Commercial PV Using the Enphase C250 Microinverter System

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Section 1: Enphase Commercial Design Fundamentals

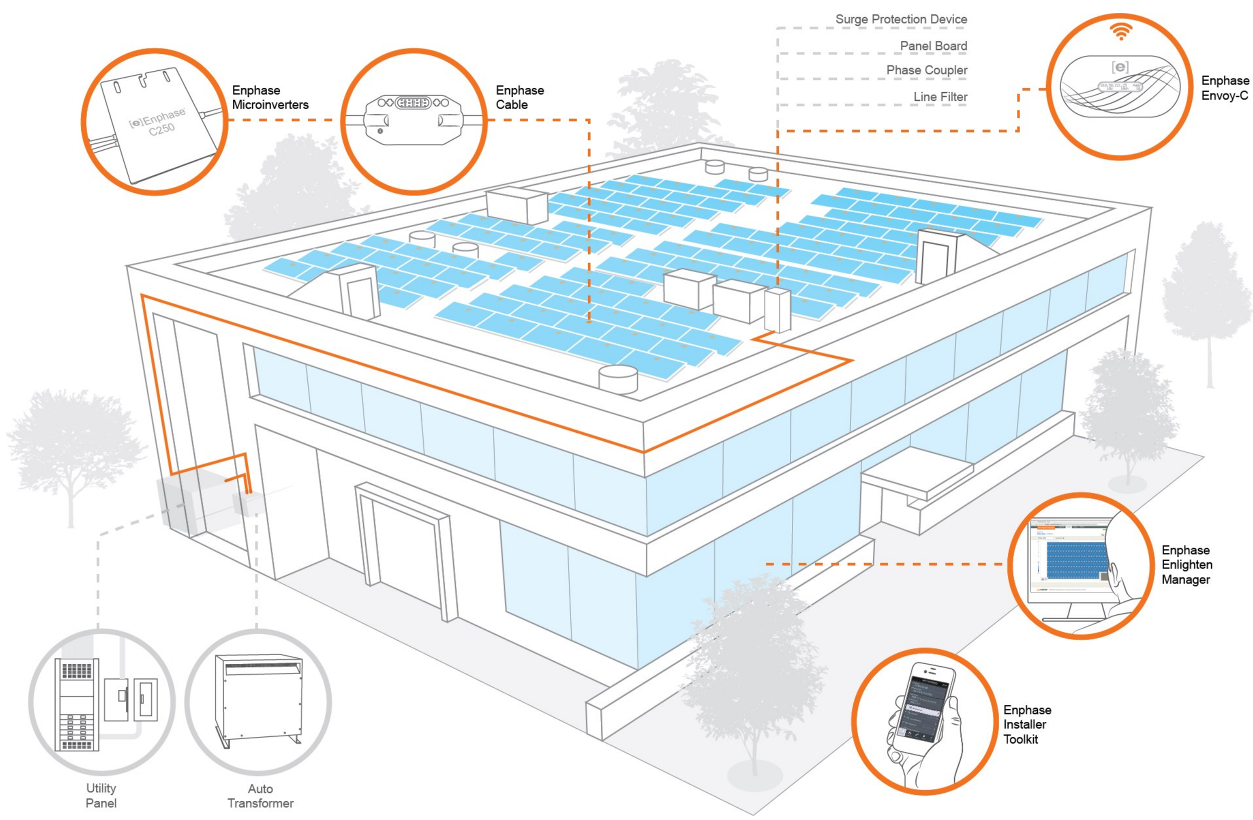
Introduction to the C250 Microinverter System

The Enphase® C250™ Microinverter System™ is the world's most technologically advanced inverter system for use in utility-interactive applications.

The Enphase Microinverter System delivers design flexibility, integrated intelligence, increased energy harvest, and system availability not found in central string and central inverter-based systems. Join the thousands of solar integrators and developers who chose Enphase Microinverters for large-scale photo-voltaic installations.

The simple and cost effective C250 Microinverter System is designed for commercial and utility scale projects and operates with an auto-transformer where the distribution voltage is 480Y/277 V.

The C250 Microinverter System can have up to 48 microinverters per branch circuit operating at 422Y/244 V three-phase. These long branch circuits operating at higher voltages allow for unparalleled reductions in the balance of system (BOS) costs. The long branch circuit lengths help to minimize electrical component costs, specifically with fewer circuit breakers, fewer branch circuits, and fewer panel boards. The higher operating voltage of the C250 Microinverter System reduces the ampacity of the system. This reduction permits a major reduction in conductor sizing due to reduced voltage drops at higher voltages.



This design guide details concepts and tips for designing commercial PV systems using C250 Microinverters.

Follow the 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-C® Communications Gateway™.

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

The key components of an Enphase C250 Microinverter System include the Enphase:

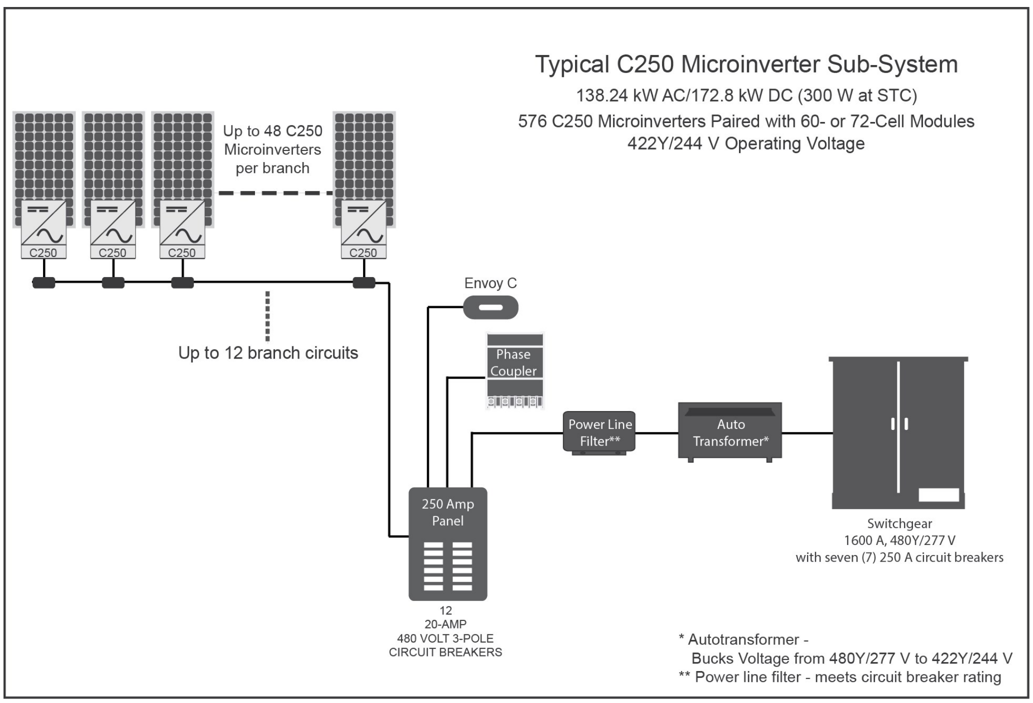
- C250 Microinverter
- Envoy-C Communications Gateway
- Installer Toolkit
- Enlighten® web-based monitoring and analysis software platform
- C250 Engage Cable

The simplified design, straightforward installation, and flexible management of the C250 Microinverter System maximizes energy harvest and increases system reliability in your commercial project.

C250 System Design Overview

The typical C250 Microinverter System consists of one or more sub-systems, with up to 600 microinverters per sub-system, installed onto a single panel board. You should base the exact number of microinverters per panel board on the site layout and array configuration.

A common design is to connect a sub-system of 576 C250 Microinverters to a 422Y/244 V 250 A panel board. This design is cost-effective because you can maximize the 250 A panel board and still maintain fewer than 600 microinverters per sub-system.



Many panel boards are limited to 42 breaker positions, with 14 three-phase circuit breakers per panel board.

In a C250 Microinverter System, you must reserve additional breaker positions for the Envoy-C and phase coupler. In a typical C250 system, you would have a limit of 12 or 13 branch circuits per panel board. With 48 microinverters per branch circuit, you still remain under the 600 microinverter limit of the Envoy-C. You can then scale the number of sub-systems to meet the total system size desired.

Enphase System Components and Concepts

This section describes Enphase Microinverter System components and concepts for your commercial design plans.

Activation Process: Activation is the process of connecting Enphase Microinverters to the Enlighten web-based monitoring software platform (enlighten.enphaseenergy.com). Enlighten provides monitoring for up to 4,000 microinverters in one activated PV system. If your project contains over 4,000 microinverters, you can activate multiple PV systems in Enlighten.

Auto-transformer: An auto-transformer is a non-isolating transformer used for adjusting voltages. The prefix, *auto-*, refers to the transformer's single coil, and not to an automatic mechanism. The advantages of auto-transformers over isolating transformers are that auto-transformers are more affordable, smaller, lighter and more efficient. When using an auto-transformer to buck voltage down, only a portion of the load kVA is actually transformed. The majority of the load is passed through to the source directly, allowing for transformer losses to occur on only a small part of the system. The primary disadvantages of auto-transformers are that they do not provide isolation and cannot create a neutral (See Isolation Transformer).

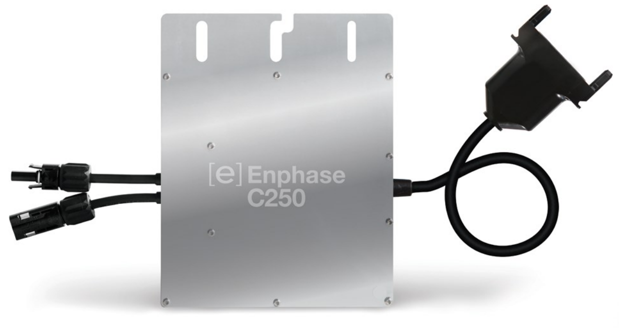
Center-Feed Method: The center-feed method separates an individual branch circuit into two sub-branch circuits on the same over current protection device (OCPD). Center-feed is standard design practice for Enphase Microinverters. Center-feeding a branch circuit lowers overall wiring costs by reducing voltage drop and potentially avoid the need to upsize distribution wiring. You can find out more in Advantages of Center-Feeding Branch Circuits on page 29.

C250 Microinverter: The C250 Microinverter operates with a transformer in commercial systems where the power distribution is 480Y/277 V. The C250 Microinverter is 96.5% efficient and works with most 60- and 72-cell modules up to 350 watts at STC.

The C250 is rated for a continuous output of 240 watts.

Use the C250 at sites with three-phase service and a nominal operating voltage range of 220 V ac to 248 V ac line-to-neutral. Each C250 branch circuit feeds a 20 A circuit breaker. You can install up to a maximum of 48 C250s on an AC branch circuit that is protected with a 20 A OCPD.

Service Type	Maximum Number of C250s on a 20 A Branch Circuit	Maximum Number of C250s on a 20 A Branch Circuit for HEI-connected projects**
Three-phase	48	42
** Refer to Appendix A: Hawaiian Electric Industries Requirements for C250 Projects on page 48 for details about inter-connecting to grids managed by Hawaii Electric Industries (HEI).		

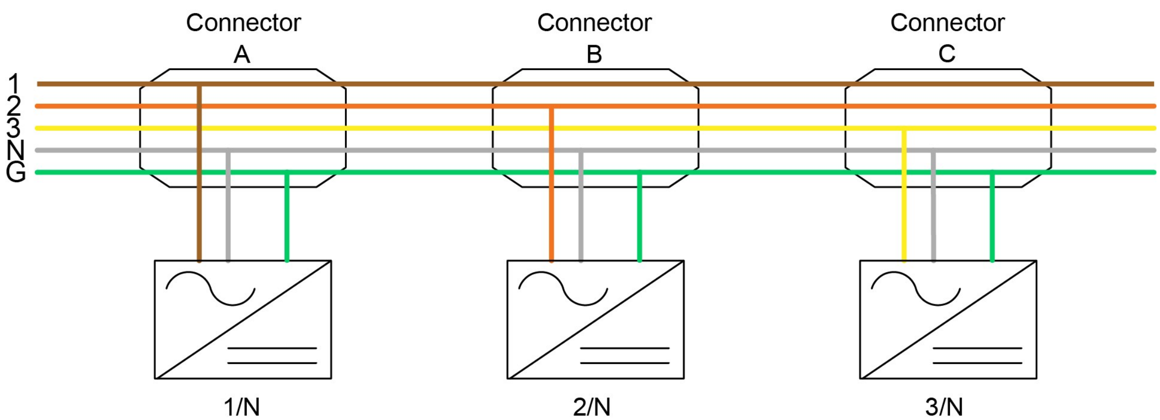


The C250 does not require a Grounding Electrode Conductor (GEC) because the DC circuit is isolated and insulated from ground.

Communication Domain: A communication domain is a group of PV module and microinverter pairs that communicates with a common Envoy-C. A single Envoy-C can monitor up to 600 microinverters. A communication domain is a standard building block in an Enphase Microinverter System and constitutes a single sub-array.

C250 Engage Cable: The C250 Engage Cable is an innovative cabling system used to connect Enphase Microinverters. The C250 Engage Cable has a connector for each microinverter, with connectors placed every 1.025 meters for portrait applications, 1.7 meters for 60-cell landscape applications, or 2.1 meters for 72-cell landscape applications. The C250 Engage cable contains #12 THWN-2 conductors and is rated to feed a 20 A circuit breaker.

Use C250 Engage Cable only with the C250 in three-phase applications. You can find specifications for C250 Engage Cable in the C250 Microinverter System data sheet.



Enlighten®: The Enlighten Monitoring software platform offers Web-based tools to manage Enphase Microinverter Systems. Use Enlighten to access and monitor your fleet of PV installations down to the individual module. Enlighten provides detailed diagnostics so that you can determine whether a system is performing as expected.

Envoy-C Communications Gateway: The Envoy-C Communications Gateway is a system monitoring device that monitors up to 600 C250 Microinverters. The Envoy-C uses power lines on site to communicate with each C250 Microinverter, uploading microinverter data to Enlighten through an Internet broadband router or other networking components. The Envoy-C power cord (NEMA 6-15P) requires a 250 V, 60 Hz, NEMA 6-15 or NEMA 6-20 receptacle.

Use the Envoy-C (ENV-C250) **only** with the C250; it is not compatible with the North American M-Series Microinverters. Furthermore, the C250 Microinverter System is not compatible with the Envoy model, ENV-120, used in 208Y/120 V and 240 V systems.

Filtering Communication Domains: If you have more than one communication domain connected to a common service panel, or to a single transformer, take steps to filter cross-talk between domains. You can prevent cross-talk by using power line communication filters or isolation transformers.

You must also physically separate the conduits and wires of one communication domain from another communication domain by at least 12 inches.

Installer Toolkit: The Enphase Installer Toolkit is a mobile app for iOS and Android devices that allows installers to configure the system while onsite, eliminating the need for a laptop and improving installation efficiency. You can use the app to:

- Connect to the Enphase EnvoyCommunications Gateway over a wireless network for faster system setup and verification.
- View and email a summary report that confirms a successful installation.
- Scan microinverter serial numbers and sync system information with Enlighten monitoring software.

Isolation Transformer: Isolation transformers are the most common transformers used in power systems, and are widely used when stepping from medium distribution voltages to lower service voltages. An isolation transformer isolates two electrical circuits, feeding AC power from one circuit into another circuit without electrically connecting the two circuits. An isolation transformer allows for the creation of a neutral conductor from the delta configured grid.

An isolation transformer is also an excellent filter of electrical noise and communication signals, and provides isolation of communication domains. Transformers generally have adjustable taps that allow for adjustments to the utility voltage.

Main Photovoltaic Panel Board or Switch Gear: The centralized point of distribution that feeds the microinverter panel boards.

