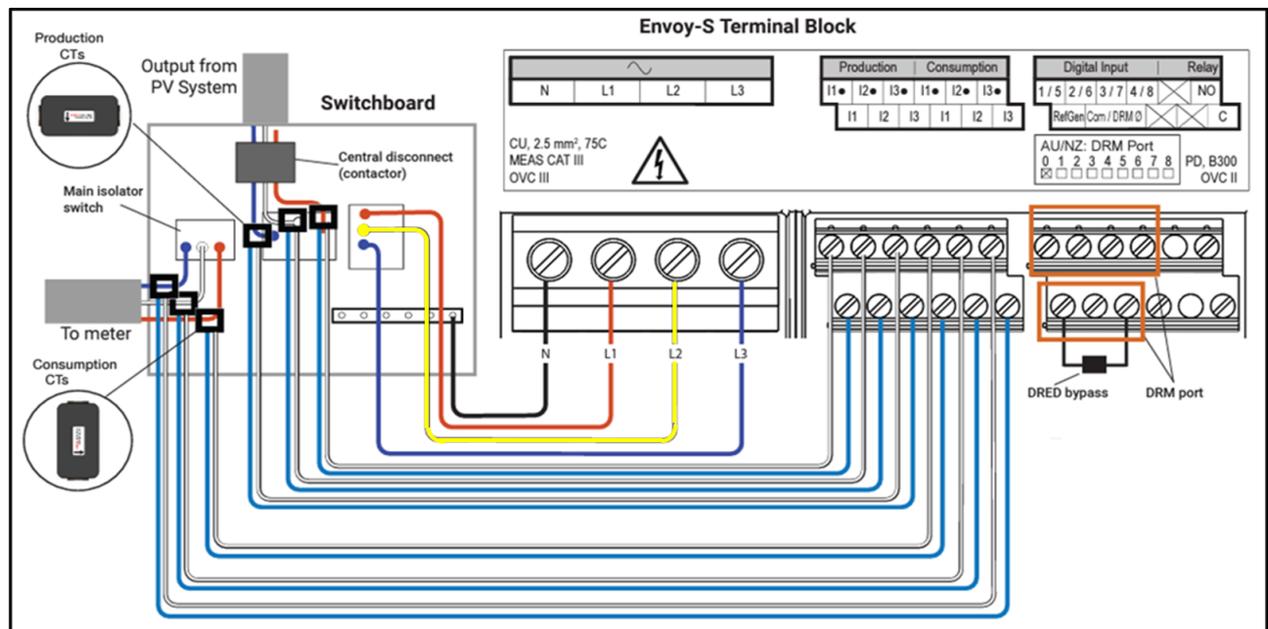


Figure 15: Envoy-S Terminal Wiring Diagram

Design for Reliable PLC

Enphase IQ Microinverter systems use power line communications (PLC) to communicate module level data between the microinverters and the Envoy. Each Envoy-S should be used to communicate with a maximum of ~400 IQ Series microinverters. The PLC signal is at 110kHz in an IQ System. In a commercial-scale system, the Envoy-S is continuously polling the microinverters for their recent power production, temperature, voltage, amperage, and frequency data.

Good communication between devices requires minimal signal interference on the cabling system.

Designs for reliable PLC require the following:

- Do not exceed ~400 IQ microinverters per Envoy. Consult Enphase if this limit needs to be exceeded.
- Install the Envoy as close as possible to the microinverters. Consult Enphase if you need to exceed 50 meters conductor length between the Envoy and the last microinverter in the circuit.
- Avoid electrical noise from competing devices or loads by installing the Envoy-S Metered onto a dedicated AC circuit.
- Install the Envoy-S Metered directly adjacent to the PV array circuits.
- For three-phase connections, a phase coupler is required to couple the PLC communication across all phases.
- Always install a line filter to reduce or eliminate interference on the supply to the ACDB.
- Always locate the Envoy-S Metered in a dedicated ACDB and ensure minimum distance between ACDB and the microinverters.
- Consider using a roof-mounted AC distribution board to avoid the requirement of a rooftop isolator as the ACDB can act as the point of isolation on the roof.

