

Commercial PV Using the Enphase M215 Microinverter



Busch Stadium, Home of the St. Louis Cardinals

Contact Information

Enphase Energy Inc.
1420 N. McDowell Blvd.
Petaluma, CA 94954

<http://www.enphase.com>

[Contact us](#) at <http://enphase.com/contactus/> for design support or more information.

Other Information

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Enphase equipment must be installed in accordance with all locally recognized electrical codes, including National Electrical Code (NEC), ANSI/NFPA 70.

User documentation is updated frequently; check the [Enphase Support Center](#) for the latest information.

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Section 1: Enphase Commercial Design Fundamentals

Introduction

The Enphase® Microinverter System™ delivers design flexibility, integrated intelligence, increased energy harvest, and system availability not found in central inverter based system. Deploying the M215 Microinverter system on commercial and utility scale projects is simple and cost effective. Join the thousands of solar integrators and developers who have selected Enphase M215™ Microinverters for large-scale photovoltaic installations.

This design guide details processes for designing commercial PV systems using M215 Microinverters. Follow these guidelines to make your project as trouble free as possible, especially when designing systems larger than 100 kW or systems with more than one Enphase Envoy Communications Gateway™.

This guide also recommends best practices and lists requirements to help minimize costs, maximize performance, and ensure robust microinverter to Envoy communications.

Enphase System Components and Concepts

The following components and concepts are key to understanding commercial design with Enphase.

Activation Process: The process of activating the Enlighten® web-based monitoring software at <https://enlighten.enphaseenergy.com>. Enlighten provides monitoring for up to 1000 microinverters in one activated PV system. If your project contains over 1000 microinverters, then you can activate multiple PV systems in Enlighten for your project.

Array Gun: The Array Gun is a tool that scans microinverter serial numbers for building virtual arrays in Enlighten. The Array Gun is a bar code scanner that synchronizes to a compatible Apple iPhone or iPod. With the Enphase Installer Toolkit App, available for free download in the Apple App Store, you can build the arrays and upload the [array map](#) directly to the Enlighten system page.

Center Feed Method: The center feed method separates an individual branch circuit into two sub-branch circuits on the same over current protection device (OCPD). This is a standard design practice with Enphase Microinverters and lowers overall wiring costs by reducing voltage drop and potentially avoiding the need to upsize distribution wiring. [Calculating AC Line Voltage Drop for M215 Microinverters with Engage Cables](#) on page 22 provides details.

Communication Domain: A group of module and microinverter pairs that all communicate with a common Envoy. When multiple Envoys are required, steps must be taken to prevent cross-talk between the communication domains. To prevent interference between communication domains, the [installation of an Enphase line communications filter or transformer](#) will likely be required. It is also important to physically separate the conduits and wires.

Engage Cable: The Engage Cable is an innovative cabling system used to connect Enphase Microinverters. The Engage Cable is manufactured with a connector for each microinverter. These connectors are placed every 1.025 meters for portrait applications or 1.7 meters for landscape applications. The cable contains #12 THWN-2 conductors and is rated to feed a 20A circuit breaker. The cabling is available for single-phase or three-phase applications and must be ordered for the appropriate application. [Engage Cable Types](#) and the [Engage Cable datasheet](#) provide details.

Enphase Line Communications Filter (LCF): When a project requires more than a single Envoy, install an LCF on every communication domain. An LCF helps prevent cross-talk between Envoy communication domains and provides noise filtration from other site loads. Each LCF contains an Envoy inside the LCF enclosure. Locate the LCF near the communication domain it serves. Using an LCF limits the number of microinverters that can be installed in a communication domain to maintain the 100A continuous output rating. [Designing with Enphase Line Communication Filters](#) and the [Enphase LCF data sheet](#) provide specifications and details about deploying the Enphase LCF.

Envoy Communications Gateway: The Envoy ENV-120 is a system monitoring device that monitors up to 600 Enphase Microinverters. The Envoy uses power lines to communicate with each microinverter. The Envoy also connects to the Internet via a broadband router and other networking components to upload microinverter data into the Enphase Enlighten web-based monitoring software.

Filtration of Communication Domains: When multiple communication domains are tied to a common service panel or off of a single transformer, install an [Enphase LCF](#), a commercially available power line filter, or a transformer between each microinverter subpanel and the main photovoltaic load center.

M215 Microinverter: The M215 Microinverter is 96% efficient and works with 60 cell modules up to 270 watts STC. The M215 is rated for a continuous output of 215 watts. The M215 automatically detects the utility voltage and exports power to either 208 VAC or 240 VAC utility services. Each branch circuit of M215s feeds a 20A circuit breaker. The maximum number of M215s on a fully populated branch circuit is 17 at 240 VAC (single-phase), or 25 at 208 VAC (three-phase).

Main Photovoltaic Load Center: An electrical load center that feeds multiple microinverter subpanels.

Microinverter Subpanel: A microinverter subpanel is an electrical load center dedicated to a single communication domain. The microinverter subpanel contains multiple 20A circuit breakers, each feeding one microinverter output branch circuit.

Power Line Communication: Power line communication (PLC) technology enables signal transmission over the same AC lines used for on-site power distribution. Enphase Microinverters and the Envoy Communication Gateway use power line communication in the 100–150 KHz range to send and receive data.

Power Line Communication Bridges: If the Envoy needs to be located away from the router at a distance where an Ethernet cable is not practical, use power line communication bridges (Ethernet bridges) or purchase a wireless Ethernet bridge. Bridges allow the Envoy to communicate with the broadband router without the need for additional Ethernet cabling.

Power Line Filter: Use power line filters or EMC filters for isolating multiple Envoy communication domains or for filtering electrical noise from site loads.

Separation of Communication Domains: To prevent induction of communication signals between conduit and wire runs, physically separate each communication domain from other communication domains. The conduits and wiring running between each communication domain must be physically separate from the conduits and wiring of all other communication domains. Conduits and wiring on the array side of the filters should be separated by 12 inches.

Startup Procedure: By following the startup procedures detailed in “Section 4: Commissioning” on page 32 of this document, you help prevent cross talk between communication domains. The [startup procedure](#) involves commissioning each communication domain individually. Before commissioning subsequent communication domains, end the device scan of the previous communication domain’s Envoy.

Transformer: A transformer is often required to interconnect commercial photovoltaic projects to the utility grid. [Use transformers to connect Enphase Microinverter systems](#) to 480V and higher utility services, to offset voltage rise over long cable runs, and to lower wire costs for long transmission runs. A transformer is also an excellent filter of electrical noise and communication signals and provides isolation of communication domains. In addition, a transformer generally has adjustable taps that allow for adjustments to the utility voltage.

Figure 1. Commercial Scale Enphase Project

Limitless Scalability

The size of an Enphase system is practically limitless. An Enphase commercial-scale project generally includes a main panel board or PV load center that feeds multiple microinverter subpanels distributed across the system. This scalable design is only limited by the utility grid that feeds the site.

The number of Envoy system monitors needed generally determines the number of microinverter subpanels to install. Since the Envoy is rated to monitor the output of up to 600 microinverters, you can divide your system into sub-systems of 600 microinverters or fewer.

Power each sub-system by a 600A, 208/120V panel board, but 532 M215s would maximize a 400 A panel board. You can install smaller sub-systems, but that may not make sense for larger projects.

Isolating Communication Domains

If you install multiple Envoy's off of a single utility transformer, you will likely need a filter to isolate each Envoy into a separate communication domain. This is particularly true for large-scale projects. Use transformers, LCFs, or aftermarket filters to isolate communication domains.

In a large-scale project, each sub-system generally consists of modules, microinverters, cables, branch circuit breakers, a microinverter subpanel, and a filter. A filter prevents power-line communication signals from one Envoy communication domain from interfering with another Envoy communication domain. The filter also offers the added benefit of eliminating electrical noise from site loads.

With multiple communication domains, the total number of filters can be one less than the total number of communication domains. That is, if all other communication domains have filters, you can build one communication domain without a filter ($n - 1$).

If your system contains fewer than 600 microinverters with a single Envoy on-site (a single communication domain), you do not need a filter to isolate communication domains. A system of 600 microinverters has an AC inverter output rating of 129kW. For systems with fewer than 600 microinverters, the content in this section is likely to not apply.

Refer the following sections and [Do I Need an LCF, Filter, or Transformer](#) to help determine filtering needs for your installation.

Using the Enphase LCF to Isolate Communication Domains

The Enphase LCF is convenient to work with because it provides communication domain filtering. The LCF is an outdoor enclosure with an Envoy inside it. It eliminates the need to install a separate receptacle for the Envoy. The LCF is rated for 100A of continuous microinverter current and must be protected by a 125A circuit breaker or smaller. If installing LCFs, limit each communication domain to 166 M215s at 208V due to the ampacity (ampere capacity) of filter.

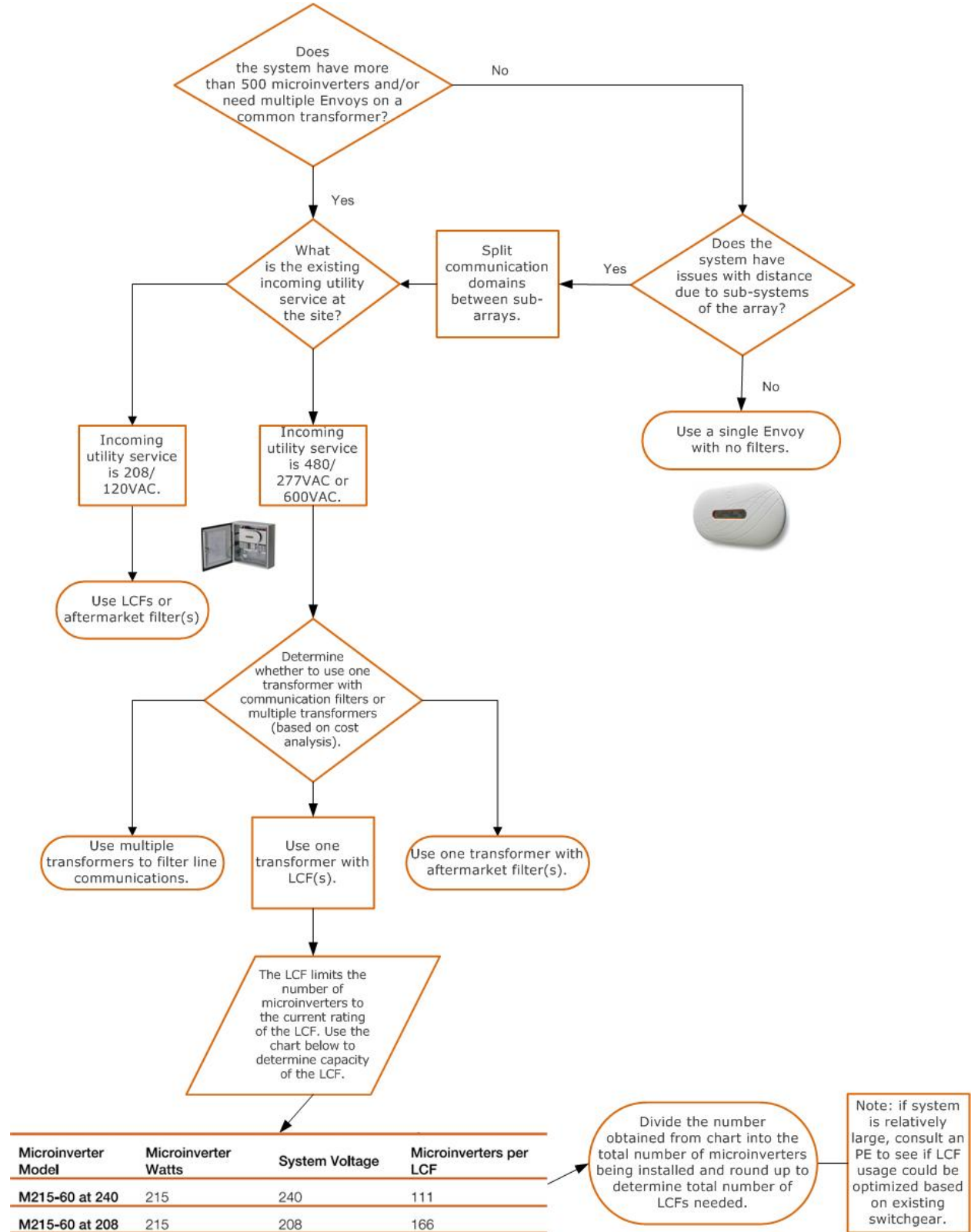
Using a Transformer to Isolate Communication Domains

Transformers also provide excellent filtering between Enphase communication domains. A 480 V, 600 V, or medium voltage interconnection requires a transformer to step the voltage down to 208/120 Wye. If the project does not require transformers, or if a single, central transformer is selected, then you can filter Envoy communication domains with Enphase LCFs or commercially available power line filters.

Using an Aftermarket Filter to Isolate Communication Domains

For some larger systems, it is convenient to install commercially available power line filter products. Power line filters are available in a variety of ampacities and voltage configurations. This variety of ratings available allows maximum flexibility in your design choices.

Do I Need an LCF, a Transformer, or Filter?

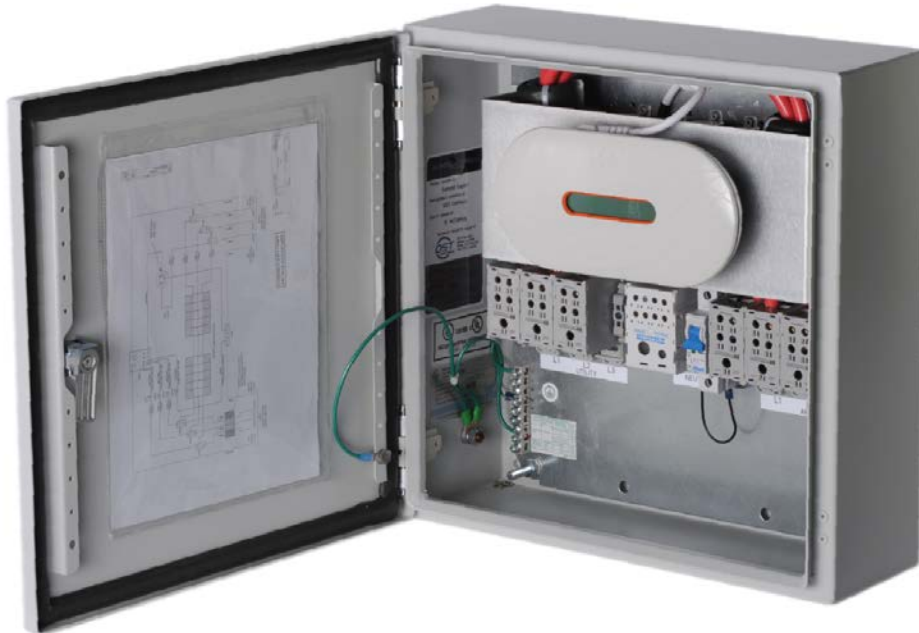


Filtering Methods

The following sections provide additional details on various filtering methodologies:

Designing with Enphase Line Communication Filters

Figure 2. Enphase LCF



To ensure reliable monitoring, locate LCF/Envoy units close to the microinverters. For commercial roof-mounted systems, the microinverter sub-panels and LCFs are generally located on the roof. For ground-mounted systems, the microinverter subpanels and LCFs are generally at or near the communication domain. Provide a network cable to each LCF/Envoy to allow for network communications with the site router. Connect each Envoy independently to an upstream Internet port. This often requires conduits and LAN/Ethernet cables to each LCF.