Microinverter Panel Board: A microinverter panel board is an electrical distribution center dedicated to a single communication domain. The microinverter sub-panel contains multiple 20 A circuit breakers. One circuit breaker feeds one microinverter AC branch circuit. When selecting a sub-panel board, you must specify a rating of 480Y/277 V for C250 Microinverter Sub-Systems. The typical *C250 Microinverter Sub-System* graphic on page 4 shows the output voltage of the auto-transformer. Note that the microinverter sub-panel is rated for 480Y/277 V.

Phase Coupler: In a three-phase system, use a phase coupler to provide a path for the Enphase power line communication (PLC) signal to transmit on each phase. This allows the microinverters on each phase in the array to communicate with the Envoy-C. Use one phase coupler with one Envoy-C.

Power Line Communication: Power line communication (PLC) technology enables signal transmission over the same AC lines used for on-site power distribution. The Enphase C250 and the Envoy-C Communication Gateway use power line communication in the 110 KHz range to send and receive data.

Power Line Filter: Use power line filters or EMC filters to isolate multiple Envoy-C communication domains or to filter electrical noise from site loads. A power line filter is also known as a Line Communication Filter (LCF).

Separating 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 within a communication domain must be physically separate from the conduits and wiring of other communication domains.

Separate conduits and wiring on the array side of the filters by at least 12 inches.

Startup Procedure: By following the start-up procedures detailed in Section 6: Commissioning at Sites with Multiple Envoy-Cs on page 40, you help prevent cross-talk between communication domains in a commercial installation. Scan the devices in one communication domain using that domain's Envoy-C.

When that scan is complete, end the Envoy-C device scan, and then commission the next communication domain.

Limitless Scalability

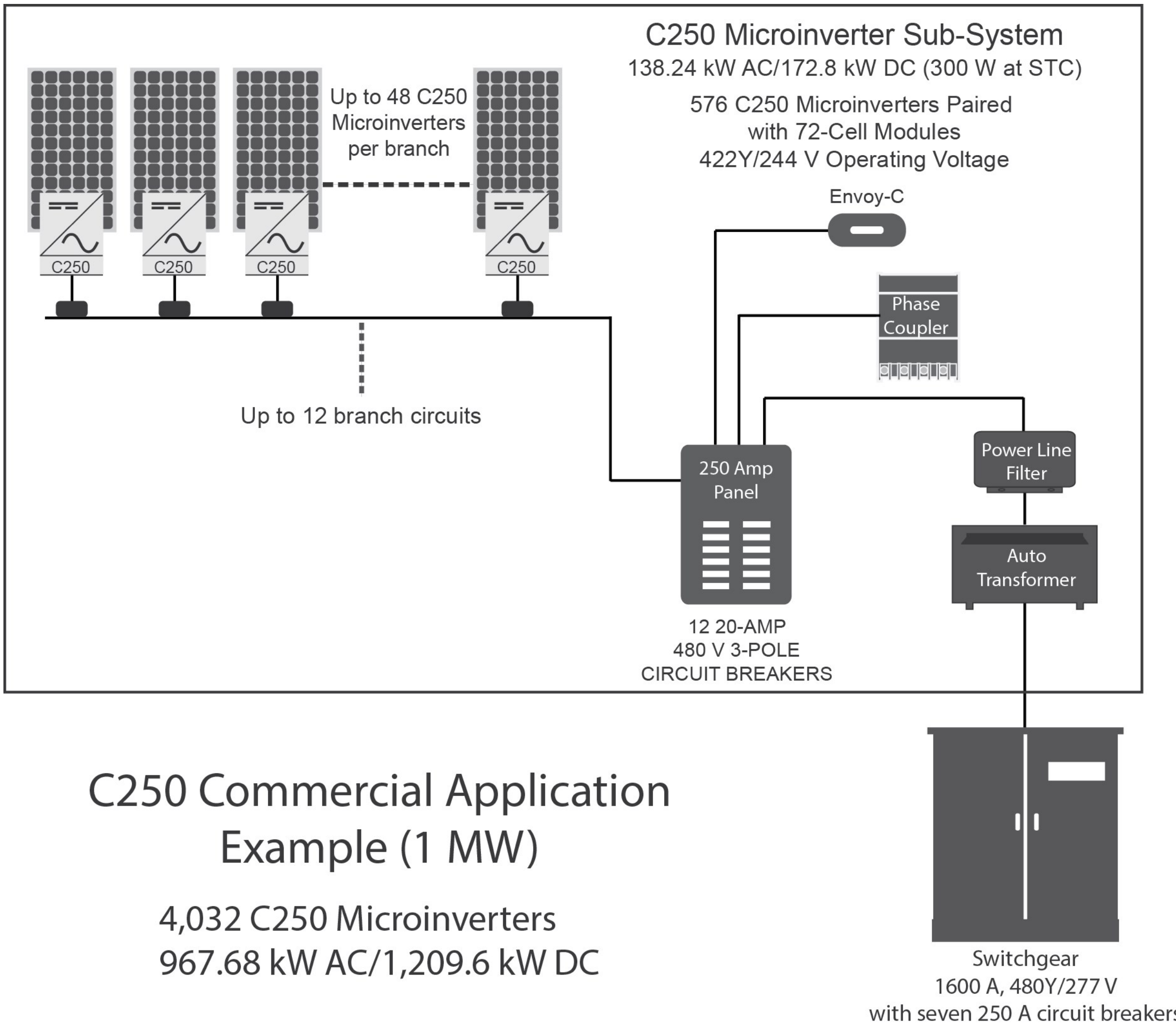
The size of an Enphase system is practically limitless. An Enphase commercial-scale project generally includes a main panel board or switch gear that feeds multiple microinverter panel boards that are distributed across the system. This scalable design is only limited by the utility grid that feeds the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

Like all Enphase Microinverter systems, the C250 Microinverter System is free of string sizing and concerns related to mismatch and partial shading. Since each microinverter uses maximum power point tracking (MPPT) on each individual module, you have total freedom to mix and match module tilts, types, and orientations. All of the benefits of a microinverter system still apply, with the added benefit of longer branch circuit lengths and significantly reduced wire costs.

The number of Envoy-C Communication Gateways needed generally determines the number of microinverter panel boards to install. Since one Envoy-C monitors the output of up to 600 C250 Microinverters, you can divide your system into sub-systems of 600 microinverters or fewer.

About Transformers, Phase Couplers, and Filters in the C250 System

This section describes some ways to create an acceptable operating voltage for the C250 Microinverter and ways to isolate communication domains.



The C250 Microinverter can operate with nominal voltages between of 220 V and 248 V, line-to-neutral. This range allows you to install the C250 into a variety of Wye-configured voltage applications.

Transformers and C250 Operating Voltages

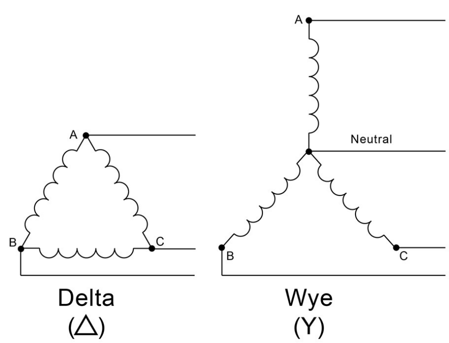
Commercial PV system designers in North America usually work with 208Y/120 V, 480Y/277 V, 480 V Delta, and 600Y/346 V power systems.

It is simple to design and install a commercial PV system that generates the operating voltage of the Enphase C250 Microinverter using readily available, off-the-shelf auto-transformers or other transformers detailed below.

Primary-Side Utility Voltage	Transformer Description	Secondary-Side Microinverter Operating Voltage
480Y/277 V	Acme Auto-Transformer[x]	422Y/244 V
208Y/120 V	Hammond Power Systems Auto-Transformer	426Y/246 V
Medium Voltage	Medium Voltage to 440Y/254 V (tapped down 2.5%)	430Y/248 V
600Y/346 V	600Y/346 V to 440Y/254 V (tapped down 2.5%)	430Y/248 V
240 V Delta or 240 V High-Leg Delta	240 Delta to 440Y/254 V	430Y/248 V
480 V Delta	480 Delta to 440Y/254 V (tapped down 2.5%)	430Y/248 V
120/240 V	Not Compatible with Single-Phase Inter-connections	Refer to the Enphase M-Series Microinverter

[x] Other sections in this guide provide details about using Acme auto-transformers in C250 systems.

These operating voltages and transformers operate in WYE (Y) configurations. You cannot use an auto-transformer to generate a neutral connection. If the utility service is a Delta (Δ) configuration, use an isolation transformer to generate a neutral connection.



Delta and Wye Wiring Configurations

If you interconnect a C250 Microinverter System to the Hawaii Electric Industries (HEI) grid, you must apply auto-transformer settings specific to that grid. You can find out more in in Appendix A: Hawaiian Electric Industries Requirements for C250 Projects on page 48

Bucking the Voltage Down from 480Y/277 V to 422Y/244 V

An easy and efficient way to generate the operating voltage for the Enphase C250 Microinverter is to use an Acme Electric distribution auto-transformer to buck the voltage down from 480Y/277 V to 422Y/244 V.

When using an auto-transformer to buck the voltage down, only a portion of the load kVA is transformed. The majority of the load passes through to the source directly, so transformer losses occur in only a small part of the system. Since only a small portion of the system power passes through the auto-transformer, auto-transformers are lighter, smaller, more affordable, and more efficient than a traditional isolation transformer.

The primary disadvantages of auto-transformers are that they do not provide isolation and nor do they create a neutral. Since an auto-transformer does not provide isolation, you will need to use additional power line filters to isolate multiple Envoy-C communication domains.

Acme Electric Auto-Transformers for 480Y/277 V Applications

This table lists Acme Electric distribution auto-transformers that Enphase has evaluated for use with the C250 Microinverter System.

Acme Electric Dry Type Distribution Auto-Transformers					
Part No.	kVA	Height (in)	Width (in)	Depth (in)	Weight (lb)
A3015K0181C	12	15.21	19.25	7.37	104
A3030K0181C	24	15.21	19.25	7.37	152
A3045K0181C	36	15.21	19.25	7.37	156
A3075K0181C	60	18.86	20.3	9.03	300
A3112K0181A	90	25.5	24.4	19.4	325
A3150K0181A	120	25.5	24.4	19.4	350
A3225K0181A	180	29.41	28.15	22.37	600
A3300K0181A	240	29.41	28.15	22.37	650
A3450K0181A	360	35.47	31.9	26.88	750
A3500K0181A	400	35.47	31.9	26.88	790

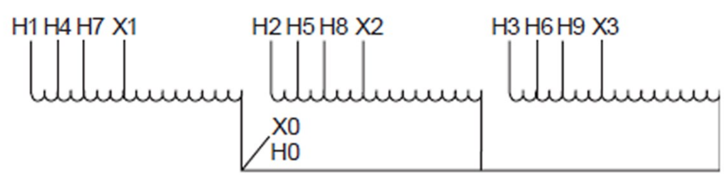
Acme Electric Auto-Transformer Wiring, 480Y/277 V to 422Y/244 V

You can wire the Acme distribution transformer to create a utility interconnection voltage of 422Y/244 V. This is an acceptable voltage for the operation of Enphase C250 Microinverters.

The following table lists wiring for auto-transformers in the 12 kVA to 75 kVA ranges.

Interconnections for Acme 12 kVA to 75 kVA Auto-Transformers:
A3015K0181C, A3030K0181C, A3045K0181C, A3075K0181C

Primary Volts	Alt Rating	Connect Primary Lines to	Interconnect	Connect Secondary Lines to
600	480	H1, H2, H3		
570	456	H4, H5, H6		
540	432	H7, H8, H9		
Secondary Volts				
480	380			X1, X2, X3
277 1-Phase	220 1-Phase			X1 to X0 X2 to X0 X3 to X0



36 KVA to 60 KVA

The 480Y/277 V wiring on the primary (utility) side for the 12 kVA to 60 kVA ranges are:

- Neutral to H0
- L1, L2, L3 to H7, H8, and H9
- Cap Off: H1, H2, H3, H4, H5, H6

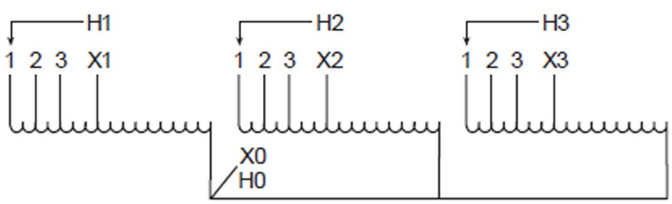
The 422Y/244 V wiring on the secondary (solar) side for the 12 kVA to 60 kVA ranges are:

- Neutral to X0
- L1, L2, L3 to X1, X2, X3

The following table lists wiring for auto-transformers in 90 kVA to 400 kVA ranges.

Interconnections for Acme 90 kVA to 400 kVA Auto-Transformers:
A3112K0181A, A3150K0181A , A3225K0181A, A3300K0181A, A3450K0181A , A3500K0181A

Primary Volts	Alt Rating	Connect Primary Lines to	Interconnect	Connect Secondary Lines to
600	480	H1, H2, H3	1	
570	456	H1, H2, H3	2	
540	432	H1, H2, H3	3	
Secondary Volts				
480	380			X1, X2, X3
277 1-Phase	220 1-Phase			X1 to X0 X2 to X0 X3 to X0



90 KVA to 400 KVA

The 480Y/277 V wiring on the primary (utility) side for the 90 kVA to 400 kVA ranges are:

- Neutral to H0
- L1, L2, L3 to H1, H2, H3 and interconnect to 3
- Cap Off: All 2s and All 3s

The 422Y/244 V wiring on the secondary (solar) side for the 90 kVA to 400 kVA ranges are:

- Neutral to X0
- L1, L2, L3 to X1, X2, X3

Stepping the Voltage Down from Medium Voltage

For most utility-scale and large commercial sites, the system interconnects directly to the utility grid at medium voltage. That voltage depends on the distribution voltage of the grid at the site, but 7.2, 12.47, 25, and 34.5 kV voltages are common in the United States.

Interconnecting directly to medium voltage requires a 440Y/254 V transformer, and the transformer must have taps that allow the distribution voltage to be tapped down 2.5%, to 428Y/248 V. A custom transformer may also be specified.

Stepping the Voltage from 208Y/120 V to 425Y/246 V

For systems operating at 208Y/120 V, the preferred configuration is the Enphase M-Series Microinverter System combined with 208 V Engage cable.

However, for sites with longer wire runs, it is cost effective to step the voltage up to reduce wiring costs. The long branch circuit lengths of the C250 Microinverter System can help to drive down system costs.

There are a number of transformers that are commercially available to provide this output voltage. Hammond Power Systems (HPS) has a line of three-phase auto-transformers that transforms 208Y/120 V to 425Y/246 V.

Phase Couplers and PLC

An Enphase C250 Microinverter System requires a phase coupler to transmit the power line communication (PLC) signal on all the three phases. You can find out more in Power Line Communication on page 42. The output of each microinverter is line-to-neutral, and since the Envoy-C only connects directly to only one of three phases, you must install a phase coupler to bridge the PLC signal onto on all three phases for Envoy-C and microinverter communication.