Multiple Envoy on Single Site

Multiple Envoys should be used when there are no limitations/design considerations of zero power export required on site. Multiple Envoys are often used where there are multiple array locations and multiple PV array sub boards installed across array locations on a site. Using multiple Envoys in this installation scenario enables more flexibility in wiring and simplifies the design.

Enphase Microinverter system design can allow multiple Envoys to be installed at a single site. Data from multiple Envoys can be aggregated as a single installation for system monitoring in Enlighten.

When to Use Multiple Envoys

- There are no limitations/design considerations of zero power export required on site
- The Installation exceeds ~400 microinverters
- To create a single system across multiple buildings or array locations, each building with their own switchboard
- To accommodate excessive distance across a solar array
- To split arrays across a site into multiple switchboards

Design Consideration for Multiple Envoys

- The minimum number of microinverters that can report to an Envoy-S Metered is one.
- The maximum number of microinverters that can report to an Envoy-S Metered is ~400.
- An AC distribution board (PV load center) must have one Envoy-S Metered per ACDB.

- CT metering with multiple Envoys is not feasible as Envoys do not communicate with other Envoys. Consumption data from one envoy does not calculate correctly if it is not measuring all the solar production across the entire site. If consumption data is required, each Envoy on site can measure ONLY the consumption load at the distribution board point that the solar PV generation supplies.
- If main service conductors are inaccessible, multiple circuit conductors can be bundled for a single CT. All Line 1 conductors are bundled to go through Line 1 CT, and all line 2 conductors are bundled to go through Line 2 CT for proper bundling. Multiple CTs can be connected in parallel if needed with a maximum of two CT wires per Envoy-S terminal block.
- For all Envoys at a site to communicate well, you must protect the communications domain for each Envoy-S Metered from inter-Envoy cross talk. Achieve protection (PLC attenuation) using line filters.
- For sites with multiple Envoys, the conductors and conduits of each communication domain must be kept physically separated from the conductors and wiring of other communications domains by at least 30cm. Coupling of the signals can occur between the conductors and conduits when run together, especially on long conduit and wire runs.

Power Line Filters

Line filters attenuate/reduce unwanted noise on an AC cabling system. Line filters helps in preventing cross-domain communication between multiple Envoys. Minimize electrical noise near PLC 100KHz frequency. Enphase recommends line filters when:

- The site has a single Envoy-S Metered and export control is required.
- The site has multiple Envoys.
- Where large capacitive and inductive loads are present and provide substantial AC noise.

Design Considerations for Power Line Filters

- Verify that the current rating of the filter meets the current capacity of the total sum of all the microinverters output at the ACDB where the line filter is located, including temperature derating.
- Check specifications to ensure a suitable location for the installation as line filters vary in size and weight.
- Enphase sells the Radius Brand LCF-250-PC line filter (rated to 250A) for commercial applications. Refer to the [data sheet](#) for details
- Four-pole filters are required, with strong attenuation at the PLC frequencies of 100- 150kHz.
- Connect both the Enphase Envoy and Enphase microinverters on the array or load side of the filter and wire the utility feed to the line side of the filter. See the following schematic:

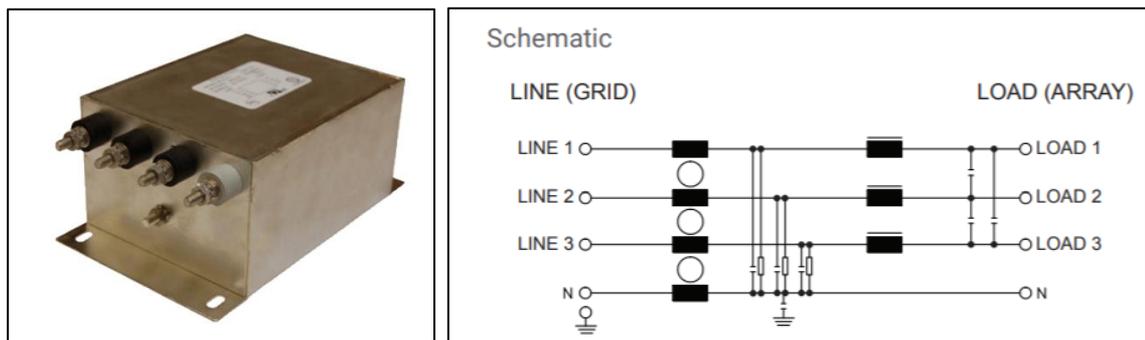


Figure 16: LC Filter and LC Filter Schematic

LCF-250-PC Line Communication Filter Mechanical Dimension / Installation Recommendation