The LCF has a maximum OCPD rating of 125 Amps. Per NEC 690.8(A)(1), connect up to 100 Amps of continuous inverter output current to the microinverter subpanel filtered by the LCF. The 100 Amp rating limits each communication domain to fewer microinverters than otherwise allowed with an Envoy. Table 1 lists the number of microinverters allowed per LCF.

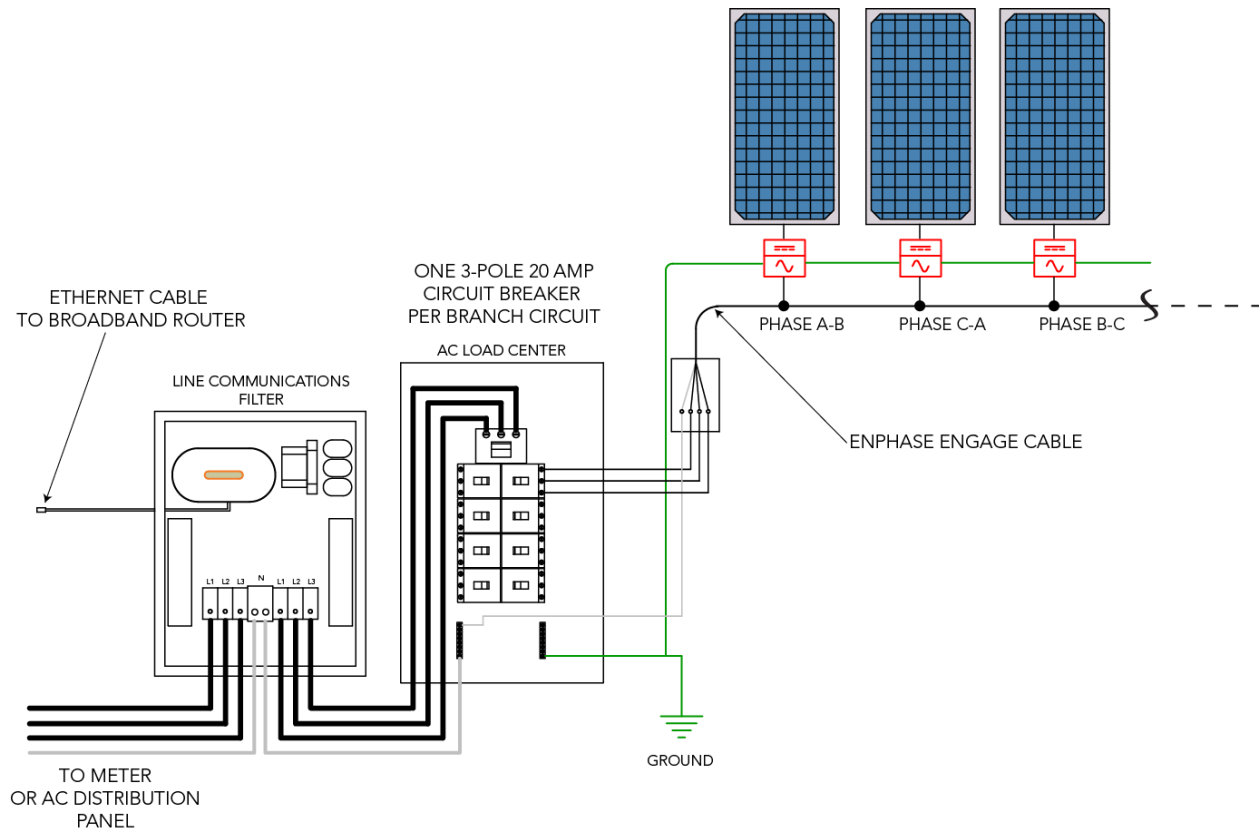
Table 1. Microinverters per Enphase Line Communication Filter

Microinverter model / Service type	Microinverters Supported
M215-60, 208 VAC three-phase, approx 36 kW AC	166
M215-60, 240 VAC single-phase, approx 24 kW AC	111

Single-Line LCF Envoy

The following diagram details a typical installation of a Line Communications Filter with M215 Microinverters in a three-phase application.

Figure 3. Typical LCF Installation with M215s



One end of the LAN/Ethernet cable coming into the LCF enclosure plugs into the Envoy Ethernet port. The other end of that Ethernet cable connects to a broadband router in a network infrastructure, which leads to an Internet connection.

Note that there is no master/slave networking architecture. Each Envoy device connects independently to an upstream Internet port.

Envoys plugged into a switch or router are no different in this context than a computer or laptop plugged into a networking switch or router. They use the same CAT5, 5e, or 6 Ethernet cable that any other computer uses.

Designing with Transformers

While transformers interconnect Enphase Microinverter Systems to any utility power voltage, they also offer some other less obvious benefits.

- For many projects, it is cost effective to distribute the power at the higher utility voltages and then step down the voltage to 208/120V at each sub-system. This practice results in more transformers, but can be cost effective when wire runs are greater than 250 feet.
- Choose transformers with adjustable taps. Use the tap to make minor adjustments when the utility provided voltage is high or when optimizing conductor sizing versus expected voltage rise for the value engineered PV system.

It is common to specify high-efficiency or ultra-high efficiency, general purpose, dry-type transformers for an Enphase Microinverter System. It is not necessary to specify power factor correcting transformers or K-factor transformers.

You will need to specify the transformer kVa size meet the inverter output in kW AC. Some additional deratings, such as an adjustment for power factor (0.95) may apply. Refer to the transformer manufacturer's specifications for transformer sizing.

Most transformers for Enphase systems are specified as delta on the primary side and as 208/120 Wye on the secondary side. The 208/120 Wye configuration is necessary for the operation of microinverters. Even if the utility voltage is Wye, a 480/277 Wye service, for example, it is still best to provide a delta configuration with no neutral to the primary side of the transformer. This configuration works well, lowers wire costs, and is recommended by the manufacturers of transformers for improved performance.

Figure 4. 3-Phase Delta and Wye Wiring

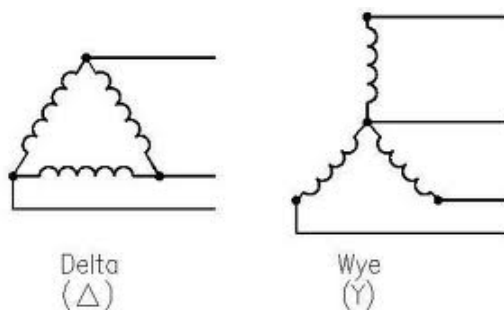


Image from Mike Holt Forums. No date. <http://forums.mikeholt.com/showthread.php?t=128508>.

The following table lists utility voltage values and transformer requirements.

Table 2. Voltage Configurations and Transformer Specifications

Utility Voltage Configurations	Nominal Voltages Between the Lines and Neutral/Ground					
	L1 to L2	L2 to L3	L3 to L1	L1 to N/G	L2 to N/G	L3 to N/G
208/120 Wye	208	208	208	120	120	120
No Transformer would be specified for interconnection						
480/277 Wye	480	480	480	277	277	277
Specify a 480Delta:208/120Wye transformer						
480 Delta	480	480	480	-	-	-
Specify a 480Delta:208/120Wye transformer						
240 Delta	240	240	240	-	-	-
Specify a 240Delta:208/120Wye transformer						
240 High-Leg Delta	240	240	240	120	120	208
Specify a 240Delta:208/120Wye transformer (see Note)						
600/347 Wye	208	208	208	120	120	120
Specify a 600Delta:208/120Wye transformer						

Note: Many utilities allow a small, single-phase system installed on the 120/240V phase of a high-leg delta system. This can imbalance a three-phase transformer and may be problematic for systems larger than 6 kW. It is best practice to consult your utility about acceptable levels of imbalance.

Designing with Aftermarket Power Line Filters

Enphase has [approved a number of aftermarket filters for use](#) with Enphase Microinverter Systems. The approved filters effectively filter noise and communication signals in the 144 kHz range, the transmission frequency of Enphase power line communications.

While aftermarket filters are simple to install, Enphase recommends that you follow these guidelines for installation:

- Wire the filters in-line between the utility and microinverter subpanels, at or near the subpanels.
- Install the filters in an 8" deep electrical enclosure, such as an 8"x8"x36" electrical gutter, and sized to meet applicable codes; such as NEC Article 314.28 for the US.
- Verify that the current rating of the filter meets the ampacity of the rated inverter output current and that it is protected by an appropriate over current protection device (OCPD). The filter ampacity may need to be adjusted for temperature correction factors as specified by the manufacturer. This is particularly important if the filters are installed in direct sunlight or in high thermal conditions as typically these filters start to derate ampacity at temperatures over 50°C.

Enphase Recommended Filters

Enphase Energy recommends the following power line filter products for single or three-phase applications. Like all electronic parts they are heavily discounted at volume so to talk to your distributor about total number of filters required for your design.

Table 3. Recommended Filters

Manufacturer	Model Number	Amperage Rating
Schaffner	FN-3280H-200-40	200A rated filter
Schaffner	FN-3280H-400-99	400A rated filter
Schaffner	FN-3280H-600-99	600A rated filter
Schurter	FMBD-B92F-K012	200A rated filter

Schaffner filters are in-stock and are available for purchase from [Digi-key](#) or from any Schaffner distributor listed on the [Schaffner web site, www.schaffnerusa.com](http://www.schaffnerusa.com).

Schaffner EMC
52 Mayfield Avenue
Edison NJ 08837
[\(800\) 367-5566](tel:8003675566)

Figure 5. Example of a Schaffner Filter



[Schaffner Datasheet FN3280 20110503](#)

Ampacity Calculations and Equipment Ratings

It is simple to calculate the ampacity (ampere capacity) on a given conductor, assuming that the system is installed with a balanced number of microinverters on each phase. You must determine the number of microinverters that will be powered by the set of conductors.



NOTE: Apply a **1.25 multiplier** to the calculated result for sizing of the OCPD per NEC Article 690.8(A)(3) or local standards, as shown in the following ampacity calculation examples.

240V Single-Phase Ampacity Calculation

The equation to calculate ampacity for a single-phase system is:

$$\text{Current} = \frac{(215 \text{ Watts/microinverter}) \times (\text{number of microinverters})}{240 \text{ volts}}$$

The equation to determine OCPD sizing is:

$$\text{OCPD Sizing} = \frac{(215 \text{ Watts/microinverter}) \times (\text{number of microinverters})}{240 \text{ volts}} \times 1.25$$

208V Three-Phase Ampacity Calculation

The equation to calculate ampacity for a 208V three-phase system is:

$$\text{Current} = \frac{(215 \text{ Watts/microinverter}) \times (\text{number of microinverters})}{208 \text{ volts} \times 1.732}$$

The equation to determine OCPD sizing for a three-phase system is:

$$\text{OCPD Sizing} = \frac{(215 \text{ Watts/microinverter}) \times (\text{number of microinverters})}{208 \text{ volts} \times 1.732} \times 1.25$$

Use these calculations to determine ampacity in three-phase systems as shown in the following sections.

Each of the three hot conductors in a balanced three-phase system carries that current. The neutral does not carry any current, but is used for microinverter communications and voltage sensing.

Ampacity Calculation Example for a 208/120V Three-Phase for a Single Circuit

The ampacity calculation for a branch circuit of 24 microinverters is as follows:

$$\text{Current} = \frac{(215 \text{ Watts/microinverter}) \times (24 \text{ microinverters})}{208 \text{ volts} \times 1.732} = 14.33 \text{ Amps}$$

The ampacity result is 14.33 Amps.

Apply the 1.25 multiplier to the continuous current of 14.33 Amps to properly size the OCPD. The OCPD sizing for this branch is:

$$\text{OCPD Sizing} = 14.33 \text{ Amps} \times 1.25 = 17.9 \text{ Amps}$$

A branch circuit of 24 microinverters requires three-pole, 20A circuit breaker or OCPD.

Ampacity Calculation Example for 208/120V Three-Phase for Multiple Circuits

Calculating the ampacity for other wire sections is same as for a single circuit, but you must know the total number of microinverters on the combined wire run.

In this example, a microinverter subpanel feeds a total of 528 microinverters divided into 22 branch circuits with 24 microinverters per circuit. The 22 3-pole circuit breakers will likely require two load centers in parallel to provide enough breaker positions. The calculation is as follows:

$$\frac{(215 \text{ Watts/microinverter}) \times (528 \text{ microinverters})}{208 \text{ volts} \times 1.732} = 315.11 \text{ Amps} \times 1.25 = 393.89 \text{ Amps}$$

The ampacity result is 315.11 Amps.

Applying the 1.25 multiplier to the continuous current of 315.11 Amps for sizing the OCPD results in a current value of 393.89 Amps.

A photovoltaic system with 528 M215 Microinverters requires a 400A (minimum) circuit breaker or OCPD.

Each of the three hot conductors in a balanced three-phase system carries that current. The neutral does not carry any current, and is used only for microinverter communications and for voltage sensing. For this reason, the neutral can be downsized to the size of the EGC as per 705.95(B).

480V Three-Phase Ampacity Calculation

If the utility voltage at the point of common coupling is greater than 208V, then your PV system requires transformer. It is often most cost effective to locate the transformer at the array or sub-array, and then transmit the power at the higher utility voltage. The feed from the PCC to the sub-array generally contains the three phase conductors and a ground wire, but the neutral is unnecessary for this wire section.

The utility voltage from line to line determines the exact calculation, but the equation to calculate ampacity for a 480V three-phase system is:

$$\text{Current} = \frac{(215 \text{ Watts/microinverter}) \times (\text{number of microinverters})}{480 \text{ volts} \times 1.732}$$

The equation to determine OCPD sizing for a three-phase system is:

$$\text{OCPD Current} = \frac{(215 \text{ Watts/microinverter}) \times (\text{number of microinverters})}{480 \text{ volts} \times 1.732} \times 1.25$$

Ampacity Calculation Example for 480V Three-Phase for Multiple Circuits

The calculation for a microinverter subpanel that is feeds 528 microinverters at 480V, is as follows.

$$\text{Current} = \frac{(215 \text{ Watts/microinverter}) \times (528 \text{ microinverters})}{480 \text{ volts} \times 1.732} = 136.54 \text{ Amps}$$

The ampacity result is 136.54 Amps.

Apply the 1.25 multiplier to the continuous current of 136.54 Amps to properly size the OCPD. The OCPD sizing for this branch is:

$$\text{OCPD Sizing} = 136.54 \text{ Amps} \times 1.25 = 170.68 \text{ Amps}$$

A photovoltaic system with 528 M215 Microinverters requires a 175A (minimum) circuit breaker or OCPD.

Each of the three hot conductors in a balanced three-phase system carries that current. The neutral does not carry any current, but is used for microinverter communications and for voltage sensing.

Revenue Grade Metering for Commercial Projects

Revenue grade metering is often required for commercial projects that are financed or receive incentives from government organizations. These projects usually require metering accuracy within 2% to meet revenue grade requirements. Incentive programs also require that a Performance Data Provider provide monthly production reporting. Even though the Enphase Envoy rated accuracy is only within 5%, it can be paired with 2% rated revenue grade meters to meet reporting requirements.

For your three-phase and large-scale projects, you can install revenue grade, web-enabled meters from Energy Tracker LLC to communicate with the Envoy. Revenue grade production is then displayed through Enlighten. Enphase describes pairing the Envoy with the Energy Tracker meters in the application note, [Performance Based Incentive \(PBI\) Requirements](#).

You can find out more about Energy Tracker meters on the [Energy Tracker LLC website](#).

Enphase provides a metering and management solution which includes a GE i210 Revenue Grade Meter, but this solution is only for single-phase applications, rated for 200 amps, and is primarily for residential applications. You can find out more about the [Enphase Metering and Management Solution](#) on the Enphase web site, www.enphase.com/products/metering.