Enphase suggests capacitors that come packaged for connection to three-phase, 480 V systems, like the ones listed here:

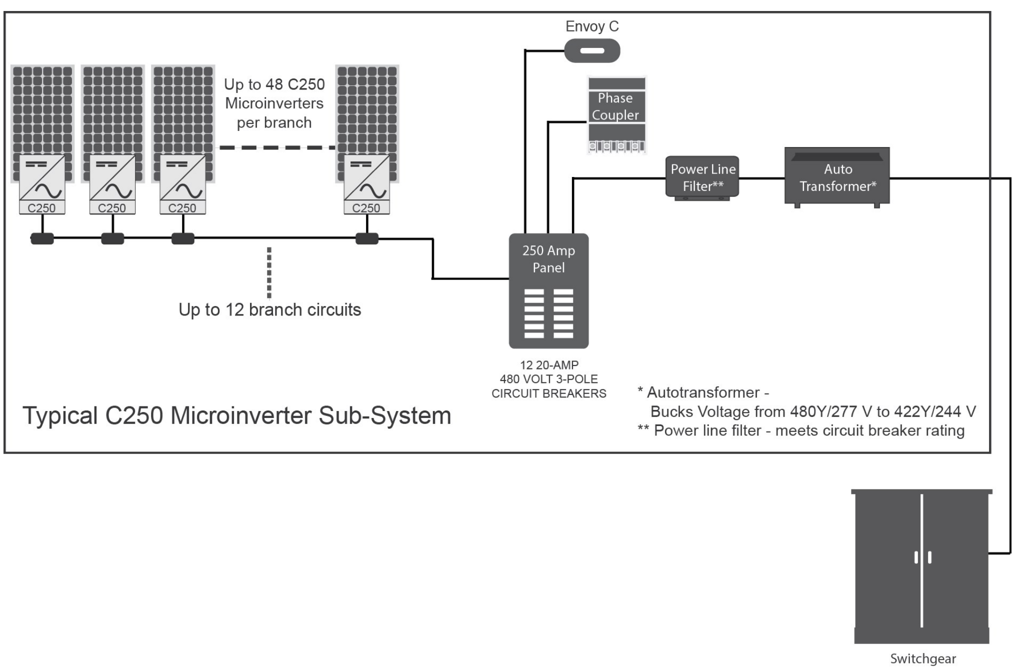
- Eaton 243JMR, Unipump, 2.0 kVAR Motor Start Capacitor
- Eaton 1X43PMURF, 1.5 kVAR Power Factor Correction Capacitor

You can install the Envoy-C and the phase coupler onto a common three-phase breaker.

Filters, Transformers, and Communication Domains

If you install multiple Envoy-Cs off of a single utility transformer, install a power line filter or isolation transformer to isolate each Envoy-C into a separate communication domain, particularly for large-scale projects. Filters and isolation transformers prevent PLC signals from one Envoy-C communication domain from interfering with another Envoy-C communication domain. A filter also offers the added benefit of eliminating electrical noise from site loads.

In a large-scale project, a sub-system generally consists of PV modules, C250 Microinverters, cables, branch circuit breakers, a microinverter panel board, an Envoy-C, a phase coupler, and a filter. A system is generally made up of more than one sub-system and more than one communication domain.



Typical C250 Microinverter Sub-System

A system of 600 C250 Microinverters has an AC inverter output rating of 144 kW. If your total system contains fewer than 600 C250 Microinverters with a single Envoy-C on-site (one communication domain), you do not need a filter, but installing a filter provides noise isolation.

Refer to the following sections to help determine filtering needs for your installation. For systems with fewer than 600 microinverters, the content in the following sections is likely to not apply.

Using an Isolation Transformer to Filter Isolate Communication Domains

Isolation transformers also provide excellent filtering between Enphase communication domains. If each isolation transformer in your system feeds a single Envoy-C communication domain, then you do not need to provide additional filters. If you install multiple Envoy-Cs on the secondary of an isolation transformer, then you need to provide power line filters to isolate communication domains.

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

- An isolation transformer provides filtering between multiple Envoy-C communication domains. If using an auto-transformer, then you might also need power line filters to filter electrical noise from the site, or to isolate the communication signals between multiple Envoy-Cs.
- 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 to meet the inverter output in kW AC. Some additional deratings, such as adjustments for power factor (0.95) and temperature may apply. Refer to the transformer manufacturer's specifications for transformer sizing.

Using a Power Line Filter to Isolate Communication Domains

Unless you are using an isolation transformer, you must use power line filters in microinverter systems with more than one communication domain. Choose filters that effectively filter noise and communication signals in the 110 kHz range, the transmission frequency of Enphase C250s and the Envoy-C.

Power line filters are available in a variety of ampacities and voltage configurations. The variety of ratings allows flexibility in your design choices.

While power line filters are simple to install, apply the following installation guidelines:

- Wire the filters in-line between the utility and microinverter panel boards, at or near the panel boards.
- Install the filters in an electrical enclosure, like an electrical gutter for example. Size the enclosure to meet applicable electric codes such as NEC Article 314.28 in the US.
- Verify that the current rating of the filter meets the ampacity of the rated inverter output current, and that the filter is protected by an appropriate OCPD. You may need to adjust filter ampacity for temperature correction factors as specified by the manufacturer. You may need to make adjustments if you install the filters in direct sunlight or in high thermal conditions, as these filters typically start to derate ampacity at temperatures over 50° C.
- Make sure that the Envoy communication domain is connected on the load side of the filter.

Enphase Energy offers a 250 A line filter (LCF-250-PC) that works in all sizes of commercial C250 systems. For smaller systems, you may prefer a smaller line filter. Contact your Enphase sales account manager for design details regarding applicable filters.

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-C accuracy is rated within 5%, it can be paired with a 2% rated revenue grade meter to meet reporting requirements.

For your three-phase and large-scale projects, you can install a revenue grade, web-enabled meter from Energy Tracking LLC to communicate with the Envoy-C. Revenue grade production displays in Enlighten. Enphase describes the Envoy-C paired with the Energy Tracking meters in the application note, Performance Based Incentive (PBI) Requirements.

You can find out more about Energy Tracking meters at www.energytracking.com.

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 Design Team and Customer Support 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 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-C and networking details
    - specification of transformers, phase couplers, and power line filters

You can find examples of a typical three-line schematic using the Enphase C250 Microinverter System under *Downloads/Schematics* at www.enphase.com/support.

- A detailed site plan or roof plan showing the locations of the main service panels, panel boards, transformers, electrical equipment, and arrays.
- Any special considerations that may impact the design, installation, or permit process.

Design Tips for Success

- Here are some ways to ensure good Envoy-C communications with the microinverters and communications domains.
    - Physically separate conduits and wires between multiple communication domains to prevent communication signals from one Envoy-C 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 including an array map and the site's electrical schematics. 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-C displays a communication level of at least three bars. If not, troubleshoot the system as described in the *Enphase C250 Microinverter System Installation and Operation Manual* before installing additional systems, Envoy-Cs or microinverters. Good communications are vital for effective large-site operation. Poor communications generate missed messages, retries, and delays in collecting microinverters production data. This leads to spotty production graphs in Enlighten.
- Refer to the *Enphase C250 Microinverter System Installation and Operation Manual* as part of your planning and design process. Follow the guidelines and instructions during microinverter installation, including:
    - Install the Enphase Microinverter 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 Enphase Microinverter black side up or vertically, with the DC connectors facing up, is not permitted.
- Turn on each system individually or provision the Envoy-C databases using the Installer Toolkit. Disable the Envoy-C **Device Scan** before commissioning another system on the same utility transformer.
- When multiple Envoy-Cs are located on a single utility transformer, ensure that each Envoy-C database is populated only with the microinverter serial numbers in that communication domain. You can do this by commissioning each Envoy-C and associated system separately. After commissioning each system, use the Envoy-C to **Disable the Device Scan** before commissioning another system. About Commissioning on page 40 guides you through this process.
- Calculate the voltage rise from the PCC (Point of Common Coupling) all the way to the microinverters. Refer to Calculating Voltage Rise in a System on page 31.
    - Calculate each circuit section independently.
    - Keep total voltage drop below 2% to avoid nuisance tripping.
- 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-C. You can find out more in Section 7: Networking and PLC Considerations in Commercial Projects on page 42.

- 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-C stores data. Then, when the connection returns, the Envoy-C sends stored data while simultaneously collecting and processing large amounts of live data. This delays data collection and transmission, and impedes the display of the most recent data in Enlighten.
  - For most sites, Enphase does not recommend using 3G or 4G cellular modems for Internet connectivity to the Envoy-C. The two disadvantages to using cellular at this time are that the 3G or 4G communications link is poor (uplink speed is too slow, and the latency is too high), and the data plan cost is high. One Envoy-C at a site with 500 microinverters requires about 240 MB of data usage every month. For this usage level, Enphase recommends using Wi-Fi with DSL, Cable Modem, or T1 Internet access. Dial-up, satellite, or 3G/4G is insufficient. Some exceptions may apply so contact your Enphase Field Applications Engineer for design guidelines.
- Properly register and activate the system online. Bring the site up on Enlighten:
  - The Enphase Installer Toolkit provides a convenient way to scan the bar codes of microinverters and upload the maps to Enlighten with a compatible iPhone or iTouch device.
  - Use the Installer Toolkit to provision the Envoy-C database with the appropriate microinverter serial numbers instead of an Envoy-C device scan.

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.

Enphase Installation Map

The Installation Map is a diagrammatic representation of the physical location of each microinverter in your PV installation. Create an array map electronically using the Installer Toolkit, or manually by peeling the serial number labels from the microinverters and placing the labels on the installation map. You then use this 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-C serial number that is monitoring 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 placement of the serial number labels.

Even if you use the Enphase Installer Toolkit, it is still best to create the paper maps so that you have a diagram of the array layout. You may want to scan the microinverter serial numbers from the paper map. In this case, it is best to place the stickers about an inch apart to prevent the scanner tool from erroneously scanning the incorrect bar codes.

Section 2: Ampacity Calculations and Equipment Ratings

For three-phase sites, design the installation with a balanced number of microinverters on each phase. To calculate the ampacity (ampere capacity or current) on a given conductor you must determine the number of microinverters powered by that set of conductors.

NOTE: Apply a 1.25 multiplier to the calculated result to size the overcurrent protection device (OCPD) per NEC Article 690.8(A)(3) or local standards. The following ampacity calculations use the 1.25 multiplier to size the OCPD.

422Y/244 V Three-Phase Ampacity Calculation for Enphase Microin-verters

The equation to calculate ampacity for one branch in 422Y/244 V three-phase system is:

$$\text{Current (amps per branch)} = \text{Microinverters per branch} \div 3 \times 1.0\ \text{A}$$

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

$$\text{OCPD Sizing} = \text{Current (amps per branch)} \times 1.25$$

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

C250s on a Single Circuit for a 422Y/244 V Three-Phase System

The ampacity of a single branch circuit of 48 C250 Microinverters (maximum output power of 240 Watts AC) at a three-phase 422Y/244 V site is:

$$\text{Current (amps per branch)} = 48\ \text{Microinverters} \div 3 \times 1.0 = 16.0\ \text{A}$$

The ampacity for a 48 microinverter branch is 16.0 amps. The OCPD sizing is:

$$\text{OCPD Sizing} = 16.0\ \text{A} \times 1.25$$

$$= 20.0\ \text{A}$$

Based on the OCPD sizing calculation, a branch circuit of 48 C250 Microinverters requires a three-pole, 20 ampere circuit breaker or OCPD.

C250s on Multiple Circuits for a 422Y/244 V Three-Phase System

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

In this example, a C250 Microinverter panel board feeds a total of 576 microinverters divided into 12 branch circuits with 48 microinverters per circuit. This entire system can be installed on a single 250 A panel board.

$$\text{Ampacity Current} = 576\ \text{Microinverters} \div 3 \times 1.0\ \text{A}$$

$$= 192\ \text{A}$$

$$\text{OCPD Sizing} = 192\text{ A} \times 1.25$$

$$= 240\text{ A}$$

Based on the OCPD sizing calculation, a system with 12 branch circuits of 48 C250 Microinverters per branch requires a 250 ampere (minimum) circuit breaker or OCPD.

480Y/277 V Three-Phase Ampacity Calculation for Enphase Microinverters

On the utility side of the transformer, you must use the utility voltage from line to line to calculate ampacity. The ampacity in a 480Y/277 V three-phase system is:

$$\text{Current (amps per service panel)} =$$

$$\text{(Microinverter Maximum Output Power)} \times \text{(Number of Microinverters)} \div 480\text{ V} \div \sqrt{3}$$

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

$$\text{OCPD Sizing} = \text{Current (amps per system)} \times 1.25$$

In a 480 V system, it may make sense to run the longer wire conductors at 480Y/277 V, and then buck the voltage down with the auto-transformer closer to the array.

C250s on Multiple Circuits for 480Y/277 V Three-Phase Site

The ampacity for a service panel that feeds 576 microinverters at 480Y/277 V is:

$$\text{Current (amps per service panel)} = 240\text{ Watts per microinverter} \times 576\text{ microinverters} \div 480\text{ V} \div 1.732$$

$$= 166.28\text{ A}$$

The ampacity is 166.28 amps.

$$\text{OCPD Sizing} = 166.28\text{ A} \times 1.25$$

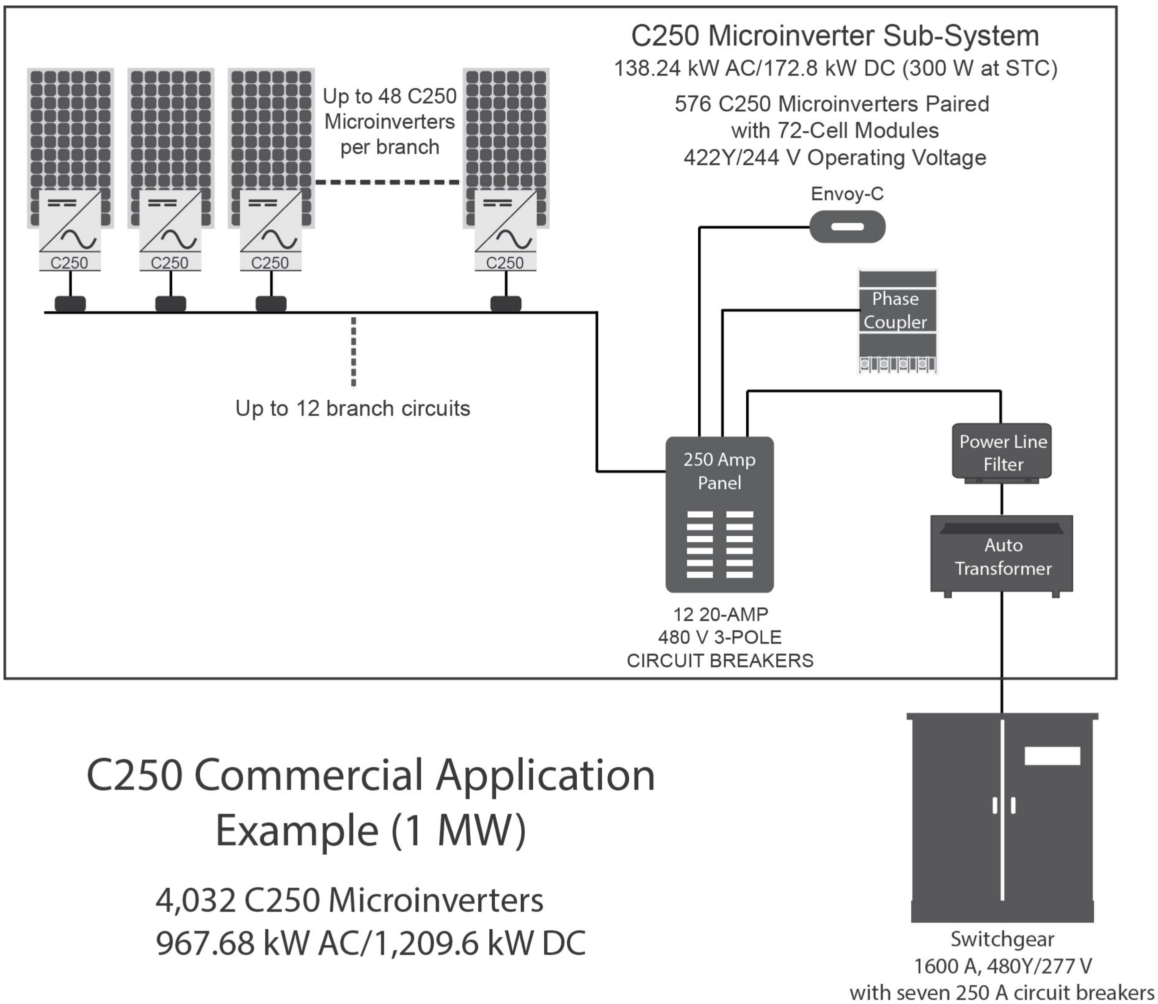
$$= 207.8\text{ A}$$

A photovoltaic system with 576 C250 Microinverters at a 480Y/277 V three-phase site requires a 225 A (minimum) circuit breaker or OCPD.