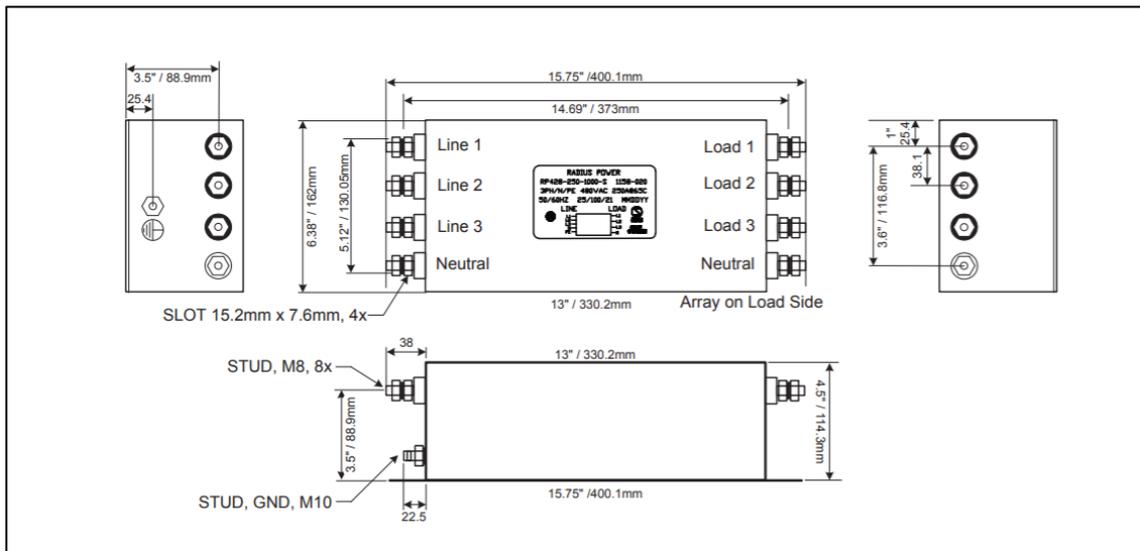


Figure 17: LC Filter Dimensions

Networking

Enlighten Monitoring

- To enable remote monitoring, the Envoy-S Metered requires Internet access. Provide access through a standard router or modem as the Internet access point.
- See [Appendix E](#) for Internet speed and data requirement for each site.
- For a commercial installation, Enphase recommends using a direct Ethernet LAN cable connected between the Envoy-S Metered Ethernet port and Internet access point.
- There are many ways to connect the Envoy-S Metered to the Internet. Refer to the [Getting Started Guide: Envoy-S Metered Internet Connectivity](#) for more details on connecting the Envoy-S Metered into a networking environment.

Power Export Limit

Power Export Limit (PEL) is one of the Enphase's advanced grid functions (AGF) where the Envoy controls PV power output to not exceed a consumption load requirement. This feature causes an IQ Series microinverters to throttle back/curtail any excess energy from solar avoids to exports into grid. The Envoy calculates instantaneous power production and consumption values internally to decide given programmed PEL function parameters how and when to curtail PV.

Design Considerations for Power Export Limit or Zero Export

To enable power export limit following conditions must be met:

- Export control for a site is managed by a single Envoy-S Metered, as Envoys do not interconnect with other Envoys. One Envoy-S Metered directly controls export for the associated array or site.
- It is recommended to use power export limit until ~50kW Capacity/~180 microinverters connected to one Envoy.
- Install the Envoy as close as possible to microinverters. It is recommended not to exceed 50-meter distance between Envoy and farthest microinverter.
- Install a line filter to reduce or eliminate interference on the supply to the AC distribution board.
- Production and consumption CTs must be directly installed into the Envoy-S Metered to enable PEL.
- CTs must be hard wired to the Envoy-S Metered. Twisted pair cable up to 2.5 sq.mm cross section area should be used with maximum length of 150-meter.