A number of meter manufacturers provide 2% revenue grade meters and are also established as Performance Data Providers. Some state SREC programs and incentive programs have generated lists of eligible data providers. It is the integrator's or developer's responsibility to procure the reporting service.

Requesting Design Support from Enphase Energy

The Enphase Energy [Commercial DesignTeam](#) and Customer Service Team are available to support commercial integrators throughout the design, commissioning, and activations process. It is always easier to solve problems during the design process than after the system is built. The following resources are available for commercial design and system support:

- Enphase offers free webinars on various aspects of commercial-scale PV deployments. You can register for these webinars on the [Enphase Training page](#).
- The Enphase Commercial team is available to review your commercial design and advise you on design details and best practices. Speak to your sales account manager about receiving design support or [contact the team](#). To receive a comprehensive design review, please provide:
 - An electrical schematic of the proposed electrical system including:
 - total system size
 - main service voltage and current ratings
 - module, microinverter, and racking specifications
 - wire specifications
 - Envoy and networking details
 - specification of transformers, LCFs, or aftermarket power line filters
 - A detailed site plan or roof plan showing the locations of the main service panels, subpanels, transformers, electrical equipment, and arrays.
 - Any special considerations that may impact the design, installation, or permit process.

Figure 6. Sample Electrical Schematic

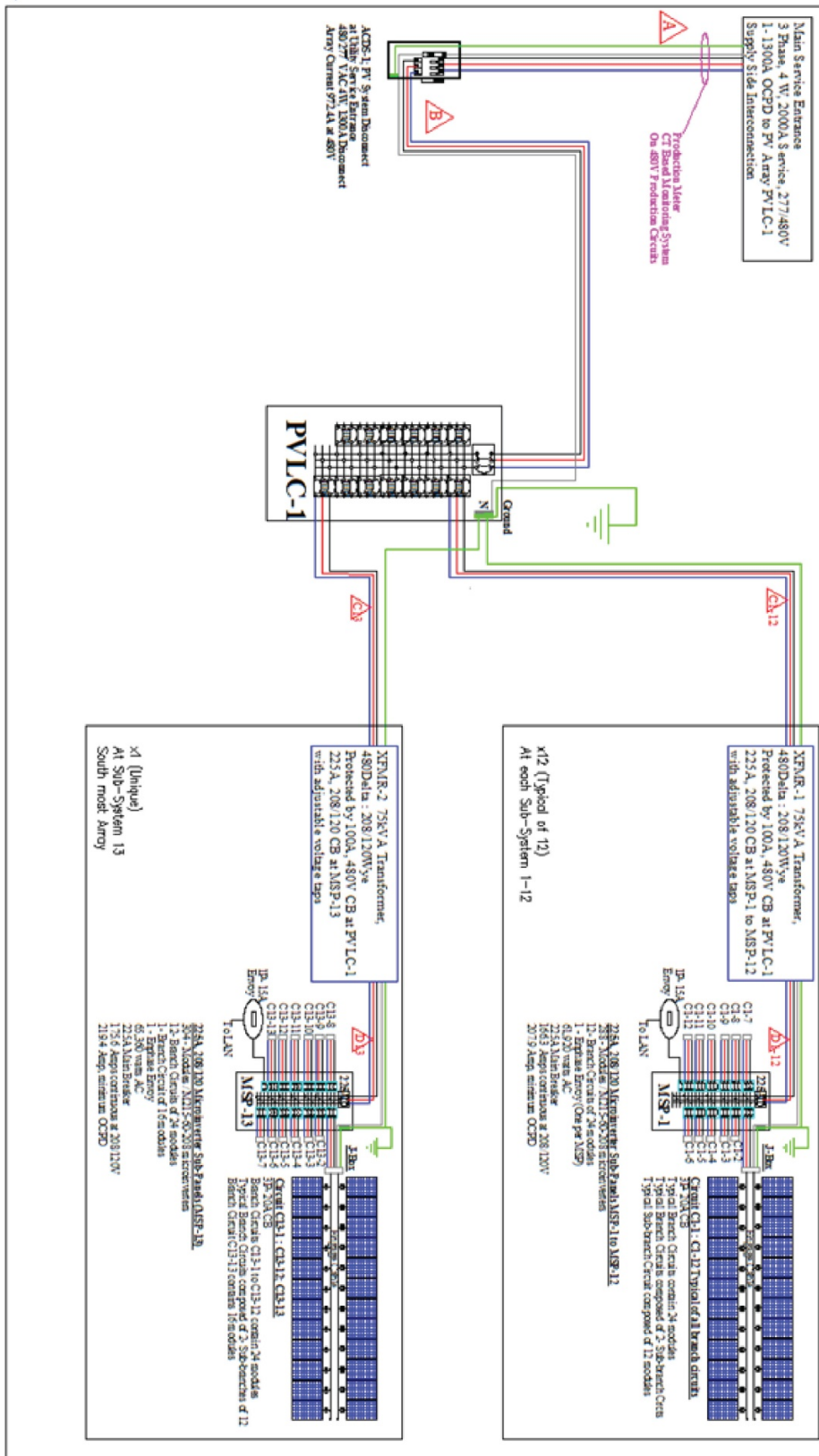


Figure 7. Sample Site Plan

SITE PLAN
SCALE: 1/64" = 1'-0"



Design Tips for Success

- Ensure good Envoy communications with the microinverters and communications domains.
 - Physically separate conduits and wires between multiple communication domains to prevent communication signals from one Envoy interfering with the communication signals of another. Signals can be inducted from one set of wires to another, even with metal conduit. Enphase recommends separating the conduits by 12 inches to prevent cross-communication.
 - Create a complete set of installation documents as shown in [Array Map](#), “Figure 9. Example of an Installation Map” and [Requesting Design Support from Enphase Energy](#), “Figure 6. Sample Electrical Schematic”. These help in system troubleshooting, especially in the case of cross-domain communications traffic issues.
 - Clearly identify communications domains and note the microinverter serial numbers in each domain.
 - Verify that the Envoy displays a communication level of at least three bars. If it does not, troubleshoot the system as described in the [Enphase Troubleshooting Guide](#) before installing additional systems, LCFs, Envoys or microinverters. Good communications are vital for effective large site operation. If communications are poor, there may be missed messages, retries, and delays in collecting the production data from the microinverters, which can lead to spotty graphs of current production in Enlighten.
- Refer to the M215 Microinverter Installation Manual as part of your planning and design process. Follow the guidelines and instructions during microinverter installation, including:
 - Install the M215 under the module, out of rain and sun. Do not mount the microinverter in a position that allows long-term exposure to direct sunlight or in a vertical orientation that allows water to collect in the DC connector recess.
 - Installing the M215 Microinverter black side up or vertically, with the DC connectors facing up, is not permitted.
- Turn on each system individually. Disable the Device Scan before commissioning another system on the same utility transformer.
- When multiple Envoys are located on a single utility transformer, take precautions to ensure that each Envoy database is populated only with the microinverter serial numbers in that communication domain. Do this by commissioning each Envoy and associated system separately. After commissioning each system, use the Envoy to Disable the Device Scan before commissioning another system. ([Commissioning for a Multi-Envoy Site](#) in Section 4 guides you through this process)
- Calculate voltage drop from the PCC (Point of Common Coupling) **all** the way to the microinverters ([Section 2: Calculating AC Line Voltage Drop for M215 Microinverters with Engage™ Cables](#))
 - Calculate each circuit section independently.
 - Keep total voltage drop below 2% to avoid nuisance tripping.
- Follow LCF installation requirements.
 - Combine branch circuits near the array using a load center.
 - Locate the LCF near the load center and run a single conductor back to the main.
 - Keep conductors from other communications domains physically separate. (See Section 5 for details).
- Run Ethernet during installation rather than as an afterthought:
 - Consider hiring a third party IT company to help.
 - Provide an outbound port and an Ethernet connection for each Envoy. You can find out more in [LAN/WAN Guidelines for Envoy Communication](#).

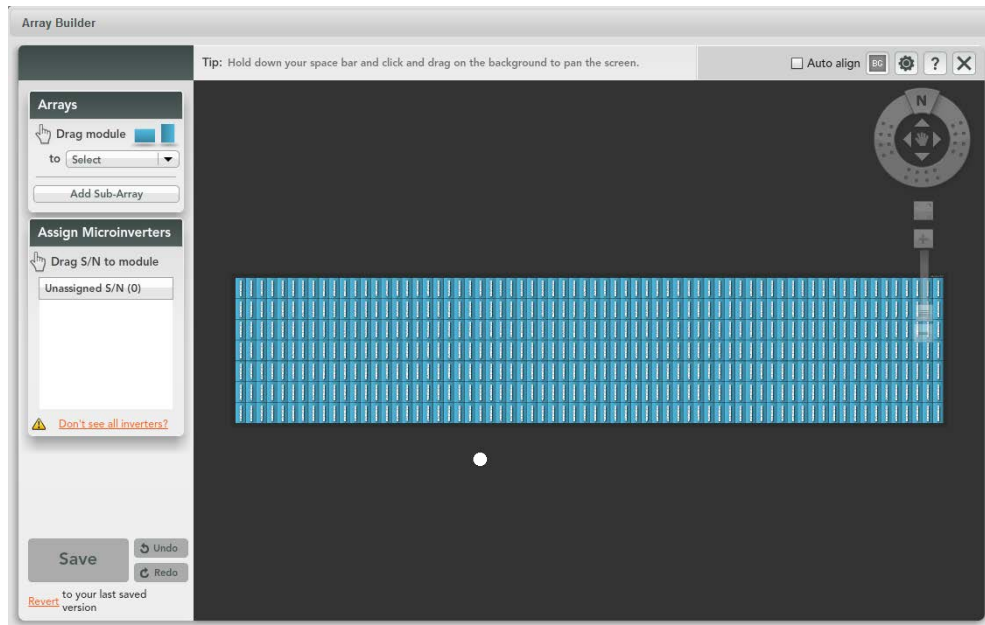


- Ensure that the site meets Internet connectivity requirements.
 - Install an always-on connection to the Internet. When the Internet connection is not on, the Envoy stores data. When the connection returns, the Envoy has to manage sending stored data while simultaneously collecting and processing large amounts of live data. This delays data collection and transmission and impedes Enlighten's ability to display the most recent data.
 - Enphase does not recommend using 3G or 4G cellular modems for Internet connectivity to the Envoy. Two disadvantages to using 3G/4G with an Envoy are that the communications link is poor (uplink speed is too slow, and the latency is too high), and that the data plan cost is high. One Envoy at a site with 500 microinverters requires about 240 MB of data usage every month. For this usage level, Enphase recommends using Ethernet bridges or Wi-Fi with DSL, Cable Modem, or T1 Internet access. Dial-up, satellite, or 3G/4G is insufficient.
- Properly register and activate the system online. Bring the site up on Enlighten:
 - Do not exceed more than 1000 microinverters on a single system in Enlighten.
 - The Array Gun provides a convenient way to scan the bar codes of the microinverters and upload the maps to Enlighten with a compatible iPhone or iTouch device. You can download the Enphase Installer Toolkit App from the Apple Store.

Building Virtual Arrays in Enlighten

Proper site documentation is an important part of activating a commercial Enphase installation on Enlighten. A well-documented installation also provides for a much easier Operating and Maintenance (O&M) regimen over the lifetime of the completed system. A detailed array map and electrical schematic can ensure that your operations personnel have all the necessary information to diagnose and resolve any issues that arise.

Figure 8. Example of an Enlighten Virtual Array



Array Map

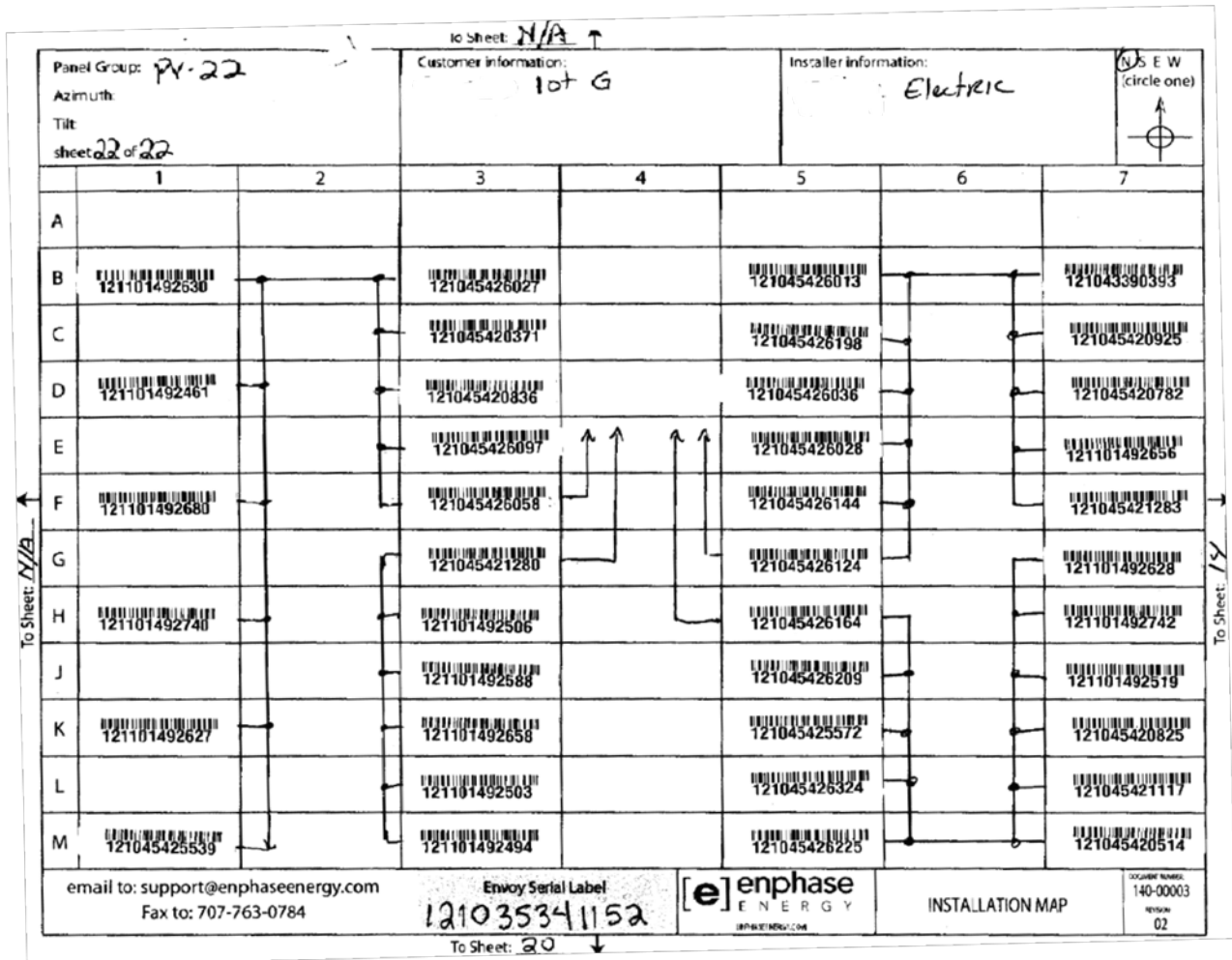
The array map is the record of where each microinverter is installed at the project. Create an array map electronically using the [Array Gun](#) or on paper by removing stickers from the microinverters and placing the stickers in position on an installation map. Use the map to build a virtual array in Enlighten. When

activating a system in Enlighten, build the systems with less than 1,000 microinverters per system, with some consideration for the shape of the arrays.

The array map should:

- List the Envoy serial number that is being monitored by the array.
- List all microinverter serial numbers and their correct placement within the array.
- List the tilt and azimuth of the array relative to the sticker placement.