Section 3: Calculating Voltage Rise for C250 Microinverter Systems

Introduction to Voltage Rise in C250 Microinverter Systems

This guide presents voltage rise guidelines for dedicated PV branch circuits and methods for calculating the AC line voltage drop (or voltage rise) for Enphase C250 Microinverters and the Enphase Engage Cable.



C250 Microinverters operate at higher voltages, so C250 voltage rise calculations result in lower losses per kW than in other photovoltaic systems. The losses are approximately a quarter of the wiring losses as compared with 208Y/120 V systems. A higher operating voltage results in less voltage rise and lower losses in the wiring.

Depending on the system design, there may be a small variance within nominal operating voltages that you apply to the C250 Microinverter System. That range is generally between 415Y/240 V and 430Y/24 V.

This section uses the most common system configuration and includes a three-phase distribution auto-transformer providing a nominal operating voltage of 422Y/244 V. The calculations in this section use the most common scenario of 422Y/244 V.

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

While these calculations are commonly called voltage drop (VDrop) when designing circuits for electrical loads, PV systems with inverters generate electricity instead of consume electricity, so voltage actually rises at the AC terminals of inverters. Because of this, these formulas calculate voltage rise (VRise) for your systems.

Background

The IEEE 1547 standard requires that grid-tied or utility-interactive inverters cease power production if voltage measured at the inverter terminal exceeds +10% or -12% of nominal. 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 Enphase Microinverter enters an AC Voltage Out-Of-Range (ACVOOR) condition and ceases to export power until this condition clears. Besides voltage variations from the AC grid, voltage changes within system wiring can also contribute to VRise and could cause microinverters to sense an over-voltage condition and cease operation.

The Enphase Microinverter reference point for voltage measurement is at the microinverter AC output. Since the microinverter is located at the array, and the point of common coupling (PCC) is generally at the site load center, the distance from the microinverter AC output to the PCC could be substantial.

All components within system wiring contribute to resistance and must be considered when calculating total voltage rise. While you can find more in Contributors to Voltage Rise on page 24, the main factors that determine voltage rise in an Enphase Microinverter system are:

1. distance from the microinverters to the PCC
2. conductor size

In a commercial installation, you can typically quantify the voltage rise of four distinct wire sections and several wire terminations as described in Voltage Rise by Wire Section on page 25. There is also some resistance associated with each OCPD, typically a circuit breaker.

Recommendations to Minimize Voltage Rise

To minimize voltage rise issues, Enphase Energy recommends that you follow these guidelines when planning your system:

- Design the PV system so that the total VRise in the AC wiring is less than 2% in all wire sections from the PCC to the last microinverter on each branch or sub-branch circuit. The wire sections are described in Voltage Rise by Wire Section on page 25. Furthermore, a best practice is to maintain less than 1% VRise in the Engage Cable and 1% VRise in the field wiring.
- Center-feed the branch circuit to minimize voltage rise in a fully-populated branch. Since VRise is nonlinear, reducing the number of microinverters in a branch circuit greatly reduces the voltage measured at the last microinverter in the branch. To center-feed a branch, divide the circuit into two sub-branch circuits protected by a single OCPD. Find out more in Advantages of Center-Feeding Branch Circuits on page 29.
- Use the correct wire size in each wire section. Using undersized conductors can result in nuisance tripping of the microinverter anti-islanding function when an AC voltage out-of-range condition occurs. Contributors to Voltage Rise on page 24 provides more information.
- Use the calculation methods in Calculating Voltage Rise in a System on page 31 to determine voltage rise values for your project.

Contributors to Voltage Rise

Install Enphase C250 Microinverter Systems as dedicated branch circuits with each branch circuit protected by a 20 A OCPD. You must consider wire size, circuit current, circuit length, voltage margin, and utility voltage for each branch circuit when calculating voltage rise.

Wire size

Wire sizing is important because 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 be outside of the IEEE limits, triggering an ACVOOR condition. This results in loss of energy harvest. 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 in practice is generally not low enough for a utility-interactive inverter.

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

Circuit current

Circuit current varies with the different wire sections that are in the installation. Voltage Rise by Wire Section on page 25 describes a typical installation with the wire sections where current is considered. 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 Branch Circuits on page 29.

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. Also, your systems distribution transformers may provide voltage taps to adjust the voltage by some percentage within your AC PV electrical system.

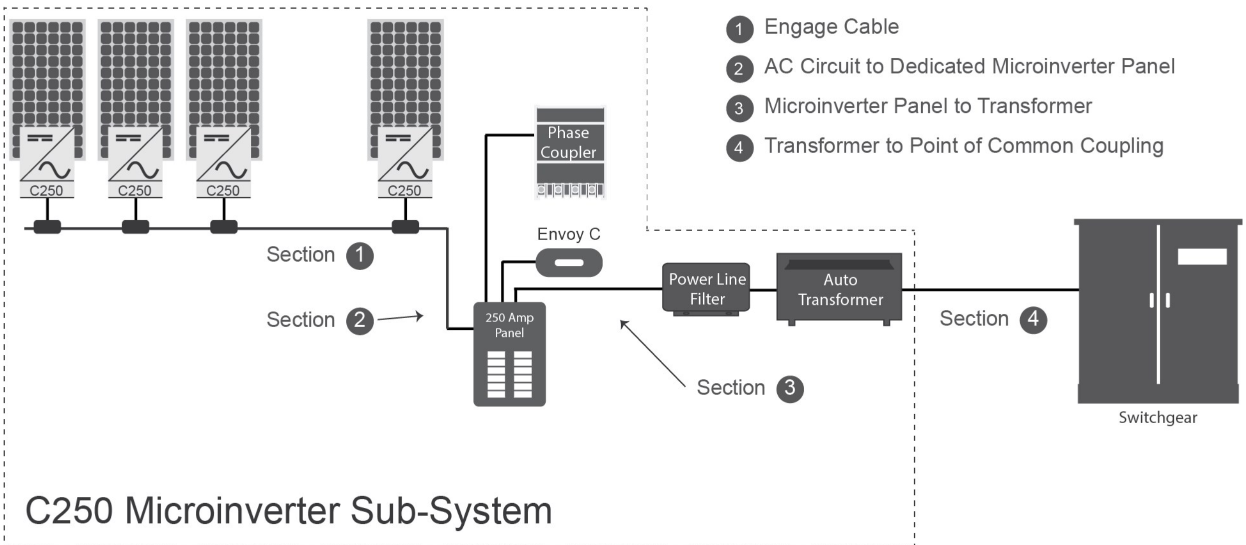
Utility voltage

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.

Voltage Rise by Wire Section

A typical commercial installation as shown in the illustration has four wire sections where you must consider voltage rise.

Wire Sections in a C250 Commercial Installation



For commercial installations, determine the voltage rise for the following four wire sections:

1. The Enphase Engage Cable section. You can find internal voltage rise values in Internal Voltage Rise for the C250 Engage Cable on page 26.
2. The AC branch circuit junction box to the dedicated microinverter subpanel section. This wire section is generally a 422Y/244 V connection. Calculate the voltage rise in the wire section between the array-mounted AC junction box and the subpanel containing the dedicated microinverter circuit breakers (load center). The tables in Wire Section Lengths for a C250 Installation on page 27 list maximum distances that maintain a 1% voltage drop for this wire section.
3. The microinverter subpanel to the distribution transformer section. This wire section is generally a 422Y/244 V connection. The tables in Wire Section Lengths for a C250 Installation on page 27 list maximum distances that maintain a 1% voltage drop for this wire section.
4. The distribution transformer to the PCC. This wire section is generally at 480Y/277 V connection.The tables in Wire Section Lengths for a C250 Installation on page 27 list maximum distances that maintain a 1% voltage drop for this wire section.

Calculate each component individually and verify that the total voltage rise is less than 2%. You can find formulas in Calculating Voltage Rise in a System on page 31. Additional losses 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.

C250 Engage Cable and Internal Voltage Rise

Engage Cable for the C250 Microinverter is a continuous length of 12 AWG stranded copper, outdoor-rated cable with integrated connectors. The following table lists the Engage Cable types available for your commercial project.

C250 Engage Cable SKU Prefixes	Connector Spacing	PV Module Orientation
ET-10-277-*	1.025 meter (40")	Portrait
ET-10-277-*	1.7 meter (67")	60-cell Landscape
ET-10-277-*	2.1 meter (80")	72-cell Landscape

It is important to calculate total voltage rise for the entire system from the array to the PCC. Enphase recommends that the total percentage of voltage rise in the AC wiring be less than 2%, including less than 1% voltage rise in the Engage Cable.

Internal Voltage Rise for the C250 Engage Cable

These tables provide voltage rise values for the available C250 Engage Cable types. The calculations used to create the tables are based on an operating voltage of 422Y/244 V. Use these tables to determine the voltage rise for the final microinverter in the branch.

48 C250s is the maximum number allowed on a branch circuit.

VRise for 1.0 Meter C250 Engage Cable for 60- and 72-Cell Modules in Portrait

Number of C250 Microinverters Per AC Branch Circuit								
	3	6	9	12	15	18	21	24
Current (A)	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0
VRise (V)	0.034	0.101	0.203	0.338	0.506	0.71	0.95	1.22
% VRise	0.008	0.024	0.048	0.080	0.120	0.168	0.224	0.288

VRise for 1.0 Meter C250 Engage Cable for 60- and 72-Cell Modules in Portrait

Number of C250 Microinverters Per AC Branch Circuit								
	27	30	33	36	39	42	45	48
Current (A)	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0
VRise (V)	1.52	1.86	2.23	2.63	3.07	3.54	4.05	4.59
% VRise	0.360	0.440	0.528	0.624	0.728	0.840	0.960	1.088

VRise for 1.7 Meter C250 Engage Cable for
60-Cell Modules in Landscape

Number of C250 Microinverters Per AC Branch Circuit								
	3	6	9	12	15	18	21	24
Current (A)	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0
VRise (V)	0.06	0.17	0.34	0.57	0.86	1.21	1.61	2.07
% VRise	0.01	0.94	0.08	0.14	0.19	0.29	0.38	0.49

VRise for 1.7 Meter C250 Engage Cable for 60-Cell Modules in Landscape

Number of C250 Microinverters Per AC Branch Circuit								
	27	30	33	36	39	42	45	48
Current (A)	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0
VRise (V)	2.58	3.16	3.79	4.48	5.22	6.03	6.89	7.8
% VRise	0.61	0.75	0.9	1.06	1.24	1.43	1.63	1.85

VRise for 2.1 Meter C250 Engage Cable for 72-Cell Modules in Landscape

Number of C250 Microinverters Per AC Branch Circuit								
	3	6	9	12	15	18	21	24
Current (A)	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0
VRise (V)	0.07	0.17	0.41	0.68	1.01	1.42	1.89	2.43
% VRise	0.02	0.04	0.10	0.16	0.24	0.34	0.45	0.58

VRise for 2.1 Meter C250 Engage Cable for 72-Cell Modules in Landscape

Number of C250 Microinverters Per AC Branch Circuit								
	27	30	33	36	39	42	45	48
Current (A)	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0
VRise (V)	3.04	3.71	4.46	4.48	5.27	7.09	8.10	9.18
% VRise	0.72	0.88	1.06	1.06	1.25	1.68	1.92	2.18

Wire Section Lengths for a C250 Installation

This section lists the maximum lengths to maintain a 1% voltage rise in a wire section between AC branch circuit junction box and the PCC (switchgear).

Maximum One-Way Distance Per Wire Section to Maintain 1% Voltage Rise in a 422Y/244 V Three-Phase Installation

Number of C250s Per AC Branch							
	3	6	9	12	15	18	21
AWG	Maximum Distance in Feet						
#12	1231	615	410	308	246	205	176
#10	1965	982	655	491	393	327	281
#8	3132	1566	1044	783	626	522	447
#6	4962	2481	1654	1241	992	827	709
#4	7911	3955	2637	1978	1582	1318	1130
#2	12559	6280	4186	3140	2512	2093	1794
#1	15821	7911	5274	3955	3164	2637	2260

Maximum One-Way Distance Per Wire Section to Maintain 1% Voltage Rise
in a 422Y/244 V Three-Phase Installation

	Number of C250s Per AC Branch								
	24	27	30	33	36	39	42	45	48
AWG	Maximum Distance in Feet								
#12	154	137	123	112	103	95	88	82	77
#10	246	218	196	179	164	151	140	131	123
#8	391	348	313	285	261	241	224	209	196
#6	620	551	496	451	414	382	354	331	310
#4	989	879	791	719	659	609	565	527	494
#2	1570	1395	1256	1142	1047	966	897	837	785
#1	1978	1758	1582	1438	1318	1217	1130	1055	989

Maximum One-Way Distance Per Wire Section to Maintain 1% Voltage Rise
in a 480Y/277 V Three-Phase Installation

	Number of C250s per AC Branch						
	3	6	9	12	15	18	21
AWG	Maximum Distance in Feet						
#12	1400	700	467	350	280	233	200
#10	2235	1117	745	559	447	372	319
#8	3562	1781	1187	891	712	594	509
#6	5644	2822	1881	1411	1129	941	806
#4	8998	4499	2999	2249	1800	1500	1285
#2	14285	7143	4762	3571	2857	2381	2041
#1	17996	8998	5999	4499	3599	2999	2571

Maximum One-Way Distance Per Wire Section to Maintain 1% Voltage Rise
in a 480Y/277 V Three-Phase Installation

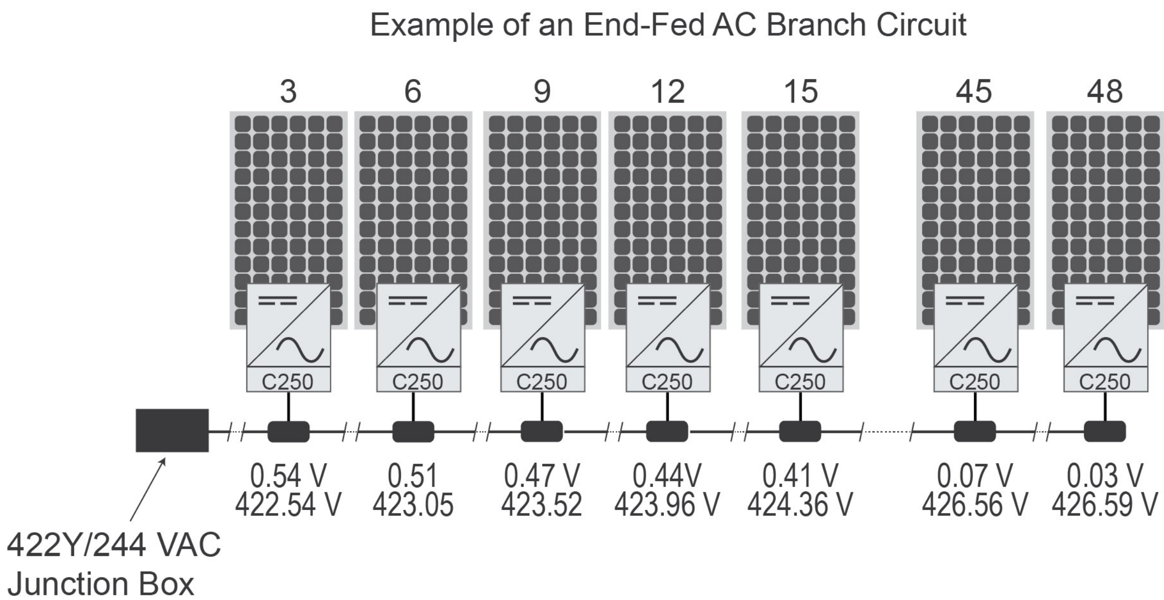
	Number of C250s per AC Branch								
	24	27	30	33	36	39	42	45	48
AWG	Maximum Distance in Feet								
#12	175	156	140	127	117	108	100	93	87
#10	279	248	223	203	186	172	160	149	140
#8	445	396	356	324	297	274	254	237	223
#6	706	627	564	513	470	434	403	376	353
#4	1125	1000	900	818	750	692	643	600	562
#2	1786	1587	1429	1299	1190	1099	1020	952	893
#1	2249	2000	1800	1638	1500	1384	1285	1200	1125

Advantages of Center-Feeding Branch Circuits

Determining the Voltage Rise a Microinverter Branch Circuit

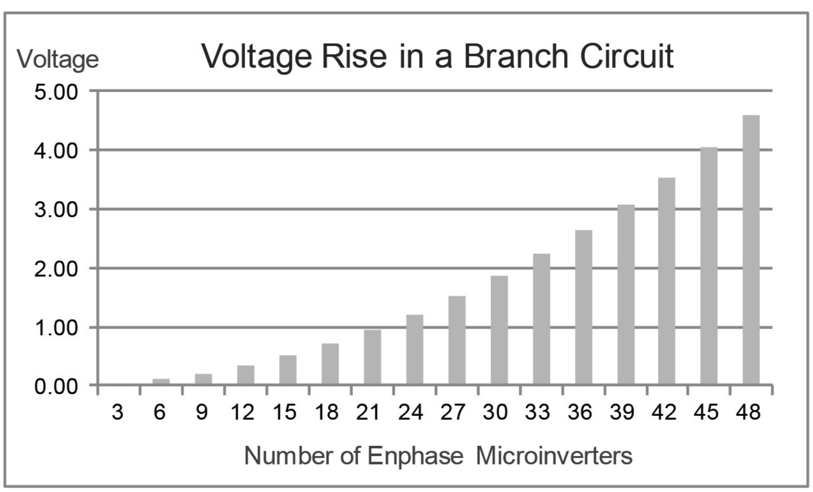
You can easily determine voltage rise within a microinverter branch circuit. The following diagram represents a 422Y/244 V system with a fully populated end-fed branch circuit. It illustrates how voltage measured at an individual microinverter increases by position in the branch circuit.