Refer to the design checklist for installations that require power export limiting: [PEL Design Checklist](#)

Design Example for Power Export Limit

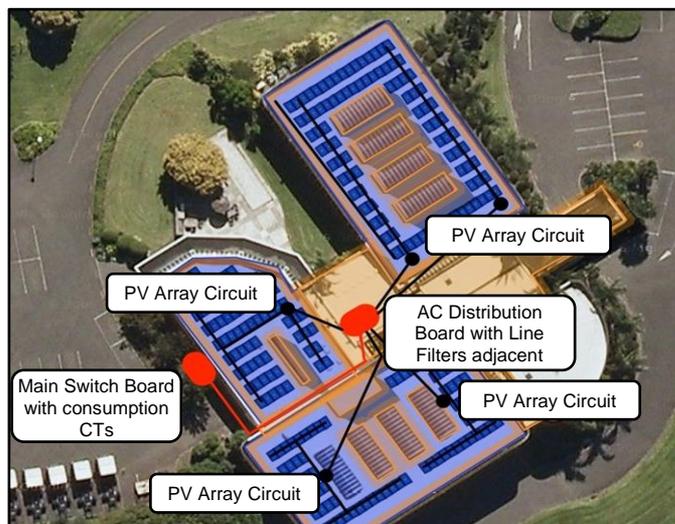


Figure 18: Design Example Power Export Limit

- One Envoy-S Metered is installed in a dedicated AC distribution board
- CTs must be installed to measure solar production and site consumption
- All PV circuits and microinverters are export controlled by one Envoy-S Metered.
- The AC distribution board must be located within 50 meters of all array locations.
- Line filtering should be installed to protect PLC

Appendix A: Enphase Frame Mount Microinverters

The Enphase frame attach solution makes installations quick, easy, and more affordable.

- Enphase Microinverters are compatible with rail-less and ballasted systems:
 - Bolts microinverters directly to the module frame, eliminating design challenges with both residential and commercial systems
 - Comes in two sizes that fit the majority of modules
- Faster Installations:
 - Bolt microinverters to module frames on the ground, then carry the complete module up to the roof for rapid, drop-in installation
 - Simple, two-piece bracket attaches in three easy steps
- Affordable:
 - Requires fewer parts than other frame mount solutions, saving you material costs
 - Reduces labor costs with faster, more efficient installations
- Reliable:
 - The Enphase Frame Mount is made of anodized aluminum for a strong, rust-free bracket
 - Engineered specifically for use with Enphase microinverters



Figure 19: Frame Mount Microinverter Bracket

Appendix B: Calculating AC Line Voltage Rise for IQ-Series Microinverters with Q Cable

This appendix presents voltage rise guidelines for dedicated PV branch circuits and methods for calculating the AC line voltage rise when using the Enphase IQ Microinverters™ and the Enphase Q Cable™.

Applying proper voltage rise calculations in your system design helps prevent nuisance voltage out-of-range trip issues due to high line voltage conditions. Less resistance in conductors also results in less power loss, less heat at the terminals, and improves performance of the PV system.

When designing circuits for electrical loads, these calculations are commonly called voltage drop (VDrop). Since PV systems with inverters generate electricity instead of consuming it, voltage rises at the AC terminals of each inverter. Therefore, this brief refers to these calculations as voltage rise (VRise).

Regardless of the application, Enphase recommends that the total percentage of voltage rise in the AC wiring be less than 2%, with (an inclusive) less than 1% voltage rise in the Q Cable. Although the Q Cable is optimized for minimal VRise, it is still important to calculate total VRise for the entire system for the array from the last microinverter on each branch of sub-branch to the PCC.