Figure 9. Example of an Installation Map



Section 2: Calculating AC Line Voltage Drop for M215 Microinverters with 208V Engage™ Cables

This section describes methods for calculating the AC line voltage drop (or voltage rise) and presents voltage rise guidelines for dedicated PV branch circuits using Enphase M215 Microinverters and Engage Cables. This document only contains calculations for 208V three-phase systems. You can find calculations for 240V single phase systems in a more comprehensive document at http://enphase.com/wp-uploads/enphase.com/2011/12/EnphaseTechBrief_Vdrop_M215.pdf

The application of proper voltage rise calculations will help to prevent nuisance trip issues due to high line voltage conditions. Moreover, less resistance in the wiring results in less heat at the terminals, less power loss, and improved performance of the PV system.

It is common to refer to these calculations as voltage drop (VDrop) calculations, but PV systems generate electricity and voltage actually rises at the AC terminals of microinverters. Voltage rises because the microinverters are a current source rather than a voltage source or a load. As such, this guide refers to these calculations as voltage rise (VRise).

Recommendations

To minimize voltage drop or VRise issues, Enphase recommends that you apply these guidelines when planning your system:

- The total VRise in the AC wiring should be less than 2%, which includes less than 1% VRise in the Engage Cable. Use the calculation examples in [Calculating Total Voltage Rise for Three-Phase Installations](#) to determine VRise values for your system.
- Center-feed the branch circuit to minimize VRise in a fully-populated branch. Since the VRise is nonlinear, reducing the number of microinverters in the branch circuit greatly reduces the voltage measured at the last microinverter in an end-fed branch. To center-feed a branch, divide the circuit into two sub-branch circuits protected by a single over current protection device (OCPD). Find out more in [Advantages of Center-Feeding AC Branch Circuits](#).
- Wire sizing is important as use of undersized conductors can result in nuisance tripping of the microinverter OCPD. [What Contributes to Voltage Rise](#) provides more information.

Background

The IEEE 1547 standard requires that utility interactive inverters cease to export power if the voltage measured at the Point of Common Coupling (PCC) exceeds +10% or -12% of nominal. The PCC is generally at the main electric service meter. Enphase microinverters, like all utility interactive inverters, sense voltage and frequency from the AC grid and cease exporting power when voltage or frequency from the grid is either too high or too low.

If the voltage measured is outside the limit, the microinverter enters an AC Voltage Out Of Range (ACVOOR) condition and ceases to export power.

All components within the system wiring contribute to resistance and must be considered when calculating the total VRise. Typically, the resistance of three distinct wire sections and several wire terminations must be quantified as follows:

- The distance from the microinverters to the PCC. The reference point for a microinverter voltage measurement is at the microinverter AC output. Since microinverters are located at the array, the distance from the microinverters to the PCC can be substantial.

- Undersized conductors can cause the voltage measured at the microinverter to be outside of the IEEE limits.
- VRise within system wiring can combine with the necessity (of the microinverter) to match AC Grid voltage, causing microinverters to sense an over-voltage condition and cease operation.

All resistances of the system components are in series, and are cumulative. Since the same current is flowing through each resistance, the total VRise is simply the total current times the total resistance. In a PV system, calculate total VRise as follows:

- For a single-phase system, total resistance is equal to two times the one-way resistance.
- For a three-phase system, each of the three line currents and resistances are calculated and then combined.

There is also some resistance associated with each OCPD (Over Current Protection Device), typically a circuit breaker.

Engage Cable and Internal Voltage Rise

The Engage Cable is a continuous length of 12 AWG stranded copper, outdoor-rated cable, with integrated Engage connectors for Enphase M215 Microinverters.

The following table lists the Engage Cable types available for your project.

Table 4. Engage Cable Types

SKU (part number)	Voltage type/ conductor count	Connector spacing	PV module orientation
ET10-208-30	208 VAC, 5 conductor	1.025 m (40")	Portrait
ET17-208-30	208 VAC, 5 conductor	1.7 m (67")	Landscape

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 Engage Cable. Although Engage Cable is optimized for minimal VRise, it is still important to calculate total VRise for the entire system from the array to the PCC.

What Contributes to Voltage Rise

Enphase Microinverters are installed as dedicated branch circuits. Each dedicated branch circuit of M215 Microinverters is protected by a 20A OCPD. Wire size, circuit current, circuit length, voltage margin, and utility voltage each branch circuit must be considered when calculating VRise.

- Wire size: There is a tradeoff to be made between increased wire size and increased cost. The wire size can often be increased by one AWG trade size with minimal cost impact. At some point, however, increasing the wire size necessitates increases in the conduit and/or terminal size, resulting in increased costs. However, these increases in wiring and conduit costs can be offset by the increase in energy production over the lifetime of the system.

Wire sizing is very important because improper wire size can result in nuisance tripping of the microinverter utility protective functions. This results in loss of energy harvest. Note also that although the National Electric Code recommends that branch circuit conductors be sized for a maximum of 3% VRise (Article 210.19, FPN 4.), this value is rarely sufficiently conservative for a utility-interactive inverter.

- **Circuit current:** The circuit current varies depending on which “wire section” is being considered in the installation. A typical installation contains three wire sections as described in Voltage Rise Calculations by Wire Section. With Engage Cable, current increases with each inverter added to the circuit.
- **Circuit length:** There is often little choice in circuit length, but center-feeding the dedicated branch circuit significantly reduces voltage rise within the branch, as described in Advantages of Center-Feeding the AC Branch Circuits.
- **Voltage margin:** If service voltage is chronically high, the utility will sometimes perform a tap change on the distribution transformer. This can provide a percent or two of additional voltage margin.
- **Utility voltage:** The utility strives to maintain voltage at the PCC within +/- 5% of nominal. The protective functions of the microinverters are set to +10%/-12% by default. The high voltage end of the tolerance is of most concern because the inverters are a SOURCE and not a LOAD. If the utility is consistently 5% high, that leaves less than 5% for all wiring and interconnection losses and inverter measurement accuracy. If you are concerned about the utility’s voltage, you may request that your utility place a data logger at the PCC and make a record of the voltages available to you at the site.

Advantages of Center-Feeding AC Branch Circuits

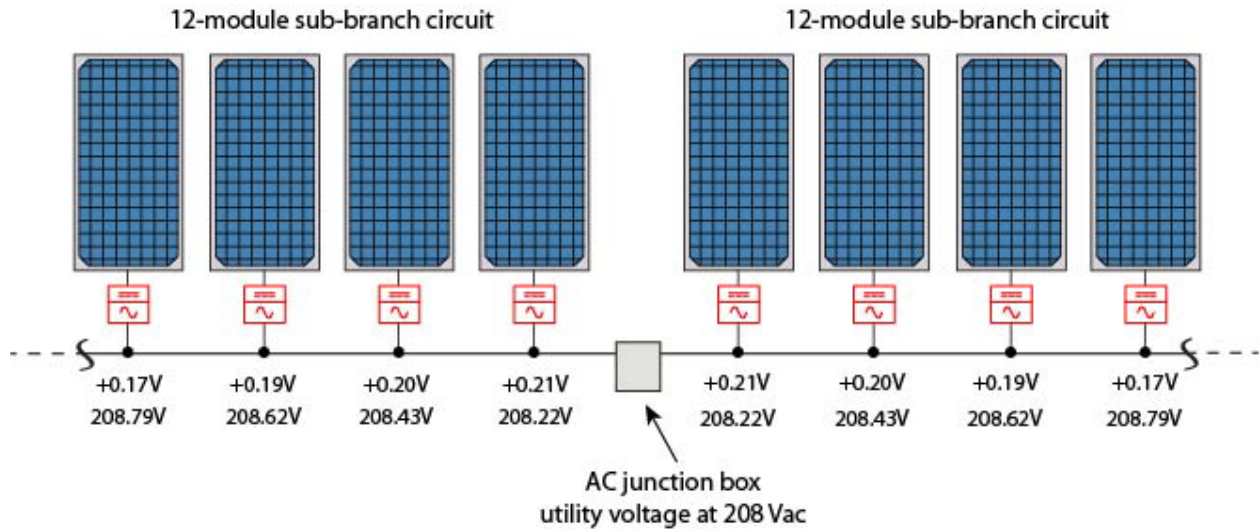
The Engage Cable is both more efficient and less impacted by the effects of VRise than past Enphase cabling systems. This is particularly true of the Engage Cable with connectors spaced one meter apart for portrait applications. However, it is still important to calculate voltage rise for the entire system from the array to the PCC.

Since voltage rise is nonlinear, reducing the number of microinverters in the branch circuit greatly reduces the voltage measured at the last microinverter in the branch. One way to minimize this voltage rise is to center-feed the branch, that is, divide the circuit into two sub-branch circuits protected by a single OCPD. The following diagram illustrates the center-fed method.

When a branch circuit feeds multiple roofs or sub-arrays, it is common to divide the sub-arrays into sub-branch circuits. It is acceptable to have different numbers of microinverters on each roof or sub-branch circuit. This is because the conductors from each Engage Cable on that branch circuit are paralleled within a junction box where all red conductors come together, all black conductors come together, etc.

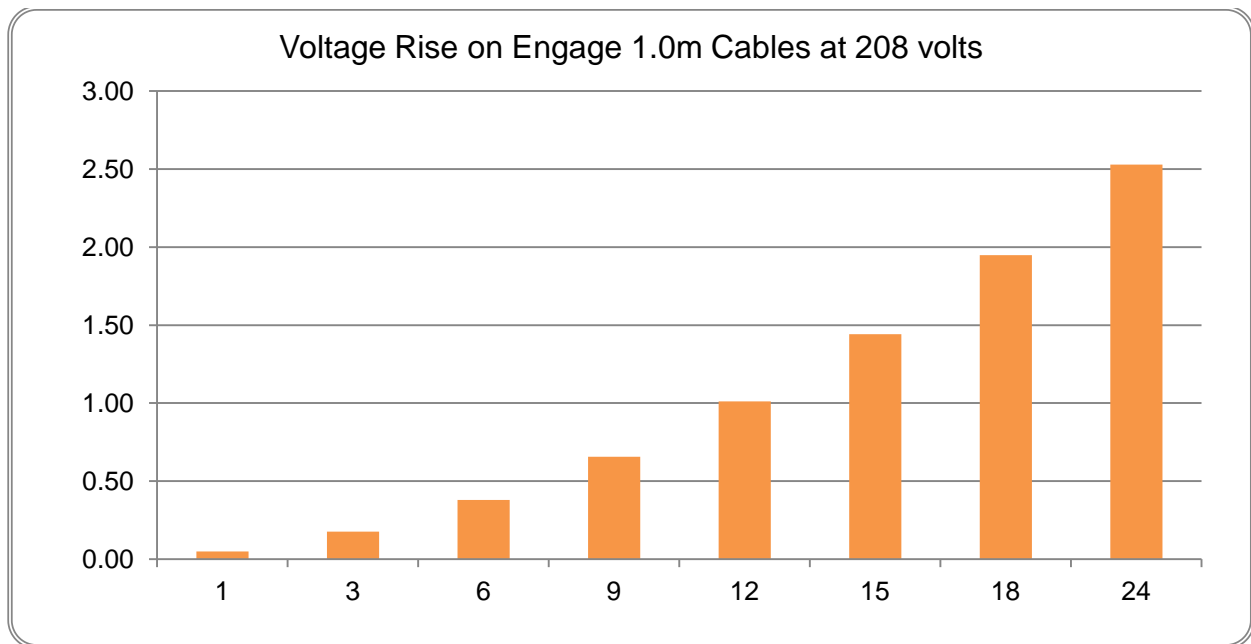
Internal VRise within the Engage Cable

VRise within the microinverter branch circuit can be easily determined. The following diagram represents a 208 VAC system with fully populated branch circuit that is center-fed. It illustrates how voltage measured at an individual microinverter increases by its position in the branch circuit. As the number of microinverters in a branch circuit increase, the voltage at each microinverter rises in a nonlinear manner.



The diagram contains a top row of numbers which are the incremental voltage rises from one microinverter to the next, and a bottom row which are the cumulative line-to-line voltages overall.

The following graph illustrates how the number of microinverters connected to a portrait-oriented Engage Cable (with connectors spaced one meter apart) causes the voltage to rise when operating at 208 VAC.

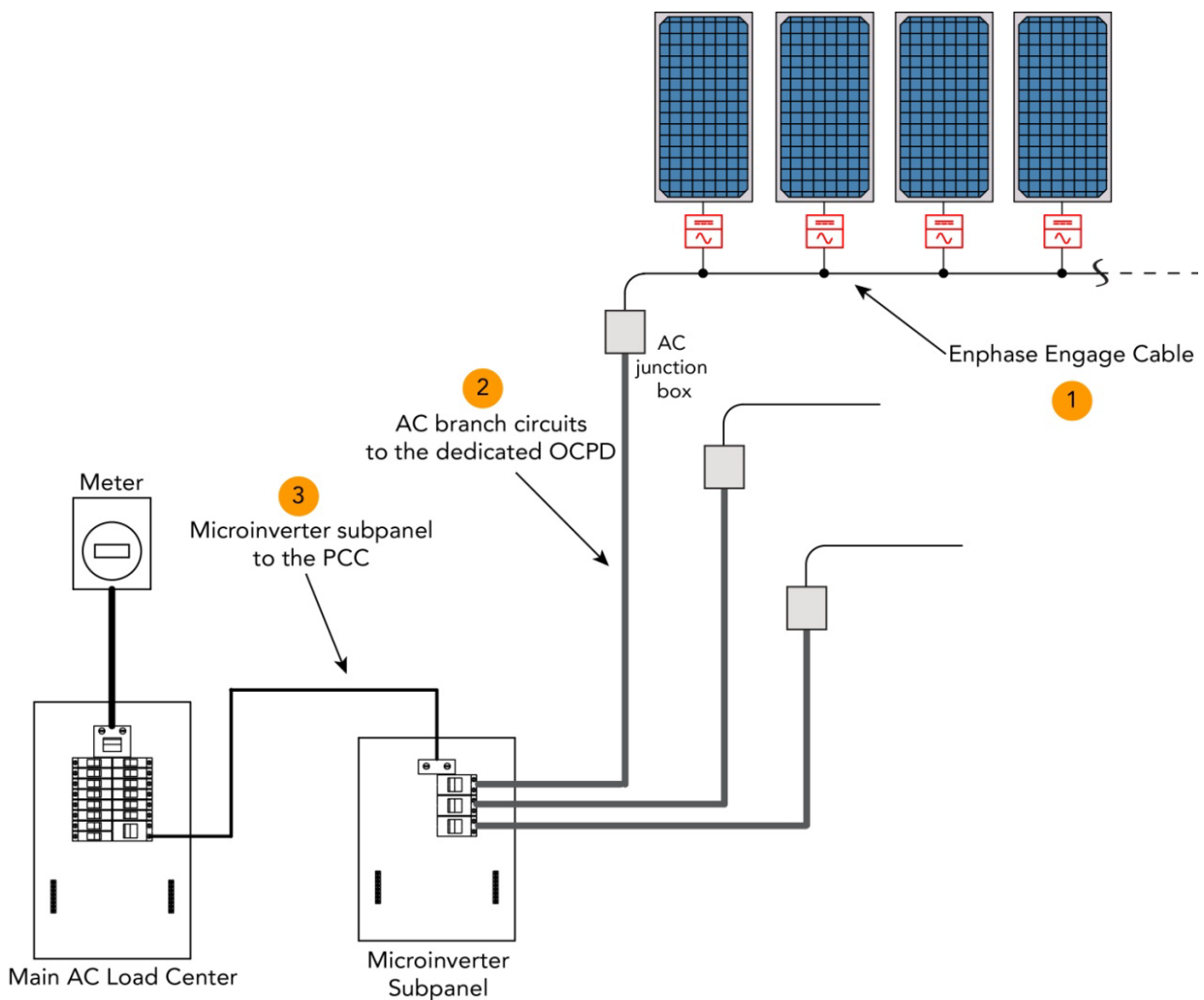


Voltage Rise Calculations by Wire Section

A typical installation has three wire sections where voltage rise must be considered:

1. Enphase Engage Cable. Internal voltage rise within the Engage Cables, from the microinverter to the array-mounted AC junction box.
2. AC branch circuits to the dedicated OCPD. Voltage rise from the array-mounted AC junction box, along the AC branch circuits, to the load center containing the dedicated microinverter OCPDs (circuit breakers).
3. Microinverter subpanel to the PCC. Voltage rise from the load center to the PCC.