As you increase number of microinverters in a branch circuit, the voltage at each microinverter rises in a nonlinear manner. Each additional microinverter increases the ampacity and the cable length, resulting in a nonlinear voltage rise.



The top row of numbers is the incremental voltage rise from one microinverter to the next, and the bottom row is the cumulative line-to-line voltage overall.

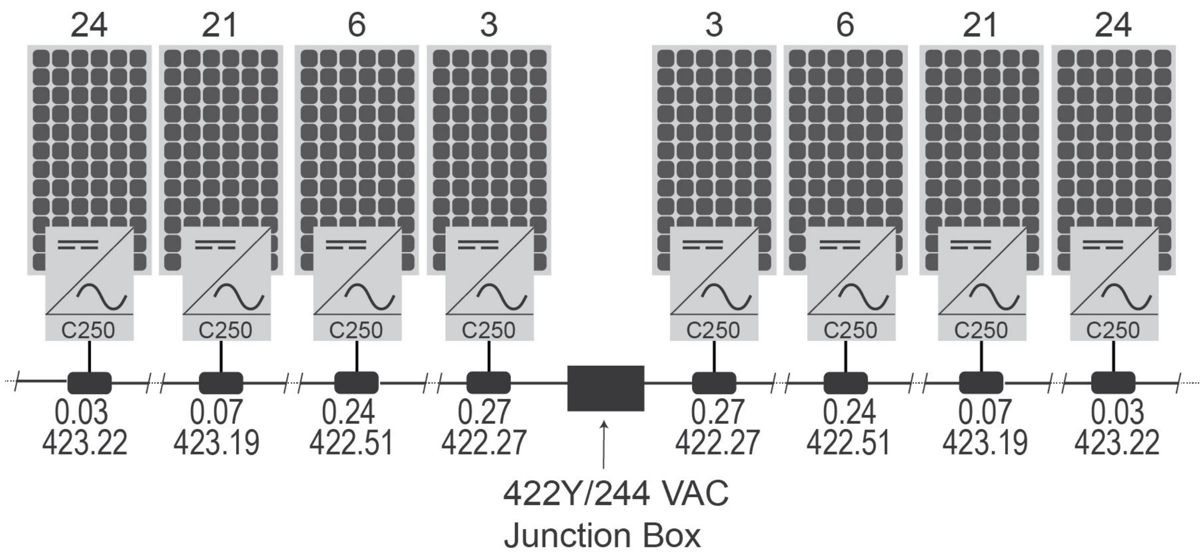
The following graph is the voltage rise (L-L) at the end of a branch circuit and illustrates how the number of microinverters connected along a portrait-oriented Engage Cable causes a nonlinear voltage rise when operating at 422Y/244 V ac.



Since voltage rise is nonlinear, reducing the number of microinverters in the branch circuit reduces the voltage measured at the last microinverter in the branch.

One way to minimize voltage rise is to center-feed the branch. To center-feed, divide the circuit into two sub-branch circuits protected by a single OCPD. The following diagram illustrates the center-fed method.

Example of a Center-Fed AC Branch Circuit



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 circuits because the conductors from each Engage Cable on that branch circuit are paralleled within a junction box. All the brown conductors connect together, all orange the conductors connect together, and so forth. The sub-branch circuits of a center-fed branch circuit meet in the same junction box.

A fully populated center-fed branch circuit has 48 C250 Microinverters, with 24 C250 Microinverters on each sub-branch. When center-feeding a 1.0 meter portrait cable, you will measure a 0.27%-volt increase at the last microinverter in the branch circuit rather than a 1.09% increase in an end-fed branch circuit.

Center-feeding a branch circuit is a great way to decrease costs, improve production, and increase system reliability. Center-feeding each branch circuit in an Enphase Microinverter system allows for optimizing microinverter operation and minimizing wire costs.

Calculating Voltage Rise in a System

Voltage Rise Formulas

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 the total current times the total resistance.

The VRise percentage for an Enphase Microinverter system is:

% TotalVRise = % VRise Section 1 + % VRise Section 2 + % VRise Section 3 + % VRise Section 4

Where,

% VRise Section 1 = % by number of microinverters in Internal Voltage Rise for the C250 Engage Cable on page 26

% VRise Section 2 = VRise Section 2 ÷ System Voltage (422V)

% VRise Section 3 = VRise Section 3 ÷ System Voltage (422V)

% VRise Section 4 = VRise Section 4 ÷ System Voltage (480V)

Calculating Ampacity in a C250 System

In an Enphase C250 Microinverter System, the microinverters are connected in a line to neutral configuration. A fully populated and balanced branch circuit of 48 microinverters has 16 microinverters on each phase. The current on each line will be 16.0 A and the neutral currents will cancel to zero.

Ampacity = 1.0 A per Microinverter x Microinverters per Branch Circuit / 3

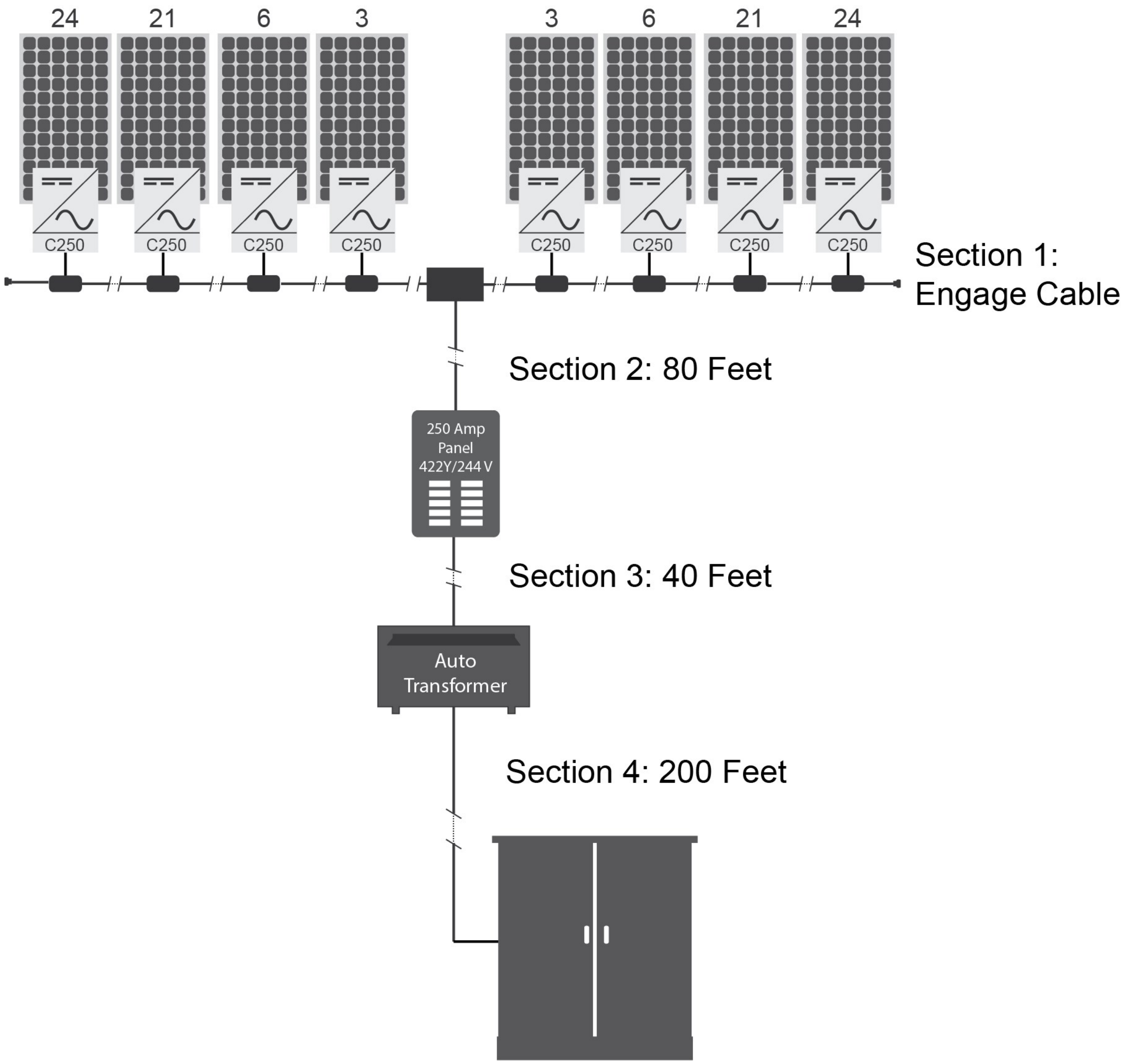
Voltage Rise Calculation Example - 115 kW AC

This section shows how to calculate voltage rise in a typical C250 Microinverter system.

The example system contains 480 C250 Microinverters interconnected to 480Y/277 V three-phase service using a 480Y/277 V to 422Y/244 V auto-transformer.

The microinverters are laid out in 10 fully-populated branch circuits of 48 C250 Microinverters in portrait orientation. Each center-fed branch has two balanced sub-branches, each with 24 microinverters.

For fully populated branch circuits, Enphase recommends that you center-feed the circuit to minimize voltage rise as shown in this example.



Calculate Voltage Rise in Four Wire Sections of a Commercial Installation

This example uses the following wire section lengths:

Section 1 - One 48 microinverter center-fed branch made up of two sub-branches of C250 Engage Cable in portrait orientation, with 24 microinverters in each sub-branch

Section 2 - 80 foot conductor length from the microinverter AC junction box circuit to dedicated microinverter sub-panel

Section 3 - 40 foot conductor length dedicated microinverter sub-panel board to the auto-transformer

Section 4 - 200 foot conductor length from the auto-transformer to the PCC

Section 1: Internal Voltage Rise for C250 Engage Cable

Refer to Internal Voltage Rise for the C250 Engage Cable on page 26 to find the Engage Cable VRise appropriate for your project.

For a 48 microinverter center-fed branch with two balanced sub-branches of 24 microinverters, look up the voltage rise for 24 microinverters in a sub-branch.

VRise for C250 Engage Cable for 60- and 72-Cell Modules in Portrait

Number of C250 Microinverters Per AC Branch Circuit																
	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
Current	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0
VRise	0.034	0.101	0.203	0.338	0.506	0.71	0.95	1.22	1.52	1.86	2.23	2.63	3.07	3.54	4.05	4.59
% VRise	0.008	0.024	0.048	0.080	0.120	0.168	0.224	***0.288***	0.360	0.440	0.528	0.624	0.728	0.840	0.960	1.088

Since the AC circuit is made up of two sub-branches connecting in parallel at the AC junction box, the total voltage rise of the Engage Cable is **0.29%**, value of one of the sub-branches of 24 microinverters.

VRise of Section 1 = 0.29%

Section 2: VRise from the AC Junction Box to the Microinverter Panel Board

Calculate the voltage rise in this wire section by multiplying the branch circuit output power (Watts) by the total resistance of the wire section, then divide by the voltage to get the percent of voltage rise.

$$\text{Section 2 VRise} = \sqrt{3} \times \text{C250 Ampacity} \times \text{number of inverters per branch} \times \frac{\Omega}{ft} \times \text{1-way wire length}$$

In this example, the numerical values are:

- C250 rated AC output in amps = 1.0 amps
- Number of microinverters per balanced three-phase branch circuit = 48 (16 microinverters per phase x 3)
- Wire gauge for individual branch circuit = #10 AWG THWN-2 CU
- #10 AWG THWN-2 CU resistance = 0.00124 Ω/ft (from NEC Chapter 9, Table 8)
- Length of individual branch circuit = 80 feet
- Ampacity for a three-phase branch circuit of 48 microinverter = 16 Amps. (1.0 A x 16 microinverters/phase).

$$\text{Section 2 VRise} = 1.732 \times 16.0\ \text{A} \times 0.00124\ \frac{\Omega}{ft} \times 80\ \text{ft}$$

$$= 2.75\ \text{volts}$$

$$\%\ \text{VRise of Section 2} = 2.75\ \text{volts} \div 422\ \text{volts}$$

$$= 0.65\%$$

The voltage rise for Section 2, from the junction box to the microinverter sub-panel, is **0.65%**.

Section 3: VRise from the Microinverter Panel Board to the Auto-Transformer

The voltage rise for Section 3 includes the combined ampacity of ten fully populated branch circuits and 480 microinverters. The values used to calculate voltage rise in this section are:

- C250 rated AC output in amps = 1.0 A
- Number of microinverters per microinverter sub-panel board = 480
- 10 three-phase branch circuits x 20 A each = 200 A
- Wire gauge of section = #3/0 AWG THWN-2 CU
- 2/0 AWG CU resistance = 0.0000766 Ω/ft (from NEC Chapter 9, Table 8)
- One-way wire length = 40 feet
- 160 A ampacity. This ampacity is 10 branches x 16 A (one phase of 48 microinverters).
- A 200 A panel board would likely be fed by a set of 2/0 CU conductors

$$\text{Section 3 VRise} = \sqrt{3} \times \text{C250 ampacity} \times \frac{\Omega}{ft} \times \text{1-way wire length}$$

$$\text{Section 3 VRise} = 1.732 \times 160\text{ A} \times 0.0000766 \frac{\Omega}{ft} \times 40\text{ feet}$$

$$= 0.85\text{ volts}$$

$$\%\text{ VRise of Section 3} = 0.85\text{ volts} \div 422\text{ volts}$$

$$= 0.20\%$$

The voltage rise of Section 3 from the microinverter panel board to the auto-transformer is **0.20%**.

Section 4: VRise from the Distribution Auto-Transformer to the PCC

The Section 4 voltage connection is at 480Y/277 V. The voltage rise in this section is calculated based on the total system ampacity of a 480 volt system.

Use the following formula to calculate the modified ampacity of a 480 volt system.