VRise Calculator Tool

The voltage rise (Vrise) calculator is a design tool to assist in the correct design and sizing when selecting cabling wire sizes for a commercial site. Please find below link to VRise calculator tool:

[Enphase VRise Calculator](#)

Appendix C: Lightning and Surge Suppression in Commercial Systems

Although not common, you must consider the possibility of lightning strikes. Also, surges can occur anywhere on the electrical grid. Enphase microinverters, like all electrical components, can be damaged by lightning strikes or voltage surges from the electrical grid. The guidelines in this section help to minimize any lightning-related issues in your commercial installation.

Enphase suggests that you protect your system with lightning and surge suppression devices.

Enphase Microinverters have integral surge protection. However, if the surge has enough energy, the protection built into the microinverter can be exceeded and the equipment may be damaged.

There are a wide range of devices available from equipment manufacturers with a range of warranties. Enphase does not warrant or guarantee the performance of any of these products. In addition to having some level of surge suppression, it is important to have insurance that protects against lightning and electrical surges. Install protective devices per vendor instructions.

Lightning Protection

A lightning arrester is a device that diverts a portion of the energy from a lightning strike to earth, using a site grounding system. More advanced lightning protection systems also dissipates electrical charges from the building, lowering the chance of experiencing a lightning strike.

A lightning strike does not actually need to strike the equipment or building where a PV system is installed to cause damage. A strike on or near to the electric grid can induce voltage spikes that can damage equipment

Surge Suppression

Surge suppression devices protect site loads from lightning and electrical surges and can be installed in parallel or in-line. A panel level surge suppressor interrupts the circuit and isolates equipment from the source of the surge.

A whole-house surge suppression system generally consists of in-line devices and surge suppressors. These systems are the most robust, but can be expensive and cost prohibitive

Enphase Recommended Device

Use UC 275V AC type I+II SPDs at the main incomer panel of the existing main interconnection panel for residential and commercial system installations. If you have already installed Type I SPDs at the main incomer electrical panels, you can add type II SPDs to handle induced surges.

Appendix D: Phase Loss Protection

For project success, you must consider phase balance when designing commercial PV systems using IQ microinverters that interconnect to a three-phase service. This appendix provides details and recommends best practices for designing systems compatible with phase imbalance, phase loss, and neutral sense guidelines that may be required by some states' electricity distribution companies.

Phase Loss Scenarios

The Enphase IQ Series Microinverters connect to the three available phases of a three-phase grid supply. Since the Q Cable is a two-wire cable and branch circuits are connected to two-pole circuit breakers, system design should consider balancing out the number of microinverters across all three phases in the panel board.

If a grid failure occurs only on one phase, then one third of the microinverters connected to the other two phases will be unable to detect the failure. These microinverters may continue to export power on those phases, contributing to a phase imbalance present on the local grid node.

Phase Loss Hardware Solution

Enphase recommends the use of a phase loss relay system when needed. A phase loss relay system is not required for the IQ microinverter to function but may be required by some state electricity distribution companies

A phase loss relay system consists of:

- A phase loss relay that monitors the three-line voltages and detects loss of phase
- A contactor that opens all three lines of the circuit to disrupt the power flow

Ideally, a phase loss relay is mounted directly onto the contactor and forms one unit. If it is not possible to procure a combined unit, the contactor must be hardwired to the phase loss relay, and the phase loss relay must be powered by a dedicated breaker connected to grid power on the grid side of the system.

Install the combined relay-contactor system on the PV system side of the interconnection point and on the grid side of the power line filter. For systems with no power line filter, install the relay-contactor system on the grid side of the main AC distribution board, as shown in the following diagram.