We must calculate each component individually and make sure that the total voltage rise is less than 2%. Additional losses will exist at the terminals, connectors, and in circuit breakers; however, if you design for a 2% total voltage rise, these other factors may be ignored.



Calculating Total VRise for Three-Phase 208 VAC Installations

Sample Calculation

For this example, we'll consider the voltage rise calculations for a system using 72 Enphase M215 Microinverters with 208 VAC three-phase service. The system has three fully-populated branch circuits of 24 M215 Microinverters mounted in portrait orientation. For fully loaded branch circuits with 208 VAC, we recommend that the circuit is center-fed to minimize voltage rise. The M215 Microinverter produces power on two legs, and the phases are balanced by the physical internal rotation of the phase cables inside the Engage Cable. A center-fed branch of 24 microinverters would have 12 microinverters on one sub-branch circuit and 12 microinverters on the other sub-branch.

Internal VRise for 208 VAC, 5 Wire, 1.0m Portrait Engage Cable and M215s

Microinverters per Branch in Portrait								
	3	6	9	12	15	18	21	24
VRise	0.08	0.21	0.39	0.65	0.96	1.35	1.79	2.30
%	0.04	0.10	0.19	0.31	0.46	0.65	0.86	1.11
Current	1.79	3.58	5.37	7.16	8.95	10.74	12.53	14.32

Internal VRise for 208 VAC, 5 wire, 1.7m Landscape Engage Cables and M215s

Microinverters per Branch in Landscape								
	3	6	9	12	15	18	21	24
VRise	0.12	0.32	0.63	1.05	1.58	2.41	2.95	3.78
%	0.06	0.16	0.30	0.51	0.76	1.16	1.42	1.82
Current	1.79	3.58	5.37	7.16	8.95	10.74	12.53	14.32

Internal VRise for 208 VAC Engage Cable

The voltage rise for a branch circuit of 24 M215s center-fed, with two sub-branch circuits of 12 microinverters each in portrait is **0.31%**.

VRise from the Array-Located Junction Box to the Microinverter Subpanel

Calculating the VRise in this portion of the circuit is determined by multiplying the branch circuit output power in watts by the total resistance of the wire run divided by the voltage.

$$VRise = \frac{(Watts / inverter) * (numbers of Inverters / branch circuit) * (\Omega / ft) * (1 way wire length)}{208 volts}$$

The following example is for a fully populated branch circuit of 25 M215 Microinverters.

Enphase M215 Microinverter output in watts = 215 watts

Number of microinverters per branch circuit = 24

Wire gauge for individual branch circuit = #10 AWG THWN-2 CU

#10 AWG THWN-2 CU resistance = 0.00129 Ω /ft (from NEC Chapter 9, Table 8)

Length of individual branch circuit = 40 feet

$$\begin{aligned} VRise &= \frac{215 \text{ watts} * 24 * 0.00129 \Omega/ft * 40 ft}{208 \text{ volts}} \\ &= 5,160 \text{ watts} * .0516 \Omega/208 \text{ volts} = 1.28 \text{ volts} \\ &= 1.28 \text{ volts} / 208 \text{ volts} = 0.62\% \text{ VRise} \end{aligned}$$

The voltage rise from the junction box to the microinverter subpanel is **0.62%**.

VRise from the Microinverter Subpanel to the Main Service Meter (PCC)

Calculating the VRise in this portion of the circuit is determined by multiplying the total microinverter subpanel output power in watts by the total resistance of the wire run divided by the voltage. The phases are balanced by the physical internal rotation of the phases inside the Engage Cable.

$$VRise = \frac{(Watts / inverter) * (number of inverters/microinverter subpanel) * (\Omega / ft) * (1 way wire length)}{208 volts}$$

The following calculations are for three fully populated branch circuits of 24 M215 Microinverters, with two sub-branch circuits of 12 microinverters each, in portrait, for a total of 72 microinverters.

M215 Microinverter output in watts = 215 watts

Number of M215 Microinverters per microinverter subpanel = 72

Wire gauge for the microinverter subpanel feed = #2 AWG THWN-2 CU

#2 AWG THWN-2 CU resistance = 0.000201 Ω/ft (from NEC Chapter 9, Table 8)

Length of microinverter subpanel feed = 80 feet

$$\begin{aligned} VRise &= \frac{(215 \text{ watts}) * (72) * (0.000201 \Omega / ft) * (80 ft)}{208 volts} \\ &= 15,480 \text{ watts} * 0.01608 \Omega / 208 volts = 1.20 volts \\ &= 1.20 volts / 208 volts = 0.58\% VRise \end{aligned}$$

The voltage rise from the microinverter subpanel to the main service meter is **0.58%**.

Summary of Calculations for Three-Phase 208 VAC Applications

With the utility operating at the upper limit of their allowable tolerance (+5%) and the microinverters having a measurement accuracy of 2.5%, we are left with a voltage rise budget of 4.88 volts (2.25%) for all wiring to the PCC. The calculated VRise for all three portions of the system must be 4.88 volts or less. For systems with long branch circuit runs and/or long runs from the inverter subpanel to the main service panel or PCC, it is best to make the VRise in the Engage Cable as small as possible. However, after accounting for additional losses within connections, terminals, circuit breakers, and unexpected increases in wire length, we recommend calculating the total system voltage rise to be less than 2%.

Voltage rise from the microinverters to the AC junction box	= 0.31%
Voltage rise from the AC junction box to the microinverter subpanel	= 0.62%
Voltage rise from the microinverter subpanel to the main service meter (PCC)	= 0.58%
<hr/>	
Total system voltage rise for all three wiring sections	= 1.51%

In this example, we were able keep the VRise to less than 2%. Note that this would have been impossible without center-feeding the circuit to create two sub-branch circuits at the array. To reiterate, center-feeding is a great way to decrease costs, improve production, and increase system reliability.

Conclusion

Center-feeding each branch circuit in an Enphase M215 Microinverter system is essential, both for optimal microinverter operation and to minimize wire costs for the installer. Following the guidelines and calculations in this document will help to minimize any voltage rise or voltage drop issues with your installation.

Section 3: Grounding Considerations for M215 Installations

This section clarifies the distinctions in commercial solar grounding terminology and in grounding methods for the M215 Microinverter. Under National Electric Code (NEC) definitions, there are three conductors that provide paths to ground:

1. The DC Equipment Ground Conductor (DC EGC) for modules and rails is bonded with WEEBs, other grounding clips, or lay-in lugs on the module frames and lay-in lugs on the rails, and then to the ground bonding point at or near the array located junction box.
2. The AC Equipment Ground Conductor (AC EGC) for inverters is provided through Engage Cables and bonded to the other grounding conductors at a point inside or near to the array located junction box.
3. The DC Ground Electrode Conductor (DC GEC) for the inverter is bonded to the case of each microinverter and to the AC EGC internally inside each microinverter. The M215 Microinverter grounding clip accepts #8 or #6 conductors.

The grounding conductors may be bonded together at or near to the array located junction box and should be a minimum #8 CU.

Follow the guidelines in this section to help minimize issues related to grounding your microinverter installation.

Grounding Scenarios for M215 Installations

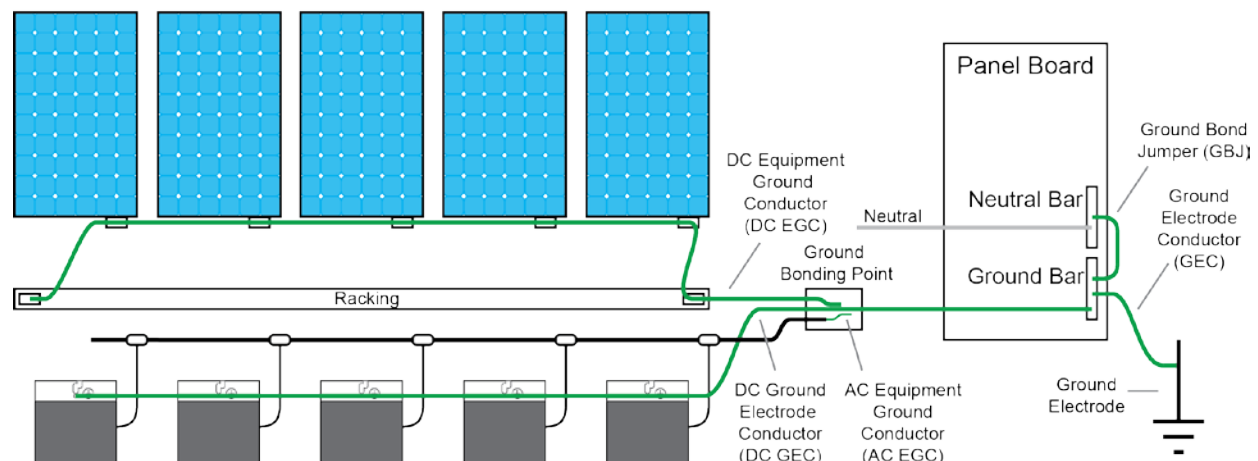
Three different scenarios are described in this section:

- Scenario One: M215 Microinverter Standard Installation
- Scenario Two: M215 Microinverter with WEEB Bond Jumpers
- Scenario Three: M215 Microinverter with Zep Groove Frames (single point of grounding)

Scenario One: M215 Microinverter Standard Installation

The following figure shows the relationship between the three conductors that provide paths to ground, as well as their configuration with respect to the PV modules, racking, ground bonding point, panel board, neutral bar, ground bar, and ground electrode.

M215 Microinverter

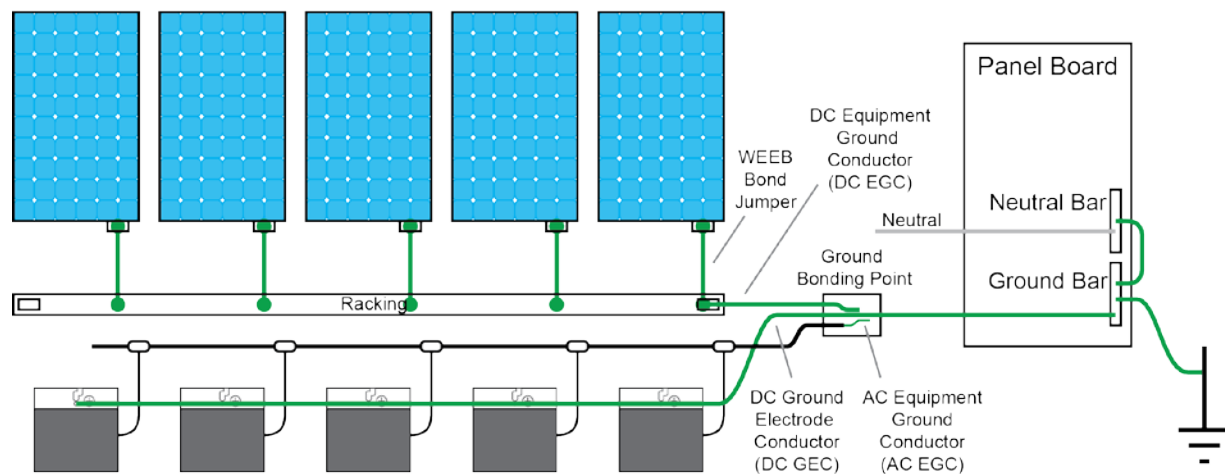


- The DC EGC connects between racking and PV module frames and to each microinverter. This conductor may be #6 to #12 AWG CU because the PV current is limited to less than 16A.
- The AC EGC is contained in the wiring harness and in the Engage Cable and connects to the DC GEC at the ground bonding point to form a combined AC/DC ground conductor. This conductor is #12 AWG CU and is protected by double insulation.
- The DC GEC connects to the combined AC/DC ground conductor at the ground bonding point. This conductor may be #6 or #8 AWG CU, depending on whether or not it is exposed to physical damage.
- The combined AC/DC ground conductor is terminated at the Panel Board Ground Bar. This conductor may be #6 or #8 AWG CU depending on whether it is exposed to physical damage.
- The Ground Bar is connected to the Ground Electrode through the Ground Electrode Conductor (GEC).

Scenario Two: M215 Microinverter with WEEB Bond Jumpers

The following figure shows how WEEB bond jumpers allow the elimination of lay-in lugs on the PV module frames and on the racking.

M215 Microinverter with WEEB Bond Jumpers

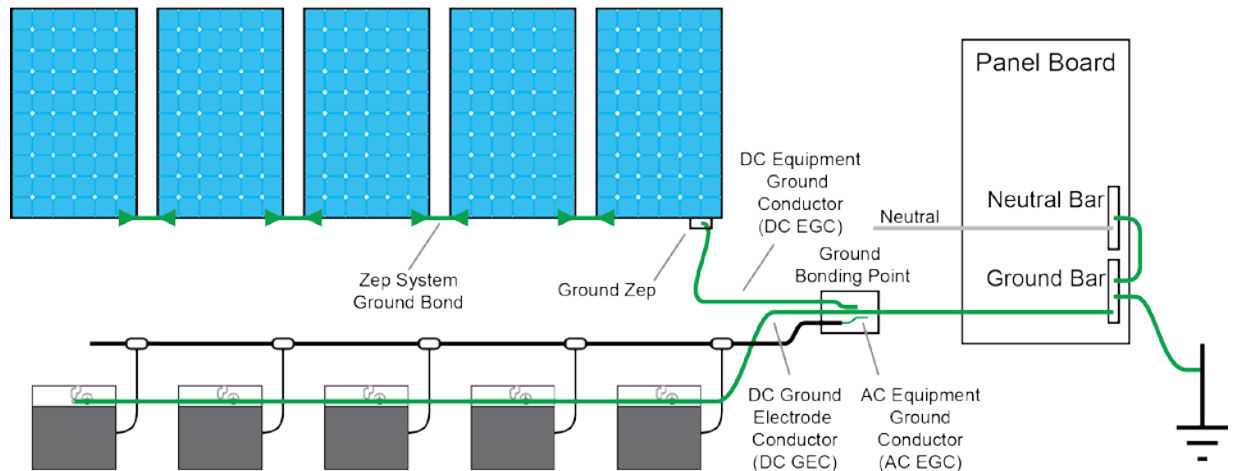


- WEEB Bond Jumpers connect the PV module frames to the racking. The racking now acts as the DC EGC.
- The DC EGC connects between the racking and the ground bonding point. This conductor may be #6 to #12 AWG CU because the PV current is limited to less than 16A.
- The AC EGC is contained in the wiring harness and in the Engage Cable and connects to the DC GEC at the ground bonding point to form a combined AC/DC ground conductor. This conductor is #12 AWG CU and is protected by double insulation.
- The DC GEC connects to the combined AC/DC ground conductor at the ground bonding point. This conductor may be #6 or #8 AWG CU, depending on whether or not it is exposed to physical damage.
- The combined AC/DC ground conductor is terminated at the panel board ground bar. This conductor can be #6 or #8 AWG CU depending on exposure to potential physical damage.
- The Ground Bar is connected to the Ground Electrode through the GEC.