Adjusted ampacity of a 480 V system

$$= \text{Total number of microinverters} \times \text{microinverter nominal voltage} \div 480\text{ V} \div \sqrt{3}$$

$$= 480\text{ C250s} \times 240\text{ W} \div 480\text{ V} \div 1.732$$

$$= 138.7\text{ amps}$$

- Adjusted ampacity of system at 480 V = 138.7 A
- Wire gauge of section = #2/0 AWG THWN-2 CU
- 2/0 AWG CU resistance = 0.0000766 Ω/ft (from NEC Chapter 9, Table 8)
- One-way wire length = 200 feet

$$\text{Section 4 VRise} = \sqrt{3} \times \text{adjusted ampacity} \times \frac{\Omega}{ft} \times \text{1-way wire length}$$

$$= 1.732 \times 138.7\,\text{A} \times 0.0000766\,\frac{\Omega}{ft} \times 200\,\text{ft}$$

$$= 3.68 \text{ volts}$$

$$\%\text{ VRise of Section 4} = 3.68 \text{ volts} \div 480 \text{ volts}$$

$$= 0.76\%$$

The voltage rise of Section 4 is **0.76%**

Total Voltage Rise for the C250 Microinverter Example

If you assume following:

1. The utility operates at the upper limit of the allowable tolerance (+5%).
2. The microinverters have a measurement accuracy of 2.5%

Then the result is a voltage rise budget of 9.5 volts (2.25%) for all wiring to the PCC. The calculated voltage rise for all four sections of the system must be 9.5 volts or less.

For systems with long branch circuit runs, or long runs from the microinverter sub-panel to the main service panel or PCC, design the system so that voltage rise in the Engage Cable is as small as possible.

Section 1: Engage Cable from the microinverters to the AC junction box
= 0.29%

Section 2: AC junction box to the microinverter sub-panel
= 0.65%

Section 3: microinverter sub-panel to the auto-transformer
= 0.20%

Section 4: auto-transformer to the PCC (main service meter/switchgear)
= 0.76%

Total system voltage = 0.29% + 0.65% + 0.20% + 0.76%

Total system voltage = 1.90%

After accounting for additional losses within connections, terminals, circuit breakers, and unexpected increases in wire length, Enphase recommends that you design systems with a total system voltage rise of less than 2%.

This example shows that you can keep the total voltage rise of a C250 Microinverter commercial installation to less than 2% by center-feeding the circuit.

Section 4: Grounding Considerations for Fourth-Generation Microinverters

Ground Fault Protection Eliminates the Need for a Grounding Electrode Conductor

The C250, like other Enphase fourth-generation integrated-ground (IG) microinverters, does not require a Grounding Electrode Conductor (GEC). The DC circuit within the microinverter is isolated and insulated from ground, and the microinverter integrates ground fault protection (GFP).These features result in shorter microinverter installation times, cost savings, and increased safety.

An Enphase Energy Microinverter System offers the safest photovoltaic system available. The Enphase Microinverter System is safer for service personnel, safer for fire fighter personnel, and less prone to the fire hazards that come with higher voltage DC photovoltaic systems. The safety advantages are:

- DC voltages are maintained at low, safe levels
- Conduits and conductors are de-energized when the main breaker is shut-off
- Enphase Microinverter Systems are free of DC arc-fault hazards and requirements

Another advantage is the high level of ground bonding that exists in an Enphase Microinverter System. Each and every microinverter in an Enphase System bonds to ground through the Enphase Engage cabling system. The Enphase Engage Cable provides a robust grounding path to each microinverter. The Engage Cable also provides robust equipment grounding for PV racking and module frames when properly bonded to this equipment.

When microinverters, racking, and modules are properly bonded together with listed and approved grounding hardware, equipment grounding may be provided through the microinverter cabling system. This results in a significant savings to labor and balance of system (BOS) costs when installing an Enphase Microinverter System.

Enphase Microinverter System Grounding and the 2011 National Electrical Code

Enphase fourth-generation microinverters meet National Electrical Code Article 690.35 requirements for Ungrounded Photovoltaic Power Systems. Photovoltaic power systems that comply with NEC 690.35 are permitted to operate with ungrounded photovoltaic source and output circuits.

Systems that meet the requirements of NEC 690.35 are exempt from the system grounding requirements of NEC 690.41 System Grounding. The NEC calls out two distinct types of grounding, equipment grounding and system grounding.

Equipment grounding provides for grounding of metal equipment and enclosures. Equipment grounding conductors (EGCs) generally provide this type of equipment grounding.

Electrical system grounding provides the primary grounding path between a grounding electrode, like a ground rod or Ufer ground, and a grounded system. System grounding requires the installation of a grounding electrode conductor (GEC).

In an Enphase System, DC conductors are not bonded to ground so microinverters do not require a GEC, but Enphase Microinverters do require that you provide EGCs for equipment grounding.

In PV installations, the term ungrounded applies to the DC output of PV modules. System designers must still provide equipment grounding of metal PV frames, equipment, and enclosures in the system. For PV systems where inverters meet NEC 690.35 requirements, a grounding electrode conductor (GEC) is not required to be installed to ground the outputs of the PV modules.

Enphase Engage Cabling provides the required equipment grounding (EGC) for the microinverter.

Equipment Grounding Requirements for an Enphase System

In a system with Enphase Integrated Ground Microinverters, using a GEC to ground the microinverters is no longer required; only equipment grounding (EGC) is required. In these systems, you can provide the EGCs to other PV system components through Enphase Engage cabling.

In an Enphase Microinverter System, bond the microinverters and modules to racking assemblies with the use of listed and approved grounding clips or grounding components. This method provides an EGC to the Enphase Microinverters through Enphase Engage Cable, which you may also use to ground the other PV system components.

Prior to the installation of the system, you must check with the Authority Having Jurisdiction (AHJ) about your proposed grounding methodology.

NEC 690.35 for Ungrounded Photovoltaic Power Systems

Enphase Microinverters meet the requirements of NEC Article 690.35 for Ungrounded Photovoltaic Power systems. 690.35 for Ungrounded Photovoltaic Power System states, *Photovoltaic Power Systems shall be permitted to operate with ungrounded photovoltaic source and output circuits where the system complies with 690.35 (A) through (G)*. Enphase Microinverters meet NEC Article 690.35 in the following areas:

A. Disconnects. In an Enphase Microinverter System, the AC and DC connectors are the disconnecting means.
B. Overcurrent Protection. In an Enphase System, the AC circuit breaker or fused disconnect feeding the branch circuit provides overcurrent protection for the inverter output circuit. As per 690.9 (A) Exception (b), overcurrent protection is not required on DC conductors.
C. Ground Fault Protection. In an Enphase Microinverter System, the microinverter provides ground fault protection. A ground fault sensing circuit provides ground fault protection.
D. The DC conductors must be Photovoltaic (PV) Wire. The DC conductors in an Enphase Microinverter are PV Wire.
E. Allowed for use in ungrounded battery systems.
F. Labeling. The Enphase Microinverters are labeled as specified in NEC 690.35.
G. Listing. Enphase Microinverters are listed for use in an ungrounded photovoltaic system.

Section 5: Lightning and Surge Suppression

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 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 lists some lightning protection and surge suppression devices, but there is 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.

Lightning Protection

A lightning arrestor 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. If the voltage spike has enough energy, the Enphase Microinverter internal surge protection might be exceeded, and there is risk of damage.

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-building 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.

Surge Suppression for C250 Microinverters

Since voltage spikes or surges, if high enough, can damage Enphase Microinverters and equipment, you should install surge protection as part of your commercial installation. The Enphase Limited Warranty does not cover “acts of God” such as lightning strikes, and lightning strikes can occur anywhere,so surge protection is a sensible addition to your installation.

Enphase has tested the following protection devices to ensure that they do not interfere with Enphase power line communications, but other devices may also work. Install protective devices per vendor instructions.

- Citel DS73-RS-230 surge protector
- Midnite Solar SPD-600 surge protective device (Two are required for a three-phase system.)
- Merson Surge-Trap® Pluggable SPD, STP4803PYGM
- Merson Surge-Trap® Type 1 SPD STT, STT4X4803PYG

An inline surge protective device provides the greatest level of protection, but is often more expensive than a surge protective device that is placed in parallel to the microinverter panel board and will likely filter the power line communications in a system.

If using an inline surge protective device, then the Envoy-C and microinverters must be located together on the load side of this device.

Section 6: Commissioning at Sites with Multiple Envoy-Cs

About Commissioning

Proper site commissioning is critical to the success of the project. Refer to the *Enphase C250 Microinverter System Installation and Operation Manual* for details. Follow these guidelines to commission an Envoy-C:

- Install the Envoy-Cs at the site before you complete your solar installation.
- Connect the Envoy-C to the Internet after you have energized the system.
- Commission the Envoy-C with microinverters in the system.

When installing multiple Envoys on the same utility transformer, commission only one system at a time.

In an Enphase system, the Envoy-C database must be provisioned with only the serial numbers of the microinverters that the Envoy-C will be monitor. Ensure that each Envoy-C is provisioned with only the serial numbers of the microinverters in its communication domain.

While you can still provision the communication domain from the Envoy-C device scan, you can now do this more easily using the Enphase Installer Toolkit.

Commissioning the Envoy-C with Installer Toolkit

The Enphase Installer Toolkit is a mobile app that provides on site system configuration capabilities, eliminates the need for a laptop, and increases installation efficiency. You can use the app to:

- Connect to the Envoy-C over a wireless network for faster system setup and verification.
- View and email a summary report that confirms a successful application of a grid profile, if needed.
- Scan microinverter serial numbers and sync system information with Enlighten monitoring software.

Follow these steps to commission one Envoy-C with Installer Toolkit in a multiple Envoy-C environment. Refer to the *Enphase Installer Toolkit Operation Manual* for detailed instructions.

1. Download and install the Installer Toolkit mobile app. In the iTunes or Google app store, search for Enphase.
2. Launch the Toolkit App and log in to Enlighten.
3. Use the on-site wireless router to connect to the same LAN as the Envoy-C. Or create a temporary LAN using a portable router like the *TP-LINK TL-MR304*0.
4. The Installer Toolkit scanning screen displays the names of the arrays and the number of microinverters associated with each array.
5. Connect to the Envoy-C that you want to provision. The Installer Toolkit automatically attempts to connect to the Envoy-C.
6. Enter or confirm the number of microinverters that you expect to report to this Envoy-C. If you have already used the Installer Toolkit to record the microinverters in the array(s) associated with this Envoy-C, the total scanned number displays.

7. For multiple Envoy-Cs, select or add an Envoy-C before scanning microinverters. To select or add an Envoy-C by scanning the bar code, tap [>] (to the right of the word “Envoy”), then follow the on-screen instructions.
8. Tap **Scan** at the bottom of the **System Overview** screen to add an array.
9. Tap the **Name** field and enter the array name. Enter other array details as needed.
10. Save the information.
11. Tap the array name or tap **Scan** to start the microinverter scan. If this is first time you have used Installer Toolkit to scan microinverters, the app will prompt you to select a scanning method, **Scanner** or **Camera**. You can change this setting later in Settings, if needed.
12. Tap the module location where you want to start scanning.
13. Scan the bar code on your first microinverter.
14. Tap on the location of the next module that you want to scan.

Repeat the steps 13–15 until you have completed the scan.

Commissioning the Envoy-C with Device Scan

Follow these steps to commission one Envoy-C with **Device Scan** in a multiple Envoy-C environment:

1. Plug the Envoy-C into a NEMA 6-15 power receptacle.
2. Connect the Local Area Network to the Envoy-C. Verify that the green link light on the back of the Envoy-C displays.
3. The Envoy-C displays **+Web** after four or five minutes.
4. The Envoy-C may automatically undergo a software update after connecting to the Web. Do not unplug the Envoy-C during the update. The Envoy-C 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-C displays **-Web** for about two minutes after the new software has been updated, but quickly returns to **+Web**.
5. Ensure that the Envoy-C displays a communication level of at least three bars. If not, troubleshoot the system. Refer to the *Enphase C250 Microinveter System Installation Operation Manual*.
6. Upon startup, the Envoy-C begins an eight-hour device scan for new devices. If the Envoy-C detects microinverters before the solar array is powered on, those microinverters have been "poached" from another system. Use a laptop to access the **Envoy-C Device Conditions and Controls** menu and delete those microinverters, or contact support@enphaseenergy.com.
7. Once 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-C. The Envoy-C will populate its database with the microinverters on site. This generally takes about 20 minutes, but can take longer. This process only happens during daylight hours as microinverters operate only when powered by DC solar.
8. Once the Envoy-C has populated its database with all of the microinverters at the site, press and hold down the menu button on the right side of the Envoy-C until the display reads **Disable New Device Scan**. After the device scan disables, you can commission another Envoy-C 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.

Section 7: Networking and PLC Considerations in Commercial Projects

This section addresses networking and power line communication (PLC) for commercial systems, with an emphasis on how to configure commercial installations for trouble-free operation and monitoring. The C250 System cannot use Ethernet bridges that are frequently used for 120 V systems. The Envoy-C in an C250 System should be connected to the network using either a hardwired network connection or other networking components. The other networking components will need to be rated for the voltage by which they are powered.

Power Line Communication

Enphase Microinverters communicate with the Envoy-C using power line communication (PLC) technology. 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, good communication between the array and the Envoy-C is necessary for system monitoring and maintenance.

Power line communication is 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-C Communication

Besides communicating with microinverters via power lines on the premises, the Envoy-C also communicates with Enlighten via an Ethernet cable connected to the on-site broadband router. The Envoy-C is like another computer at the premises, connecting through a standard Ethernet LAN (Local Area Network) cable and using standard TCP/IP protocols.

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

When the Envoy-C 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-C.

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

DHCP versus Static IP Addressing

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

1. Use the Envoy-C 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. Determine whether the Envoy-C is using DHCP or Static IP, and change this setting if needed.
4. Click **Check Network Connectivity** to view the Envoy-C connections.

For more information on how to use the Envoy-C Interface, refer to the *C250 Microinverter Installation and Operation Manual.*

WARNING: Do not change the Envoy-C DHCP setting to a static IP address unless you also reserve the same IP address on your broadband router. Refer to the section on DHCP Reservations in the router setup manual.

Failure to reserve the static IP address on the router results in duplicate IP addresses and an intermittent Internet connection for the Envoy-C.

MAC Filtering

Media Access Control (MAC) address filtering is a security mechanism that allows network administrators to specify which devices can use the router for Internet access. MAC address filtering prevents unauthorized or unknown personnel from using the router to get to the Internet.

A MAC address is a 48-bit address that uniquely identifies a hardware device. An example of a MAC address is, 00:17:F2:D6:B1:45. MAC addresses contain six pairs of hexadecimal characters, from 0 through 9 and A through F. The MAC address of the Envoy-C begins with 00:D0:69:*.

Check to determine if MAC filtering is in use at the site. If MAC filtering is in use, find the MAC address of the Envoy-C to add to the list of authorized devices on the router.

To get the Envoy-C MAC address, access the local Envoy-C interface using a web-browser. The Envoy-C home page contains the unit MAC address. You can also find the MAC address on the back of the Envoy-C.

Firewall Settings

The Envoy-C 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-C and set up rules to allow outbound access. Configure the rules as follows:

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

The Envoy-C connects to servers using Domain Name System (DNS) names. If you add firewall rules for Envoy-C 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-C DHCP setting to a static IP address unless you also reserve the same IP address on your broadband router. Refer to the section on DHCP Reservations in the router setup manual.

Failure to reserve the static IP address on the router results in duplicate IP addresses and an intermittent Internet connection for the Envoy-C.

The Envoy-C with Wireless Adapter

The Envoy-C Communications Gateway is compatible with the Enphase Wireless Adapter. The adapter is available for purchase separately from the Envoy-C and enables connection to a wireless network.

The Enphase Wireless Adapter (Wi-Fi USB stick) allows the Envoy-C to transmit Enphase Microinverter System data through the on-site wireless network to the Enlighten Monitoring platform.

Using the wireless adapter simplifies Envoy-C installation and reduces system commissioning time.