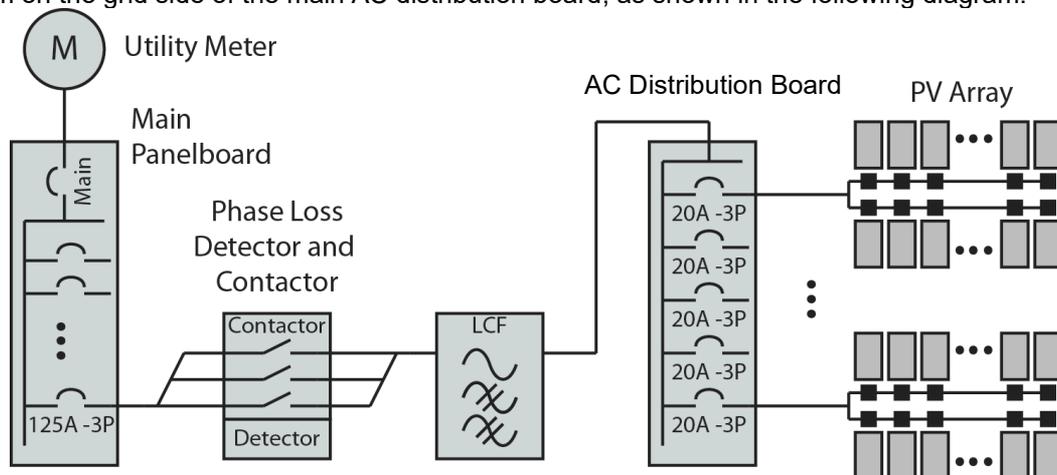


Figure 20: Phase Loss Detector

Third Party Solution

A third-party panel is available to address this phase loss problem. The phase failure relay coil of voltage rating 230 VAC detects any imbalance or phase loss in any of the three phases and disconnects all the three phase lines, disallowing any power flow back to the grid.

The schematic drawing, SLD of the panel and the other details of the panel is shown:

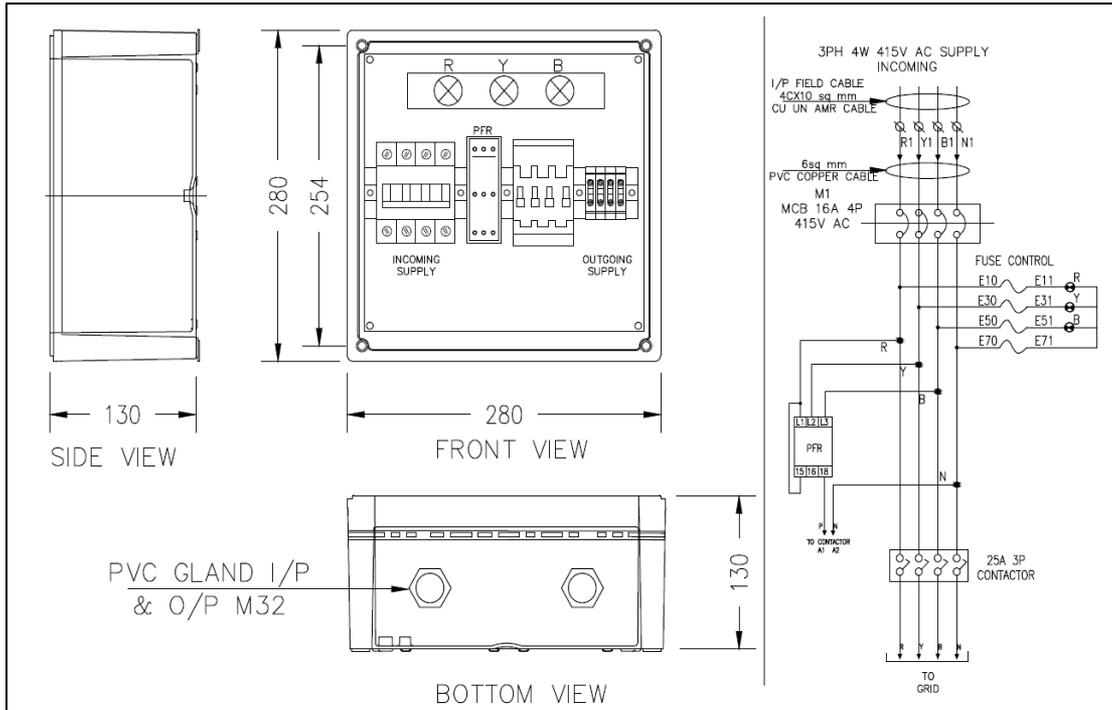


Figure 21: Single Line Diagram Phase Loss Protection

Appendix E: Internet Speed, Data Calculations, and Illustrative Example

Upload Internet Speed Calculator		
Description	Details	
Every 5 mins. Each microinverter performance report size:	300	Byte
Required upload Internet speed	300	Byte / Sec
Required upload Internet speed (1Byte = 8 Bits)	2400	Bits / Sec
Required upload Internet speed for one microinverter	0.0024	Mbps