Scenario Three: M215 Microinverter with Zep Groove Frames

The following figure shows how PV modules with the Zep Groove frame technology eliminate the need for all lay-in lugs on the PV module frames and the need to use racking as a ground component.

M215 Microinverter with Zep Groove Frames



- The Zep System connections bond the PV module frames to each other to form the racking. The PV module frames now act as the DC EGC.
- The DC EGC connects between the PV module frames and the ground bonding point. This conductor may be #6 to #12 AWG CU because the PV current is limited to less than 16A.
- The AC EGC is contained in the wiring harness and in the Engage Cable and connects to the DC GEC at the ground bonding point to form a combined AC/DC ground conductor. This conductor is #12 AWG CU and is protected by double insulation.
- The DC GEC connects to the combined AC/DC ground conductor at the ground bonding point. This conductor may be #6 or #8 AWG CU, depending on whether or not it is exposed to physical damage.
- The combined AC/DC ground conductor is terminated at the Panel Board Ground Bar. This conductor may be #6 or #8 AWG CU depending on whether it is exposed to physical damage.
- The Ground Bar is connected to the Ground Electrode through the GEC.

Section 4: Commissioning for a Multi-Envoy Site

Proper site commissioning is critical to the success of the project. Install the Envoy and connect it to the Internet at least one hour before you complete your solar installation and before the microinverters are producing power. If you install multiple Enphase systems in the same neighborhood or on the same utility transformer, commission only one system at a time.

Commissioning Steps

Follow these steps to commission one Envoy in a multi-Envoy environment:

1. Plug in the Envoy to a standard 120VAC receptacle.
2. Plug in the Local Area Network connection to the Envoy and verify that the green “link light” on the back of the Envoy is illuminated.
3. The Envoy displays “+Web” after four or five minutes.
4. Once the Envoy has connected to the Web, it may automatically update its software. **Do not unplug the Envoy during this time. The Envoy displays “Upgrading... Do Not Unplug.”** The software update may last for 15 minutes or longer, depending on the connection speed and software version. The Envoy displays “-Web” for about two minutes after the new software has been updated, but quickly returns to “+Web”.
5. Ensure that the Envoy displays a communication level of at least three bars. If it does not, troubleshoot the system as described in the Enphase Troubleshooting Guide at <http://www.enphase.com> before installing any additional system components at the site.
6. Upon startup, the Envoy begins an eight-hour device scan for new devices. If the Envoy detects any microinverters before the solar array is powered on, those microinverters have been “poached” from another system. Use a laptop to access the Envoy Device Conditions and Controls menu and delete them, or contact support@enphaseenergy.com.
7. Once the installation is complete and all electrical panels and junction boxes have been properly closed and covered, turn on the photovoltaic system that is associated with this Envoy. The Envoy now begins to populate its database with the microinverters on site. This generally takes about 20 minutes, but can take longer. This will not work at night as the microinverters operate only during daylight hours as they are powered by DC solar power.
8. Once the Envoy has populated its database with all of the microinverters at the site, **hold down the “menu button” on the right side of the Envoy until the display reads “Disable New Device Scan.”** After the device scan is disabled, you can commission another Envoy at the site.
9. As an additional precaution, you may send a request to support@enphaseenergy.com to “Inhibit Device Scanning” at the site so that no further device scans can be run by the site owner.
10. Once the scan is complete, request that the microinverters be upgraded to the latest version. To request an upgrade, contact support@enphaseenergy.com.

Section 5: Networking and PLC Considerations for Commercial Projects

This section addresses networking and power line communications (PLC) for commercial systems, with an emphasis on how to configure commercial installations for decades of trouble-free operation and monitoring.

PLC Considerations

Enphase Microinverters communicate with the Envoy through power line communications. Enphase equipment sends and receives signals in the 100–150 kHz band over the same conductors that carry AC system power. With all Enphase installations, communication between the array and the Envoy is key to system monitoring and maintenance. Besides communicating with microinverters via power lines on the premises, the Envoy also communicates with Enlighten via an Ethernet cable connected to the broadband router on site.

The Envoy, in this sense, acts just as another computer at the premises, connecting through a standard Ethernet LAN (Local Area Network) cable and using standard TCP/IP protocols.

Power line communications are very robust and reliable in a commercial Enphase system because array-located transformers or filters generally provide a clean communications environment.

LAN/WAN Guidelines for Envoy Communication

This section covers networking basics and troubleshooting.

DHCP and Self Assigned IP Address (169.254.x.x)

When the Envoy first boots up, it performs a Dynamic Host Configuration Protocol (DHCP) broadcast to request an IP address from a DHCP source. A DHCP source is usually a server or computer, but almost all consumer-grade broadband routers also provide DHCP services as well. The broadband router is the usual source of IP addresses for network hosts like computers, laptops, and the Envoy.

If the Envoy LCD window displays an IP address beginning with 169.254, the Envoy was unable to receive an IP address from a DHCP source and assigned this address to itself. To troubleshoot, first check the Ethernet cabling connection, then check that the router is providing DHCP services.

DHCP versus Static IP Addressing

If the site owner prefers not to use DHCP, you can set up the Envoy to use a static IP address as follows.

1. Use the Envoy web interface and navigate to the **Administration** page.
2. Log in with the user name, **admin**, and password, **admin**.
3. Click the **Network Connectivity** menu item. This allows you to see if the Envoy is using DHCP or Static-IP, and allows you to change this setting if needed.
4. Click **Check Network Connectivity** to view the Envoy connections.

For more information on how to use the Envoy Interface, refer to the *Envoy Communications Gateway Installation and Operation Manual* at <http://www.enphase.com>.



WARNING: Do not change the Envoy DHCP setting to a static IP address unless you also reserve the same IP address on your broadband router. See the section on DHCP Reservations in your router's setup manual. Failure to reserve the static IP address on the router results in duplicate IP addresses and intermittent Internet connection problems with your Envoy.

MAC Filtering

Check to determine if Media Access Control (MAC) filtering is in use at the site. MAC address filtering is not related Apple Macintosh computers. Rather, a MAC address is a 48-bit address on each individual network card which uniquely identifies a piece of hardware. The MAC address filtering is a security mechanism by which routers allow administrators to specify which devices can use the router for access to the Internet. MAC address filtering prevents unauthorized or unknown personnel from using the router to get to the Internet.

An example of a MAC address would be, 00:17:F2:D6:B1:45. MAC addresses contain six pairs of hexadecimal characters, including any number 0-9 and letters A-F. The MAC address of the Envoy begins with 00:D0:69:41.

If MAC filtering is in use at the site, you need to identify the specific MAC address of your Envoy to be added the list of authorized devices on the router. To find the Envoy MAC address, browse to the home page of the Envoy's web-service using an ordinary web-browser. The Envoy home page contains the unit's MAC address. The MAC address is also on a sticker on the back of the Envoy.

Firewall Settings

The Envoy initiates **outbound** connections to Internet servers. Such connections may be restricted by firewall rules set up on the broadband router on site. Broadband routers typically allow all outbound connections but restrict any/all inbound connections.

If outbound firewall rules restrict access to the site, then configure a static IP address for the Envoy and rules to allow outbound access. Configure the rules as follows:

Direction	Source	Protocol	Port	Destination
OUT	<Envoy IP address>	TCP	443	reports.enphaseenergy.com
OUT	<Envoy IP address>	TCP	443	securereports.enphaseenergy.com
OUT	<Envoy IP address>	TCP	443	home.enphaseenergy.com
OUT	<Envoy IP address>	UDP	123	us.pool.ntp.org

The Envoy connects to servers using Domain Name System (DNS) names. If you add firewall rules for Envoy reporting, Enphase recommends using DNS names rather than the underlying IP addresses because IP addresses are subject to change without notice.



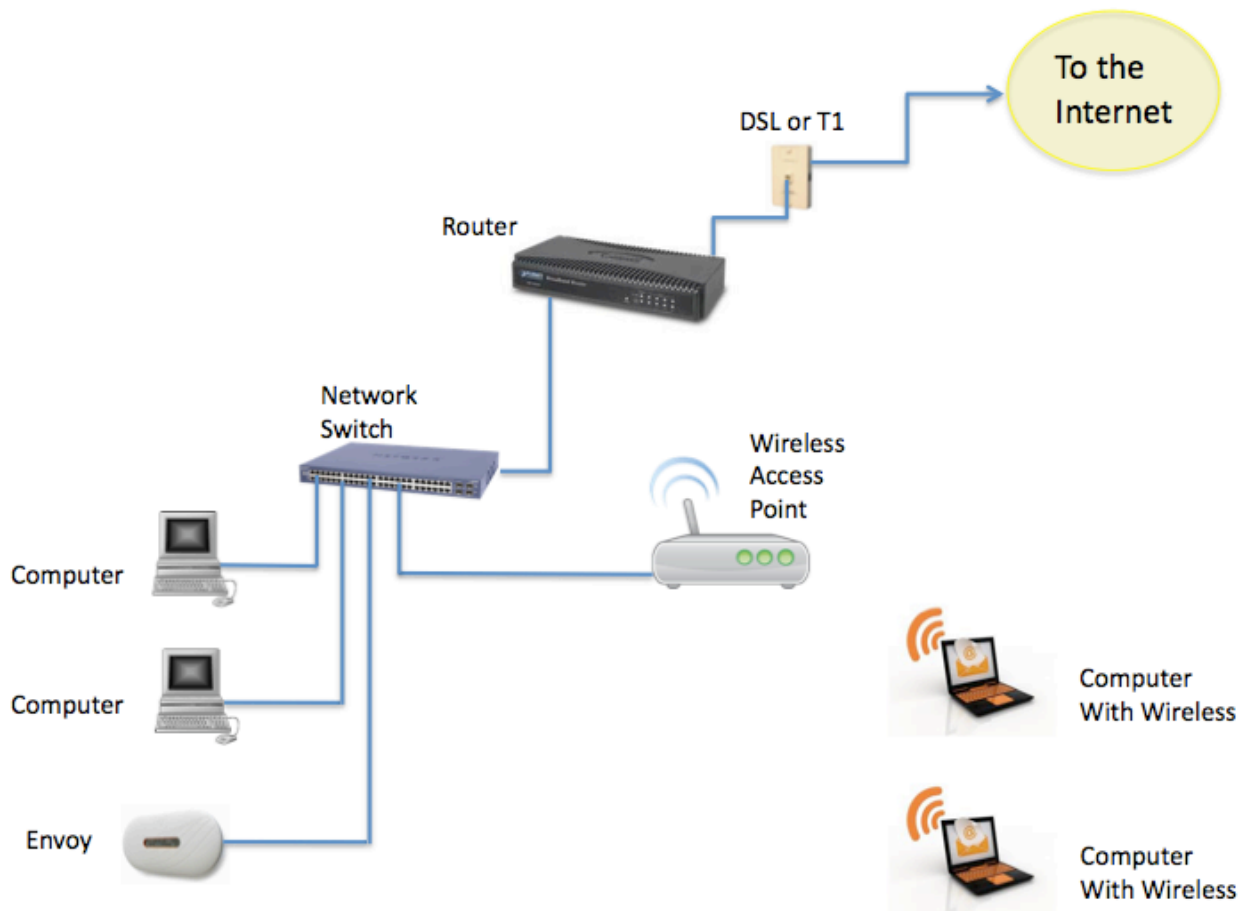
WARNING: Do not change the Envoy DHCP setting to use a static IP address unless you also reserve the same IP address on your broadband router. See the section on DHCP Reservations in your router's setup manual. Failure to reserve the static IP address on the router will result in duplicate IP addresses and intermittent Internet connection problems with your Envoy.

Enphase Typical Commercial Deployment Networking Examples

The networking and communications side of installing a commercial Enphase Microinverter System is fairly straightforward. Following the recommended practices in this section minimizes communications issues with your commercial installations.

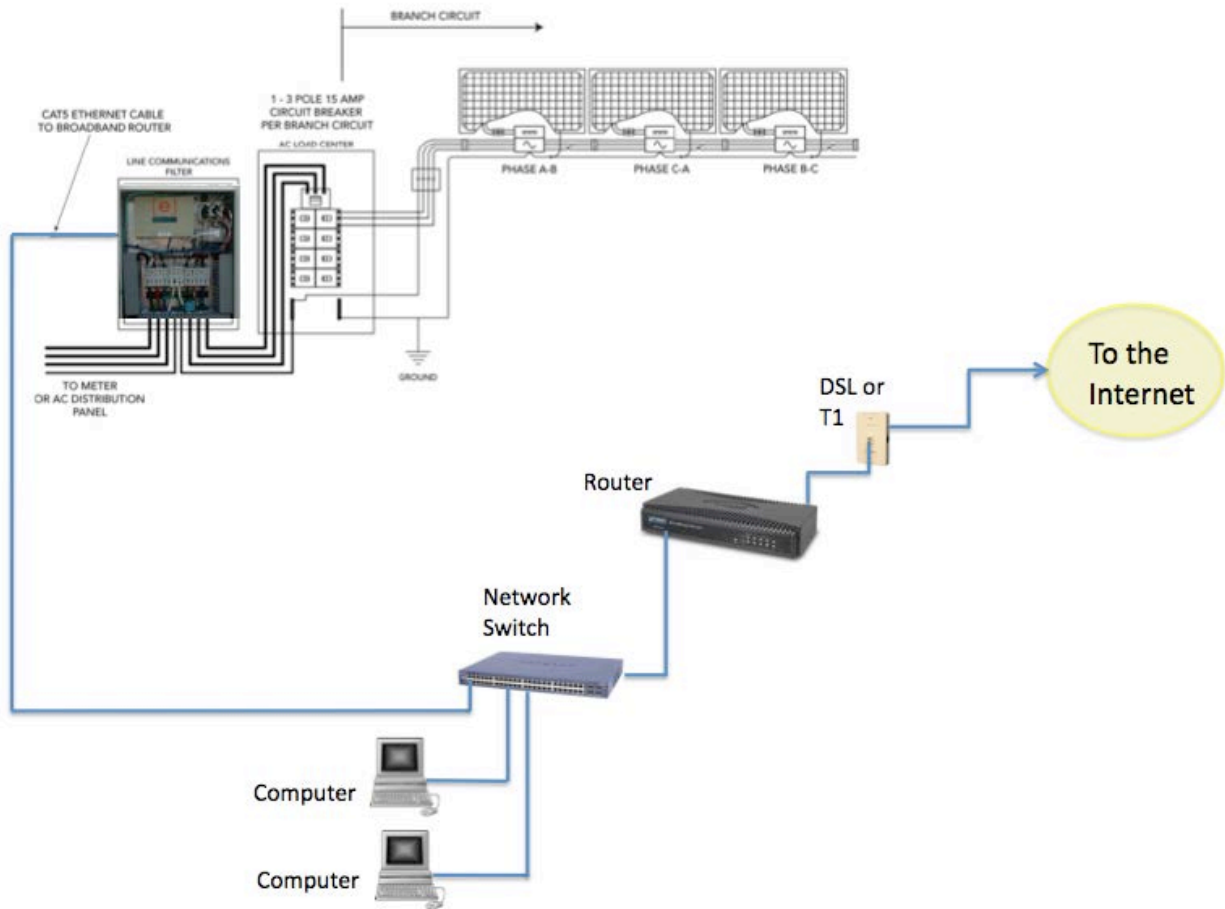
Typical LAN/WAN Network with an Enphase Envoy

In a local area network (LAN)/wide area network (WAN), computers connect to a network switch via standard Ethernet cables. Computers with wireless (Wi-Fi) capability access the LAN through a separate wireless access point, which connects to the network switch. The network switch connects to an upstream router. The router then plugs into the wall plate where the business has a DSL or T-1 connection to the Internet. The Envoy connects to the wired LAN just like another computer would.