With the Enphase wireless adapter, you can connect the Envoy-C to the Internet in one of two ways.

- Use the Wi-Fi WPS button on the wireless router.
- Configure the Envoy-C manually using the Envoy-C local interface.

Refer to the *Enphase C250 Microinverter System Installation and Operations Manual* for detailed installation steps.

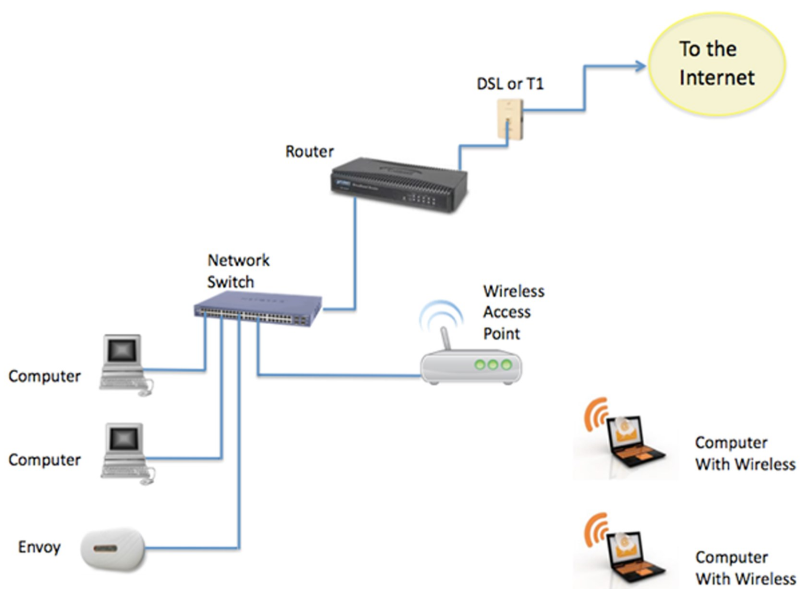
Some installation sites may require that you extend the range of the existing Wi-Fi network so that the Envoy-C with the wireless adapter can connect to the Internet.

Typical Networking Examples in Enphase Commercial Installations

The networking and communications side of installing a commercial Enphase Microinverter System is straightforward. Follow the practices in this section to minimize communication issues with commercial installations.

Typical LAN/WAN Network

In a local area network (LAN) or 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 that 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-C connects to the wired LAN just like another computer.

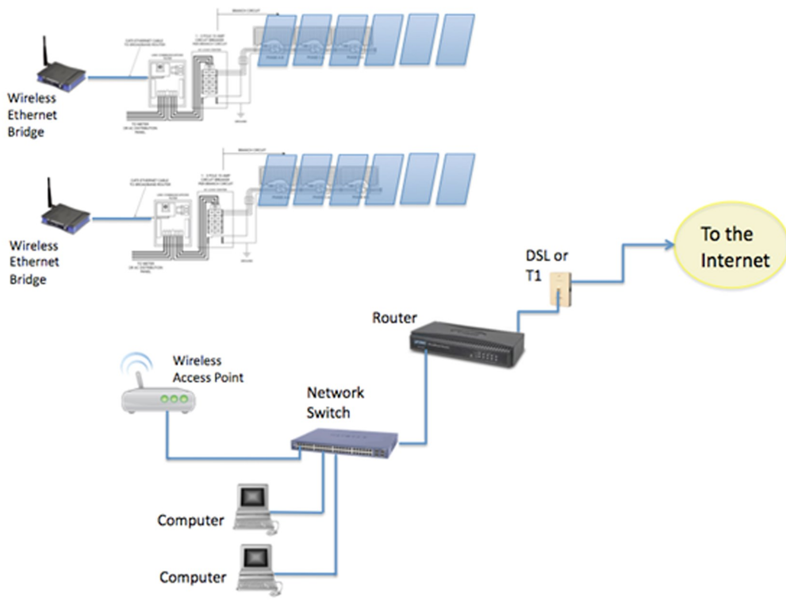


Ethernet and Wireless LAN Networks

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

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-C so that it can communicate across Wi-Fi services.

As shown in the diagram, each Envoy-C 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 wireless coverage. Not all Wi-Fi vendors specify the product's unobstructed distance for 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.

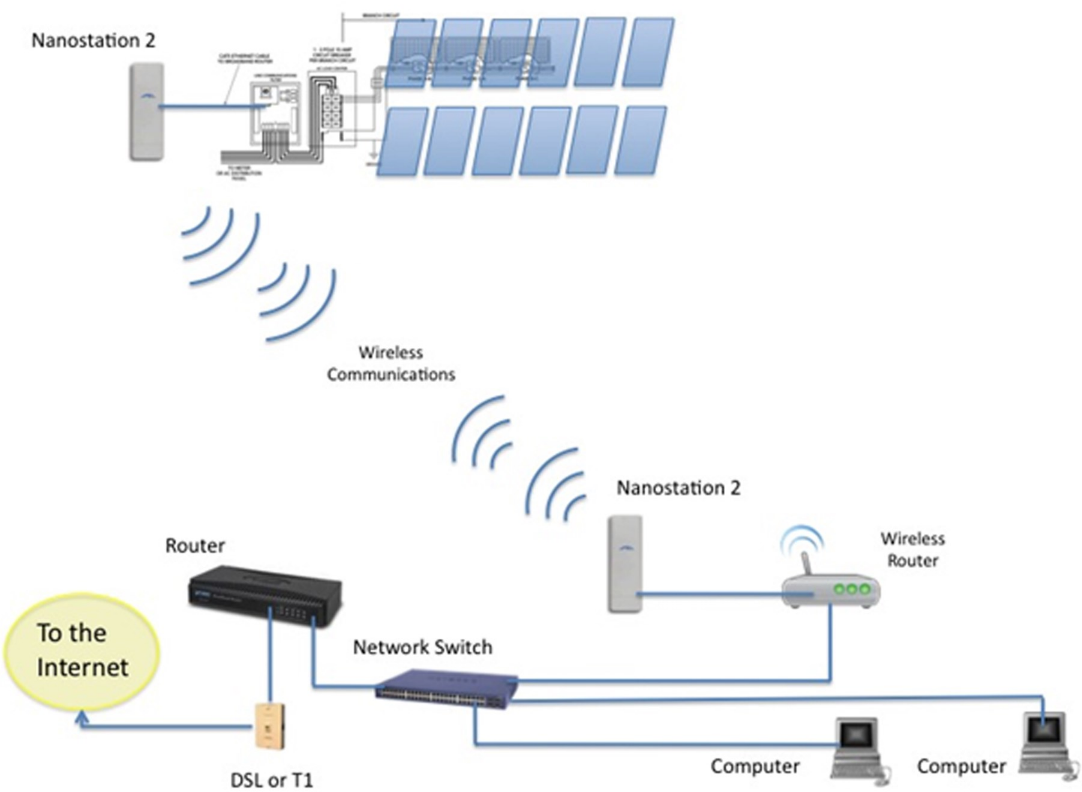
Wireless Ethernet Bridges

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* bridges are often used.

The Envoy-C 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-C USB port. The *Netgear WNCE2001* is about the size of a deck of cards, connects to the Envoy-C through an Ethernet cable, and is a less cumbersome than some other Ethernet (to Wi-Fi) bridges.

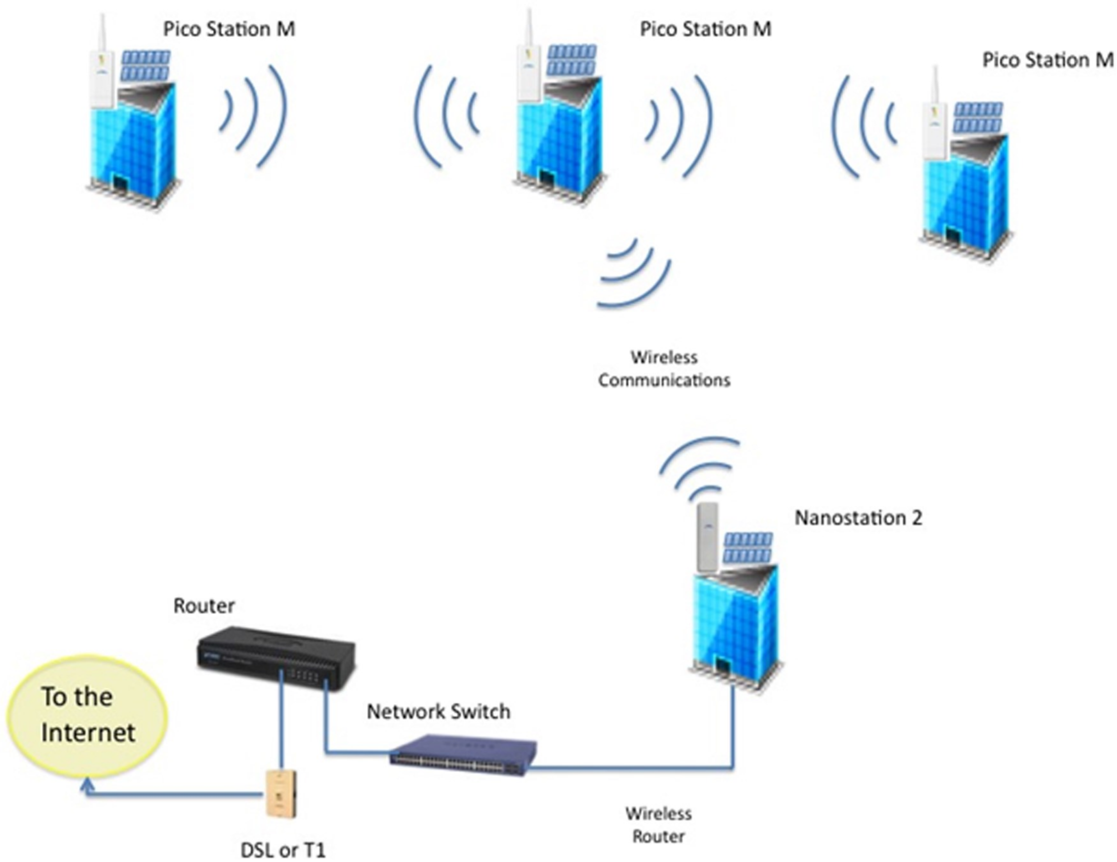
Wireless Hi-Gain Antenna Systems

Wireless Hi-Gain Antenna systems can be useful when the distance from the filter to a wireless router is over 500 feet. Enphase suggests using 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 to connect a filter and transmit a signal to extend reach to other OD2 devices.



Appendix A: Hawaiian Electric Industries Requirements for C250 Projects

The C250 Microinverter System has been evaluated and is approved for installation in Hawaii. Hawaiian Electric Company (HECO), a subsidiary of Hawaiian Electric Industries (HEI), requires some design and microinverter grid setting changes on C250 projects to comply with local requirements and to help support the grid.

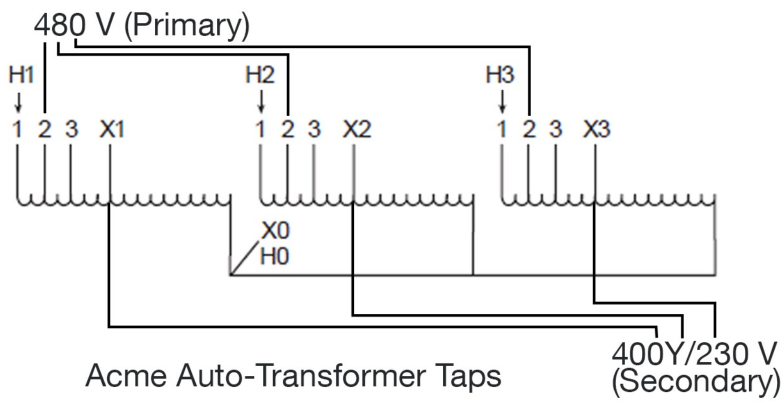
This appendix details the required changes for C250 projects interconnecting on the islands of Hawaii.

Adjustments to Auto-Transformer Connections

To make the HEI-required adjustments to the C250 Microinverter, you must also make a small adjustment to the ACME auto-transformer.

For most C250 projects, the primary (line) side of the transformer connects at the 432 V taps and the secondary (load/array) side connects at the 380 V taps. This ratio steps the 480Y/277 V provided by the utility down to about 422Y/244 V.

However, for C250 Microinverter Systems that interconnect to HEI grid, you must connect at the 456 V taps on the primary side. This ratio yields 400Y/230 V at the 380 V (X1, X2, X3) terminals of the auto-transformer and allows ample adjustments to conform to HEI high voltage ride-through requirements on the C250 Microinverter side.



Branch Limit Variation for HEI

Because the C250 operates at a lower AC voltage, the maximum number of microinverters allowed on a branch limit for HEI interconnected projects is 42. This is lower than the maximum number listed on the C250 datasheet. For an HEI interconnection, the maximum number of 42 C250 Microinverters on a branch circuit is required so as not exceed the limit for a 20 A circuit.

Service Type	Maximum Number of C250s on a 20 A Branch Circuit	Maximum Number of C250s on a 20 A Branch Circuit for HEI-connected projects
Three-phase	48	42

Grid Profile Adjustments for Trip Management

To comply with HEI grid interconnection requirements, you must make adjustments to the C250 Micronverter grid profiles. The values listed here assume nominal voltage of 400Y/230 V.

To make changes to the grid profile, you need to access the Envoy-C on site.

How to configure a Grid Profile

This procedure assumes that you installed the Envoy-C and that the Envoy-C has detected all the microinverters in the communication domain. For details, refer the *C250 Installation and Operations Manual*.

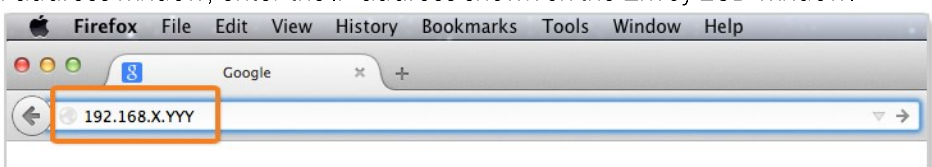
You need a laptop computer to access the Envoy-C interface and configure a grid profile.

The high-level steps to configure a microinverter grid profile from the Envoy-C are:

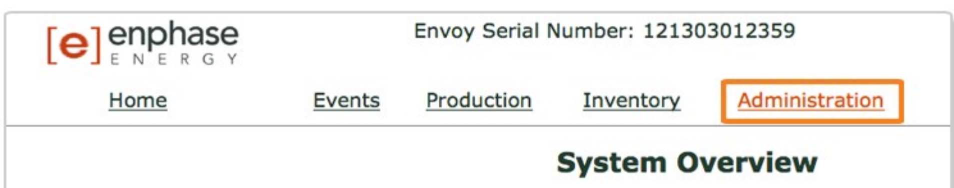
1. Log in to the Envoy-C interface.
2. Create the grid profile for your region.
3. Apply the grid profile to the microinverters.

Log In to the Envoy Interface

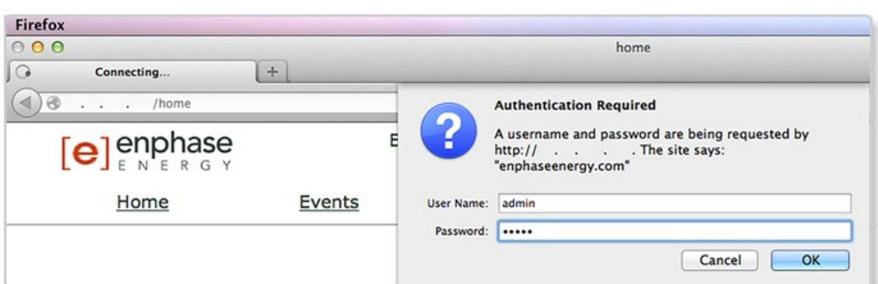
1. Connect a computer to the same network (same broadband router) as the Envoy and open an Internet browser.
2. In the browser address window, enter the IP address shown on the Envoy LCD window.