Internet Speed Calculator Illustration			
Site Name	No of Microinverters	Upload Speed	Unit
Site 1	300	0.72	Mbps
Site 2	250	0.60	Mbps
Site 3	270	0.65	Mbps
Site 4	300	0.72	Mbps
Actual calculated value		2.69	Mbps
Exact requirement with 20% additional		3.3	Mbps

Internet Total Data Requirement		
Description	Details	
Every 5 mins. Each microinverter performance report size:	300	Byte
Required upload Internet data for one hour	3600	Byte
Required upload Internet data for one day	86400	Byte
Required upload Internet data for one microinverter per day	0.0000864	GB

Internet Total Data Requirement Calculations Illustration			
Site Name	No of Microinverters	Total GB	Unit
Site 1	300	0.026	Gb
Site 2	250	0.022	Gb
Site 3	270	0.023	Gb
Site 4	300	0.026	Gb
Actual calculated value		0.097	Gb
Exact requirement with additional buffer		0.15	Gb

Use the following Internet speed and data calculations tool for your site. Enter the number of microinverters on site and the tool will provide you with the Internet upload speed required and per day data required for the site: [Internet speed & data calculations tool](#)

Appendix F: Design Example of 100kW Rooftop PV System

Location Examples of AC Distribution Board, PV Array, and Envoy

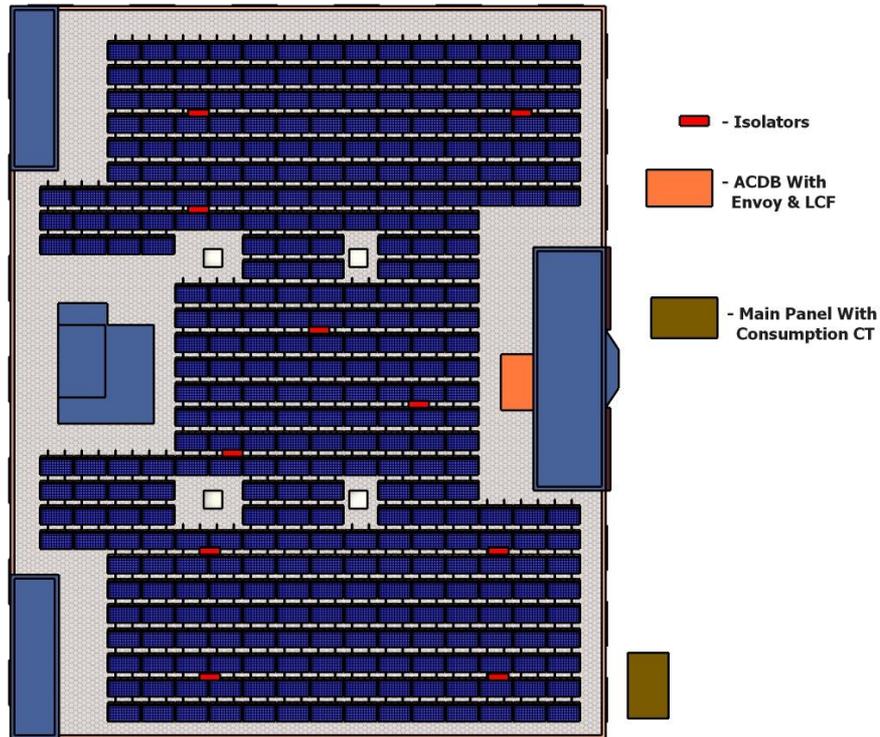


Figure 22: Design Examples: 100kW System: ACDB, PV Arrays, Envoy-S

Design Example: Single Line Diagrams (SLD) for 100kW System

SLDs are often required with a PV generation application. It confirms the interconnection requirements for relevant installation site.

Following is a typical design example of single line diagram for 100kW system:

[Single Line Diagram for 100kW System](#)