Commercial Deployment with a Single LCF and Envoy Pair

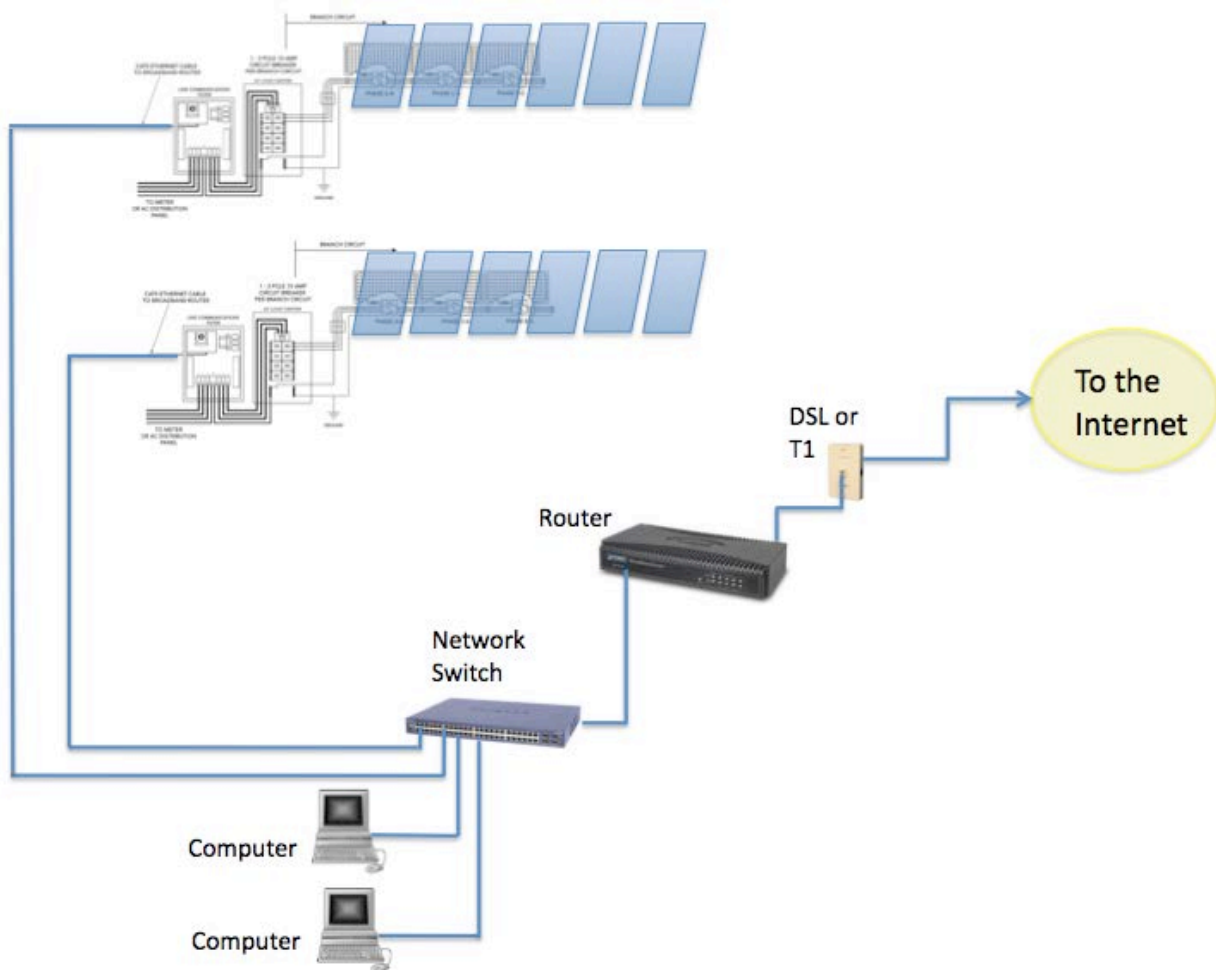
The scenario presented here is similar to the previous LAN/WAN except that the Envoy is inside the LCF near the solar array(s).



While the Envoy is mounted inside of the LCF enclosure, it still needs a standard Ethernet cable for the upstream Internet connection.

Typical Commercial Deployment: Multiple LCF/Envoy

This example shows a commercial deployment with multiple LCFs, each with a built-in Envoy. Each Envoy communicates with its own domain of microinverters through the power lines. The diagram below shows two LCFs, each with its own domain of microinverters and attached photovoltaic (PV) modules.



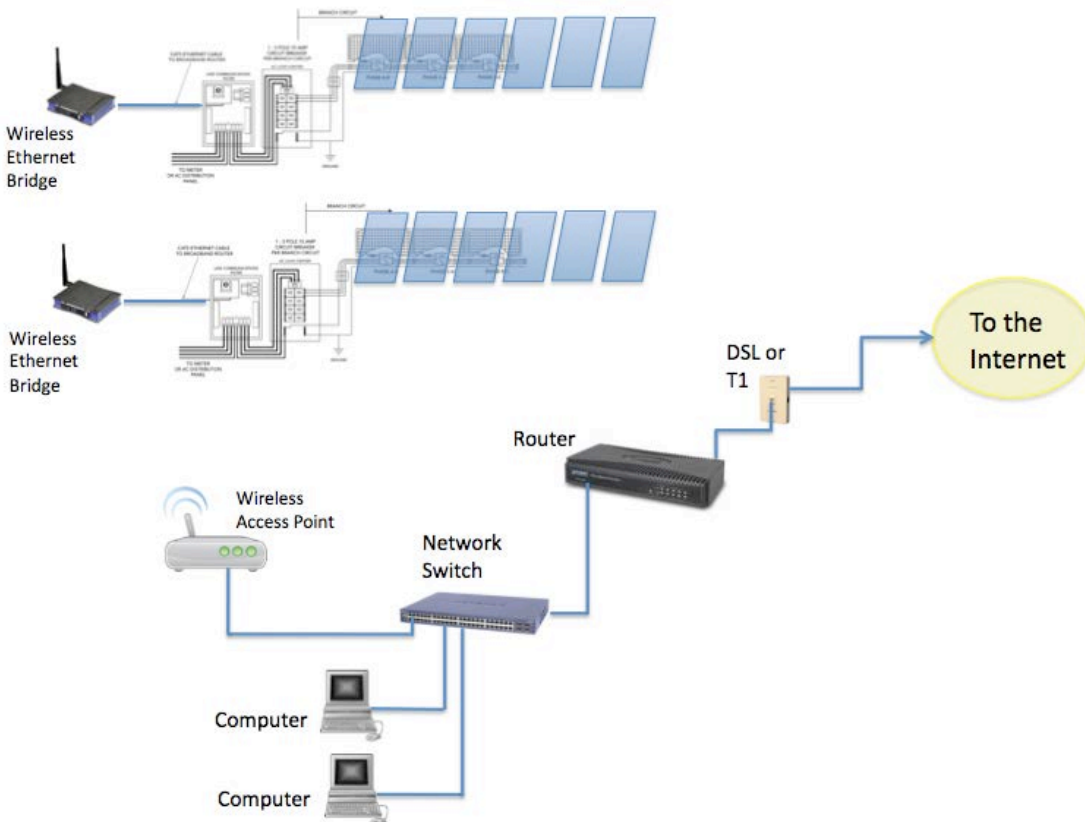
This model scales as large as needed. For each additional communications domain, add another LCF and Envoy pair. The filtering mechanism of the LCF, the power line communications from one communications domain is isolated and separated from any others.

Ethernet Network and Wireless LAN

In commercial deployments, you can install a wireless access point to provide Internet connectivity for one or more LCF and Envoy pairs.

On the network side, the wireless access point is hard-wired connection to an Internet switch or router. On the PV module side, connect a wireless bridge to the Envoy so that it can communicate across Wi-Fi services.

As shown in the diagram below, each Envoy requires its own wireless Ethernet bridge to pass data to the wireless access point.



Wireless LAN Technologies

Consumer-grade Wi-Fi devices have varying ranges of operation. Not all Wi-Fi vendors specify the unobstructed distance for which their product provides wireless coverage.

Wireless specification 802.11g is the current standard, with 802.11n recently ratified. Check vendor specifications for claims of distance and coverage. Also factor in obstructions, such as buildings, walls, and such, for your site.

Wireless vendors include:

- Linksys: <http://home.cisco.com/en-us/wireless/linksys/>
- Netgear: <http://www.netgear.com>
- Ubiquity Networks: <http://www.ubnt.com/>
- Meraki: <http://meraki.com/>

Wireless Routers

Wi-Fi routers provide a wireless gateway to the Internet. Wireless vendors Linksys and Netgear produce reliable Wi-Fi routers. Most come with installation DVDs and software for easy setup, have excellent documentation, and come with phone/online technical support.

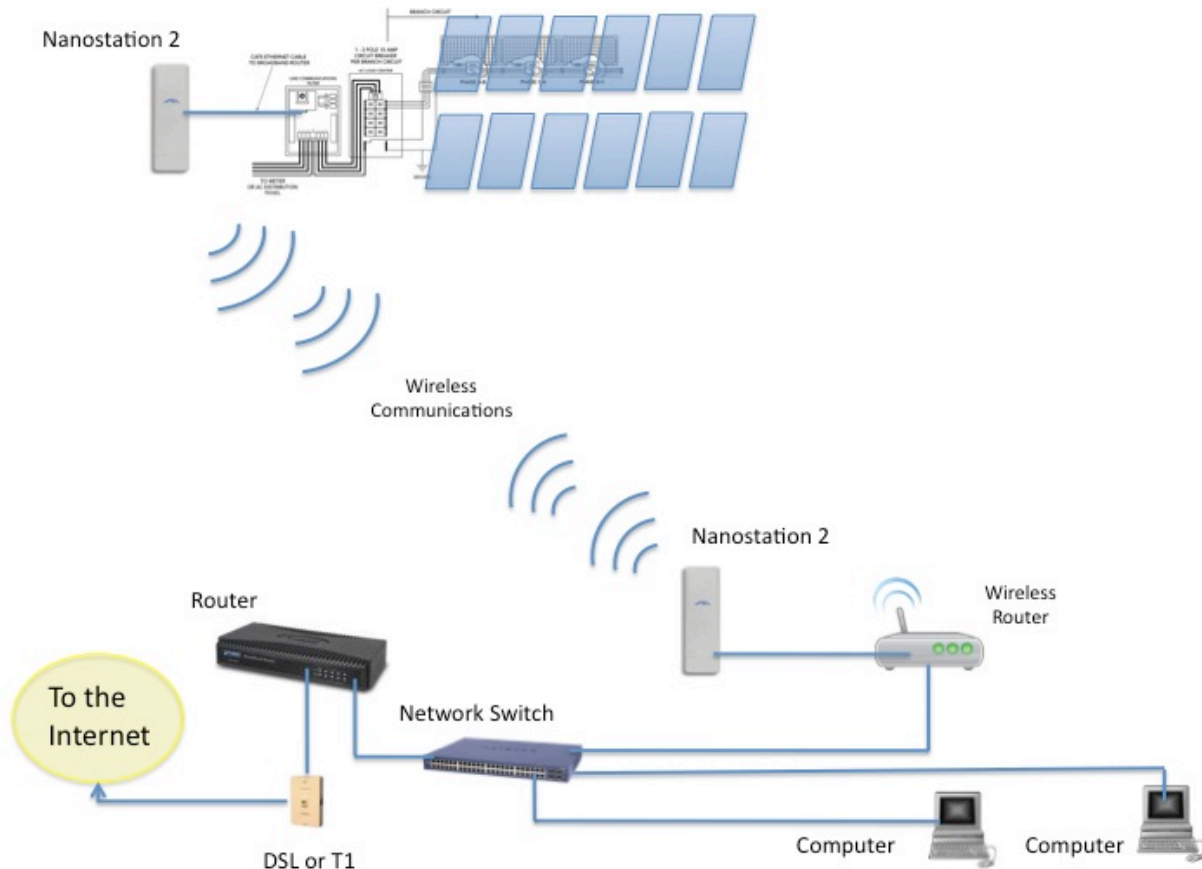
Wireless Ethernet Bridges

A wireless Ethernet bridge converts a wired Ethernet device for use on a wireless network. (Think of it as an external wireless network card). The Linksys WET610N and Netgear WNCE2001 are often recommended.

The Envoy has a USB port currently used for engineering diagnostics, and is not configured for Wi-Fi support. You can, however, power the Netgear WNCE2001 through the Envoy USB port. The Netgear WNCE2001 is about the size of a deck of cards, connects to the Envoy through an Ethernet cable, and is a lot less cumbersome than some other Ethernet (to Wi-Fi) bridges.

Wireless Hi-Gain Antenna Systems

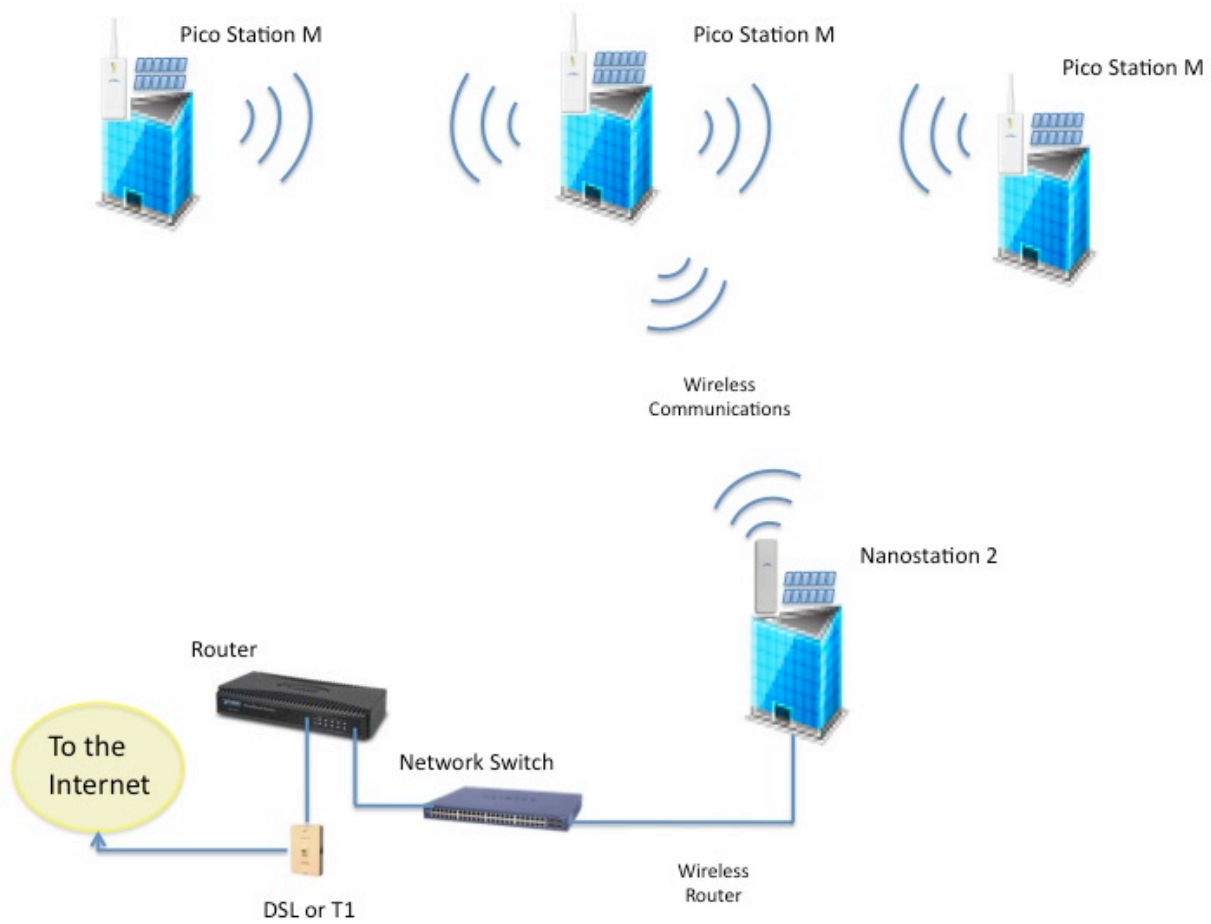
Wireless Hi-Gain Antenna systems can be useful when the distance from the LCF to a wireless router is over 500 feet. Enphase recommends Ubiquity Networks directional Nanostation 2s. The system is made for outdoor use, with a variety of mounting brackets available. Configuration is done through a web interface and tools are available to verify signal strength between devices.