3. From the Envoy home screen, click **Administration**.



4. Enter **admin** for username and **admin** for password, then select **OK**. The Envoy-C Administration page displays.

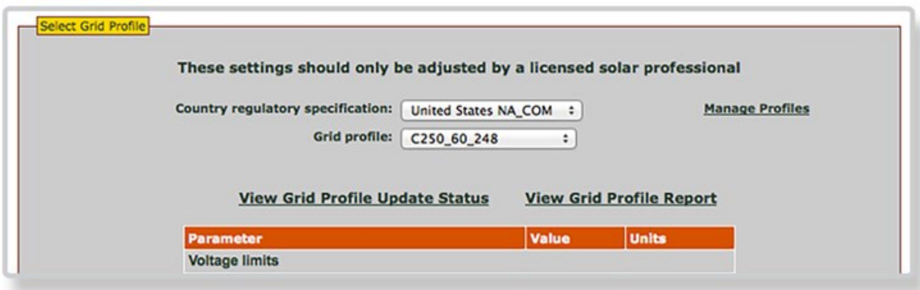


Create the Grid Profile for your Region

1. From the Envoy Administration menu, select **Device Grid Configuration**.

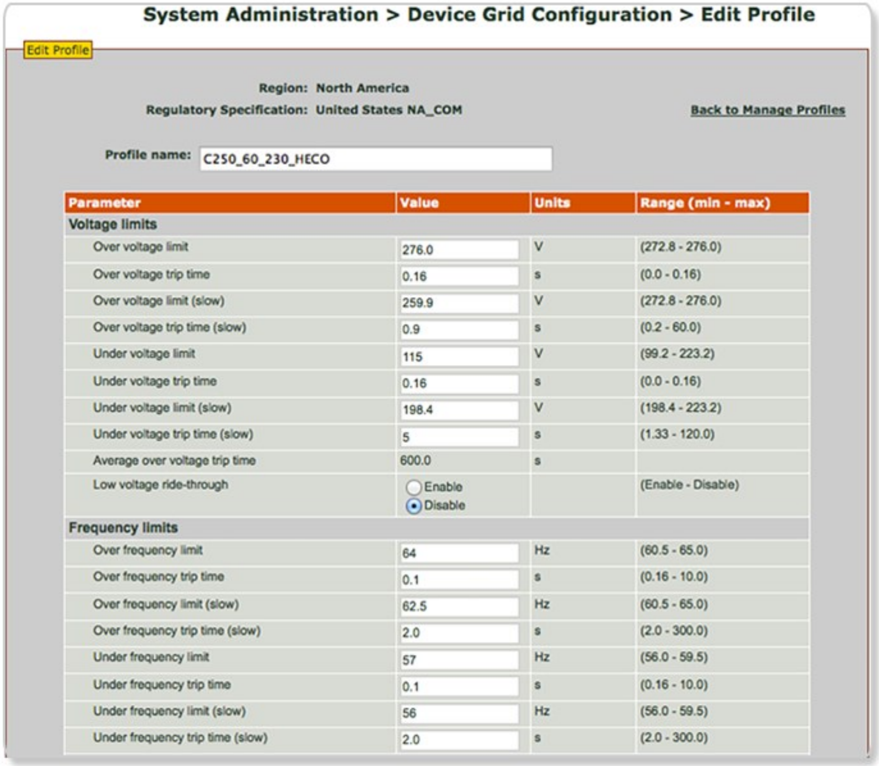
2. From the **Select Grid Profiles** section, click **Manage Profiles**.

3. From the Country regulatory specification drop-down list, select **United States NA_COMM**. **C250_60_48** displays in the Grid Profile.



4. From the Profile Name list, select **C250_60_48**. The Edit Profile page displays.

5. In the **Profile name** field of the Edit Profile page, enter a new name for the profile, such as C250_60_230_HECO.



6. Change the following parameters to the values listed here:

Parameter	Value
Fast over-voltage limit	276 V
Slow over-voltage limit	259.9 V
Fast under-voltage limit	115 V
Slow under-voltage limit	198.4 V
Fast over-voltage trip time	0.16 s
Slow over-voltage trip time	0.9 s
Fast under-voltage trip time	0.16 s
Slow under-voltage trip time	5 s
Fast over-frequency limit	62.5 Hz
Slow under-frequency limit	56 Hz
Fast under-frequency limit	57 Hz
Fast over-frequency trip time	0.16 s
Slow under-frequency trip time	2 s
Fast under-frequency trip time	0.16 s
Slow over-frequency trip time	2 s
Slow over-frequency limit	65 Hz

7. Click **Make Copy**. This creates your HECO grid profile, **C250_60_230_HECO**.
8. Click **Save Profile**.

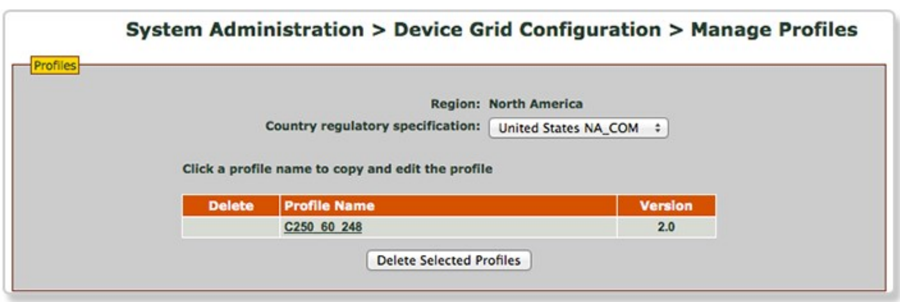
Apply the Grid Profile to the Microinverters

NOTE: A Profile Change Token is not required the first time an Envoy-C grid profile is modified. Any subsequent changes to the grid profile require additional steps. For more information about generating a Profile Change Token, contact your Enphase Sales Lead or Enphase Customer Support.

To apply your custom Grid Profile, select the grid profile from the Envoy-C Device Grid Configuration menu as follows:

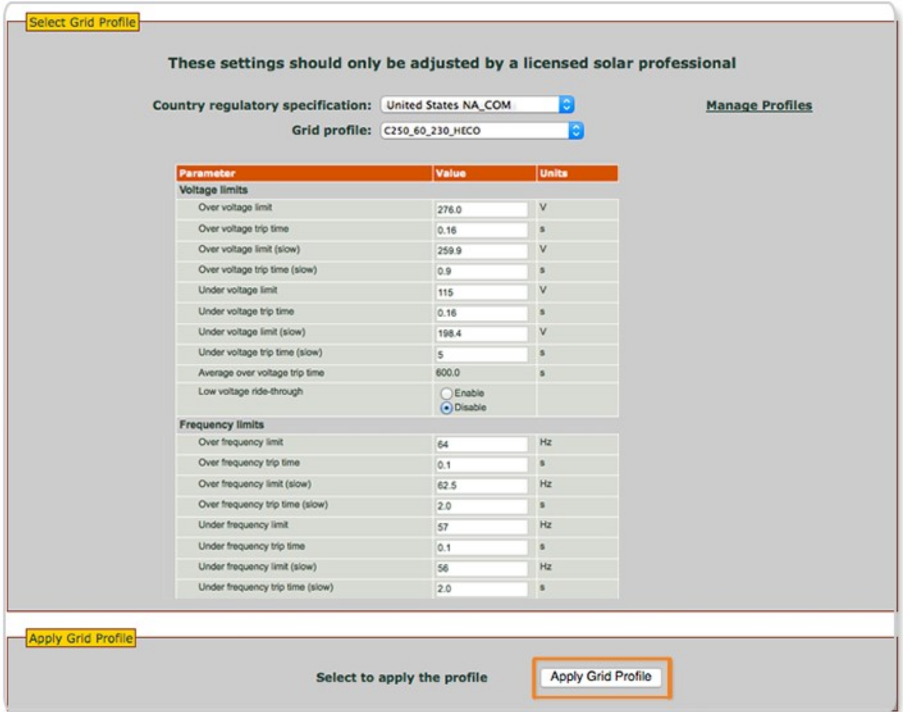
1. Go back to the Envoy Administration page and select **Device Grid Configuration.**

2. In the Select Grid section, select **United States NA_COM** from the Profile Country regulatory specification drop-down list.
3. From the Grid profile drop-down list, select the grid profile you created, **C250_60_230_HECO**, for example.



The grid profile you created displays.

4. Scroll down to the **Apply Grid Profile** section.



5. Click **Apply Grid Profile**. The microinverter software updates automatically, and the grid profile propagates to the microinverters. A Grid Profile Incompatible alert may display but clears automatically when the update is complete.

If appropriate, continue with System Activation.

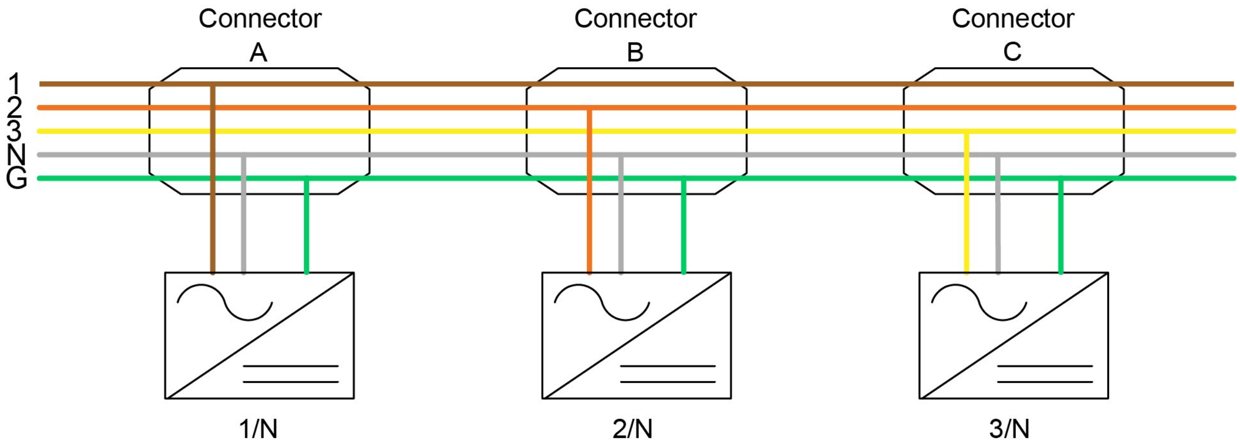
For details, refer to the Enlighten Help Center in Enlighten or to the *C250 Installation and Operations Manual* found on www.enphase.com/support.

Appendix B: Dropped Phase Hardware Solution

For project success, you must consider phase imbalance when designing commercial PV systems using M-Series or C250 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 C250 Microinverter connects to one of the three available phases of a three-phase 422Y/244 V service. Three-phase C250 Engage Cable includes five conductors and is used for C250 commercial installations. Because Enphase C250 Microinverters output onto one phase, 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 line 1, then the second will be connected to line 2, the third to line 3, and the fourth to line 1 once again. The pattern continues to repeat itself, as shown in the following diagram.



If a grid failure occurs only on phase A, then two thirds of the microinverters connected exclusively to lines 1 and 2 are 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

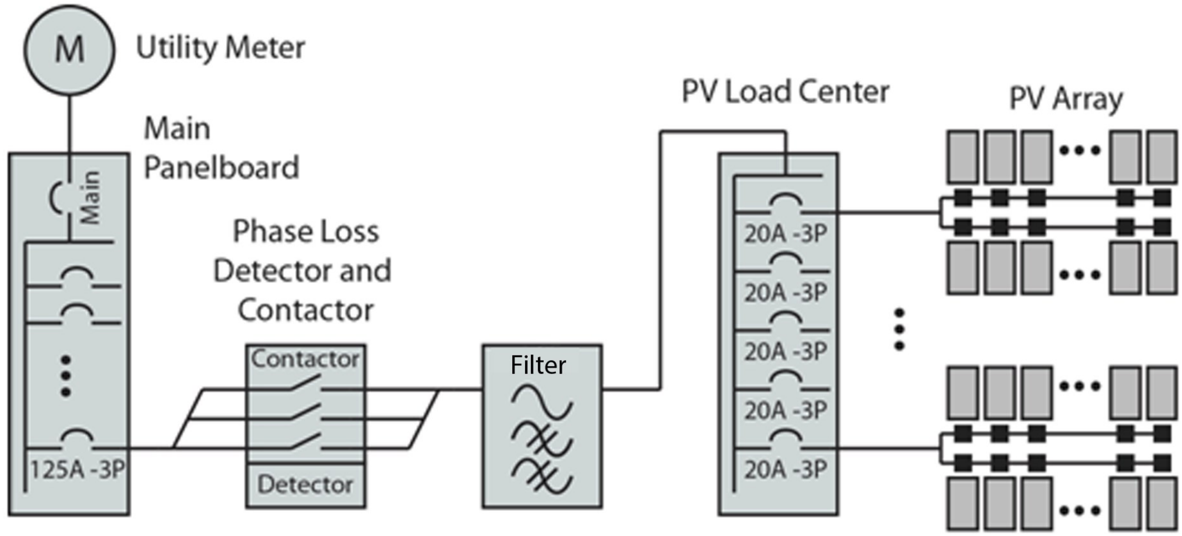
Enphase suggests the use of an overload relay system for loss of phase applications. An overload relay system consists of:

- 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 mounts directly onto the contactor and forms one unit.

If you cannot procure a combined unit, then you must hard wire the contactor to the overload relay. You must also use a dedicated breaker connected to grid power on the grid side of the dedicated PV portion of the system to power the overload relay.

Install the combined relay-contactor system on the PV system side of the PCC and on the grid side of the main PV load center, as shown in the following diagram.



For example, in a 10 kW installation, we recommend a 40-50 A, general use, IEC-rated, 277 V coil contactor, available from *Allen-Bradley* or equivalent. The voltage sensing relay part number is in the group 813S-xx. 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 C250 Microinverters

Appendices C and D address two technical characteristics of power output in the Enphase 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.

Fault Current Contribution

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

Enphase Microinverters do not require a kAIC rating. 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 require an AIC rating.

Calculating Fault Current Contribution

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

For a C250 Microinverter, the fault contribution value is 1.05 ARMS for three cycles.

In an installation with 576 microinverters and with a main breaker rated at 10 kAIC, the fault current contribution from the microinverters is:

576 microinverters x 1.05 ARMS = 604.8 ARMs for three cycles

Since this value is only a small fraction of the main breaker's kAIC, the main breaker is more than adequate to interrupt any fault current contributed by the DG.

Likewise, the utility must ensure that the fault current supplied from the utility is less than 10 kA. 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 and 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.*

The UL 1741 standard requires a short circuit test and listing of 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 total distortion, the other technical characteristic of power output in the Enphase C250 and M-Series Microinverter Systems.

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

Distortion is measured at 40 different harmonics, from the 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 C250 and M-Series Microinverters meet the specifications as outlined in IEEE 1547, Clauses 4.3.3 and 5.1.6:

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

The C250 and M-Series 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 (AHJ) and your utility, as appropriate, may lessen power quality related issues in your commercial Enphase Microinverter design and installation.

Glossary and Acronyms

Acronyms and Glossary

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

AC: Alternating Current

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 United States.

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).

DC: Direct Current

Delta Configuration: Delta (Δ) power is a three-phase wire configuration without a defined neutral. You can find a diagram of a Delta configuration in About Transformers, Phase Couplers, and Filters in the C250 System on page 10

DER: Distributed energy resource.

DG: Distributed generator.

EGC: Equipment grounding conductor.

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

GEC: Grounding electrode conductor.

GFDI: Ground Fault Detection and Interruption

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.

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 (RGM): A metering device capable of measuring power production within ± 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.

SREC: Solar Renewable Energy Certificate.

WAN: Wide area network.

WEEB: Washer, Electrical Equipment Bonding

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 (Y) power is a three-phase configuration where phase-to-neutral is equal on all three legs. You can find a diagram of a Y configuration in About Transformers, Phase Couplers, and Filters in the C250 System on page 10