Wireless Mesh Network

A wireless mesh network is a communications network made up of multiple wireless bridges and antennas organized in a mesh topology. Apply this topology at sites with multiple buildings where cabling

can be difficult to deploy. Ubiquity Networks makes a weatherproof Nanostation 2 with PicoStation M units. Meraki Networks also makes a weatherproof unit called the OD2, which is an Omni-directional Wi-Fi access point. The OD2 can connect an LCF and transmit a signal to extend reach to other OD2 devices.



Appendix A: Lightning and Surge Suppression in Commercial Systems

Although not common, the possibility of lightning strikes must be addressed. Following the guidelines in this Appendix helps minimize any lightning related issues with your commercial installation.

Enphase M215 Microinverters, like all electrical components, can be damaged by lightning strikes or voltage surges from the electrical grid. For this reason, Enphase recommends that you protect your system with lightning and/or surge suppression devices. While lightning is not common in all regions, surges can occur anywhere on the electrical grid.

Enphase Microinverters have integral surge protection that is more robust than most string inverters. However, if the surge has sufficient energy, the protection built into the microinverter can be exceeded and the equipment may be damaged.

This section recommends some lightning protection and surge suppression devices, but there are a wide range of devices that can be installed with a wide range of warranties available from the equipment manufacturers. However, 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.

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. Enphase Microinverters have integral surge protection that is more robust than most string inverters. However, if the surge has sufficient energy, the protection built into the microinverter can be exceeded, and the equipment may be damaged.

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 Devices

Since the Enphase Limited Warranty does not cover “acts of God” such as lightning strikes, and since lightning strikes can occur anywhere, it is best practice to install surge protection as part of any solar installation. Enphase recommend the following protection devices. These have been tested to ensure that they do not interfere with Enphase power line communications, but most devices should work fine. Install per vendor instructions.

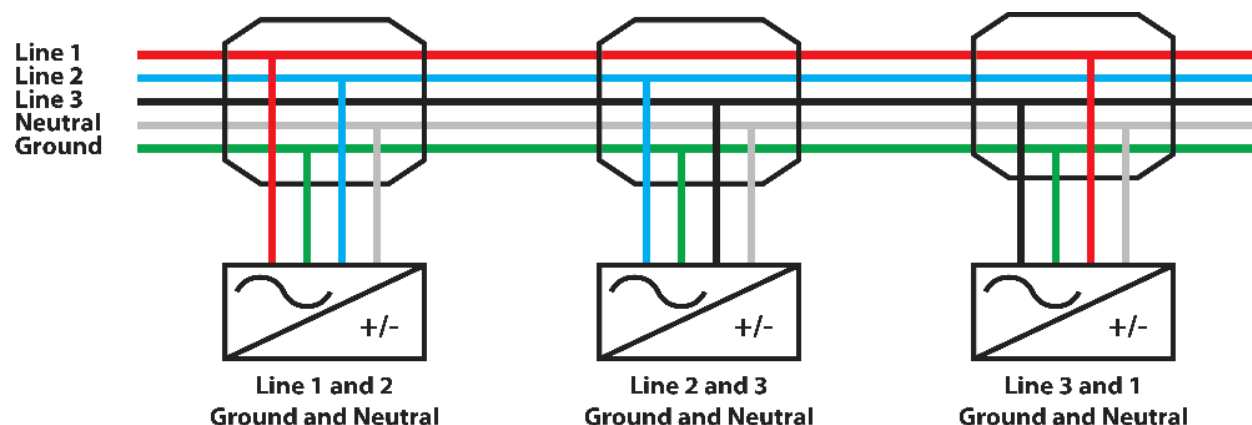
- Delta LA-302 Lightning Arrester for single-phase AC applications
- Delta LA-303 Lightning Arrester for three-phase AC applications
- Leviton 51110-001 Single-Phase Surge Suppression Device
- Citel SP-120 Branch Panel Protector

Appendix B: Dropped Phase Hardware Solution

For project success, you must consider phase imbalance when designing commercial PV systems using M215 Microinverters that interconnect to a three-phase service. This appendix provides details and recommends best practices for designing systems compatible with utility phase imbalance guidelines.

Dropped Phase Scenario

The Enphase M215 Microinverter connects to two of the three available phases of a three-phase 208V WYE service. Three-phase 208VAC Engage Cable includes five conductors and is used for most commercial installations. Because Enphase Microinverters output onto two phases, three-phase cabling balances the phases by rotating conductor use from one microinverter to the next by alternating between phases (within the cabling) between each microinverter. For example, if the first microinverter (connector A) is connected to phases 1 and 2, then the second will be connected to 2 and 3, the third to 3 and 1, and the fourth to 1 and 2 once again. The pattern continues to repeat itself, modulo three, as shown in the following diagram.



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

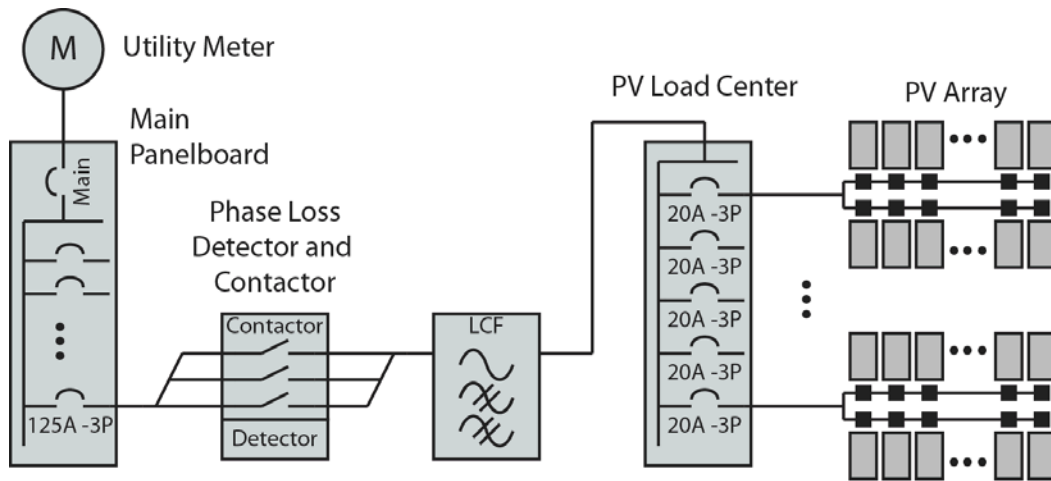
Dropped Phase Hardware Solution

Enphase recommends the use of an overload relay system for loss of phase applications. An overload relay system consists of:

- An overload 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, an overload 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 overload relay, and the overload relay must be powered by a dedicated breaker connected to grid power on the grid side of the dedicated PV portion of the system.

Install the combined relay-contactor system on the PV system side of the PCC and on the grid side of the LCF. For systems with no LCF, install the relay-contactor system on the grid side of the main PV load center, as shown in the following diagram.



For example, in a 10kW installation, we recommend a 40-50A, general use, IEC rated, 120V coil contactor, available from Allen-Bradley or equivalent. The overload relay part number is in the group 193-xxxx. The contactor part number, also from Allen-Bradley (Rockwell Automation), is in the group 100-xxx.

Siemens, ABB and Square D are all examples of reputable manufacturers of overload relays and contactors.

Appendix C: Fault Current Contribution in the M215 Microinverter

Appendices C and D address two technical characteristics of power output in the Enphase M215 Microinverter system, *fault current* contribution and *total distortion*: Utilities are interested in these characteristics because:

- The total maximum fault current that a distributed energy resource (DER) contributes determines how robust the over-current protection device (OCPD) on the downstream (grid) side should be.
- Total distortion indicates how closely the device output power signal adheres to an ideal sine wave.

Follow the guidelines in this Appendix to help minimize any loss of phase issues that might arise.

Fault Current Contribution

This section is in response to inquiries received by Enphase about the relationship of fault current contributions to kilo-Ampere Interrupting Capacity (kAIC) ratings.

The fault current contribution of Enphase Microinverters is far less than the kAIC rating of any circuit breaker. Only circuit breakers, fuses, and some load-rated switches have AIC ratings. As a current source, a utility interactive inverter does not by itself, require an AIC rating.

Some utility electrical services requirements state that the short circuit current and OCPD shall be based on the type of service that is provided to the system (PCC). For instance, for residences, duplexes, and mobile homes supplied at 120/240 volts, one phase, three wire:

- At 0–225A service ampacity, the short circuit current rating (SCCR) required is 10kA.
- At 226–400A service ampacity, the SCCR required is 22kA.

Utilities are concerned with the kAIC rating of the main breaker for two reasons:

1. Will the breaker interrupt the current when a fault is present on the residential (load) side of the breaker?
2. Will the breaker interrupt the current supplied by the Distributed Generator (DG) when the short is located on the grid side? Is it possible for the DG to deliver more current than the circuit breaker can interrupt?

Calculating Fault Current Contribution from Enphase Microinverters

When calculating the fault current contribution from Enphase Microinverters, add up the fault current contribution from all microinverters. Compare this sum to the AIC rating of the main breaker.

For a M215 Microinverter on a 240V single-phase connection, the correct fault contribution value is 1.05 ARMS for 3 cycles.

In an installation with 120 microinverters and with a main breaker rated at 10kAIC, the fault current contribution from the microinverters is:

$$120 \text{ microinverters} * 1.05 \text{ ARMS} = 126 \text{ ARMS for } t/hree \text{ cycles}$$

Since this value is only a small fraction of 10 kAIC, the 10 kAIC main breaker is sized correctly to interrupt any fault current contributed by the DG.

Likewise, the utility must insure that the fault current supplied from the utility is less than 10kA. The utility determines this based on several factors, including:

- The full load amps of the transformer (Most important)
- The transformer impedance

This information should be available from the nameplate rating of the utility transformer. From this information, you can determine the fault current available from the utility. For the previous example, the fault current should be less than 10 kAIC. For larger service ampacities, the rating should be higher.

In *Understanding Fault Characteristics of Inverter-Based Distributed Energy Resources*, a National Renewable Energy Laboratory study published in January 2010, Keller & Kroposki address fault current contributions of Distributed Energy Resources (DERs) and inverters in particular:

Inverters do not dynamically behave the same as synchronous or induction machines. Inverters do not have a rotating mass component; therefore, they do not develop inertia to carry fault current based on an electro-magnetic characteristic. Power electronic inverters have a much faster decaying envelope for fault currents because the devices lack predominately inductive characteristics that are associated with rotating machines. These characteristics dictate the time constants involved with the circuit. Inverters also can be controlled in a manner unlike rotating machines because they can be programmed to vary the length of time it takes them to respond to fault conditions. This will also impact the fault current characteristics of the inverter.

Conclusion

The UL 1741 standard requires a short circuit test and listing the available fault current and duration. The discharge at the output of the inverter is through as short a length of wire as possible at an extremely low resistance. The discharge is not sustained and as soon as any real world resistance from circuit conductors is included, the available fault current is dramatically reduced. PV modules and utility interactive inverters are both current limited devices. For a fault condition in any portion of the system, the fault current required to open over current protection devices would necessarily always come from the utility, which remains the only source of a current of sufficient magnitude to do so.

Appendix D: Total Rated-Current Distortion and Total Demand-Current Distortion

This appendix addresses the other technical characteristic of power output in the Enphase M215 Microinverter System, *total distortion*.

Harmonic rated distortion and demand distortion are both measurements of how closely a device's output power signal adheres to an ideal sine wave.

Distortion is measured at 40 different harmonics, fundamental (60Hz) to the 40th harmonic (50.4kHz), and across three power levels, 33%, 66%, and 100% of rated output capacity.

Two measurements are recorded, Total Rated-Current Distortion (TRD) and Total Demand-Current Distortion (TDD). All measurements are made according to the procedures outlined under IEEE 1547.1, Clause 5.11

The M215 meets the specifications as outlined in IEEE 1547, Clauses 4.3.3 and 5.1.6:

- Typical value for TRD for the M215 is 2.0%
- Typical value for TDD for the M215 is 1.3%

Conclusion

Enphase Microinverters do not require a kAIC rating. M215 Microinverter power outputs have a total distortion far lower than that required by IEEE 1547 or UL 1741.

Sharing the above information with your local Authority having Jurisdiction and Utility, as appropriate, may lessen power quality related issues in your commercial Enphase Microinverter design and installation.

Acronyms and Glossary

3G/4G: 3rd and 4th generation mobile technology application defined by a set of ITU standards.

AIC: Ampere Interrupting capacity Applies to protective interrupting devices and is measured as Amps RMS Symmetrical. AIC is the maximum fault current that a protective device can safely clear.

Ampacity: Ampere capacity.

ANSI: The American National Standards Institute oversees consensus standards for products and services in the US.

CAT5/6: Types of twisted cable pairs used for computer network transmission manufactured according to specifications defined by American National Standards Institute/Telecommunications Industry Association/Electronics Industry Association (ANSI/TIA/EIA).

Delta Configuration: Delta power is a three-phase configuration where ground and neutral are not referenced equally to all three legs but are halfway between the voltages derived from two of the legs.

DER: Distributed energy resource.

DG: Distributed generator.

EGC: Equipment ground conductor.

Ethernet: A physical and data link layer technology used as a transmission medium, normally measured in megabits per second (Mbps).

GEC: Ground electrode conductor.

IEC: The International Electrotechnical Commission is an organization that published international standards for electric and electrical products.

K-Factor: K-factor is the value that measures how much harmonic current a transformer handles before exceeding the maximum temperature rise level. The range is from 1 to 50. A K-factor transformer is rated to withstand harmonic heating and currents when operating within specified temperature limits.

LAN: Local area network.

LCF: Enphase Line Communication Filter.

NEC: National Electric Code. Standardized U.S. electrical code, widely adopted and used in all 50 states and US territories.

O&M: Operations and maintenance.

OCPD: Over current protection device.

PBI: Performance-based incentive.

PCC: Point of Common Coupling.

PLC: Power line communication. PLC technology enables signal transmission over the same AC lines used for on-site power distribution.

PV: Photovoltaic.

Revenue grade meter: A metering device capable of measuring power production within $\pm 2\%$ per ANSI standard C12.1-2008.

SCCR: Short Circuit Current Rating applies to equipment or components and is measured as Amps RMS Symmetrical. SCCR is the maximum fault current that a component can safely withstand.

WAN: Wide area network.

Wi-Fi: Wi-Fi is a trademark of the Wi-Fi Alliance and is a technology for wireless data transmission in a wireless local area network (WLAN). Wi-Fi is an acronym of the phrase, wireless fidelity.

Wye Configuration: Wye power is a three-phase configuration where phase-to-neutral is equal on all three legs.

Enphase Energy Inc.
1420 N. McDowell Blvd.
Petaluma, CA 94954
www.enphase.com
info@enphaseenergy.com
support@enphaseenergy.com