Application Note

Commercial System Design Guidelines with M215s

Purpose

When designing commercial PV systems using Enphase M215 Microinverters, some important considerations must be taken to ensure project success. This document details the process of designing systems larger than 50 kW or systems with more than one Enphase Envoy Communication Gateway. Additionally, this document will recommend some best practices. These recommendations and requirements can help minimize costs, maximize performance, and ensure strong communications. We will discuss the fundamental steps for designing a commercial project with M215s, as well as stepping through the process of designing a 250 KW DC System.

Glossary

Enphase M215 Microinverter- The M215 Microinverter is 96% efficient, and has been designed to work with 60 cell modules up to 260 watts STC. The M215 is rated for a continuous output of 215 watts. The M215 automatically detects the utility voltage, and will export power to either 208 Vac or 240 Vac utility services. Each branch circuit of M215s feeds a 20A circuit breaker. The maximum number of M215s on a fully populated branch circuit is 17 at 240 Vac or 25 at 208 Vac, three-phase.

Enphase Engage Cable- The Engage cable is the innovative cabling system that has been developed exclusively for connection of M215 Microinverters. The Engage cable is manufactured with a connector for each microinverter. The cable contains #12 THWN-2 conductors and is rated to feed a 20 circuit breaker. The cabling is available for single-phase or three-phase applications, and must be ordered for the appropriate application. Additionally, the cable comes with its connectors spaced every 1.0 meter for portrait applications or 1.7 meters for landscape applications.

Enphase Envoy Communication Gateway- An Envoy allows module level monitoring for up to 250 Enphase Microinverters. The Envoy uses the power line to communicate with each of its microinverters. Also, the Envoy can be connected to

the internet via a network router. Enphase provides an Ethernet Bridge with each Envoy, which allows for the option of using power line communications between the Envoy and the router.

Communication Domain- A group of module/microinverters pairs which all communicate with a common Envoy. Steps must be taken to prevent cross-talk between multiple communications domains. To prevent interference between communication domains, the installation of an Enphase Line Communications Filter or transformer will likely be required.

Enphase 100A Line Communications Filter (LCF)- When a project requires more than Envoy, an LCF may be required to be installed on every communication domain. An LCF provides noise filtration for each communication domain, which helps to prevent cross-talk between multiple communication domains and filters electrical noise from the site loads. Each LCF includes an Envoy inside it, and must be located near the communication domain it serves. Installation of an LCF limits the number of microinverters which can be installed in a communication domain to its 100A continuous output rating.

Microinverter Sub-Panel- A Microinverter sub-panel is an electrical load center which is dedicated to a single communication domain. The Microinverter sub-panel will feed multiple 20A inverter output branch circuits.

Main Photovoltaic Load Center- An electrical load center which feeds multiple Microinverter sub-panels.

Transformer- A transformer is often required to interconnect commercial photovoltaic projects to the utility grid. Transformers can be used to connect Enphase Microinverter systems to 480V and higher utility services. Also, a transformer can be utilized to lower wire costs for long transmission runs. A transformer works as an excellent filter of electrical noise and communication signals, and can provide isolation of communication domains. Additionally, a transformer generally has adjustable taps which allow for adjustments to the utility voltage.

Separation of Communication Domains- Due to induction of communication signals between conduit and wire runs, each communication domain must be physically separated from the other communication domains. Therefore, the conduits and wiring running between each communication domain must be physically separated from the conduits and wiring of all other communication domains.

Filtration of Communication Domains- When multiple communication domains are tied to a common service panel or a single transformer, an LCF must be installed between each microinverter sub-panel and the Main Photovoltaic Load Center. Transformers also serve as good communication filters.

Center Feed Method- The "Center Feed" method is the process of separating individual branch circuits into sub-branch circuits. This is a standard design practice with Enphase Microinverters, which will lower overall wiring costs by

reducing voltage drop on the Engage Cable, and improving communications. This is discussed extensively in the M215 Voltage Drop Technical Brief.

Start-up Procedure- Following the startup procedures detailed in the Best Practices section of this document can help to ensure that all Microinverters are communicating with the correct Envoy. The start-up procedure involves the commissioning of each communication domain individually. Before commissioning other communication domains, se the button located on the side of the Envoy to "End Device Scan."

Enphase Line Communications Filter (LCF)

Line Communications Filter

The Enphase Envoy Communications Gateway is the data logger / internet gateway for an Enphase Microinverter system. Each microinverter's performance and production data is provided to the Envoy using power line communications. The signal is communicated on the inverter output conductors and requires a neutral conductor. For systems larger than 250 Microinverters or 54kW AC, more than one Envoy is required. When multiple Envoys are required, LCFs are also required to prevent communications data from one communications domain from cross-talking with another communication domain.

To ensure reliable monitoring, the Envoys and the LCFs should be located close to the microinverters. The Inverter Sub-panels and LCFs will generally be located on the roof for commercial roof mounted systems. For ground mounted systems, the Inverter Sub-panel and LCF should be at or near the communication domain. A network cable should be provided to each Line Communication Filter/Envoy, to

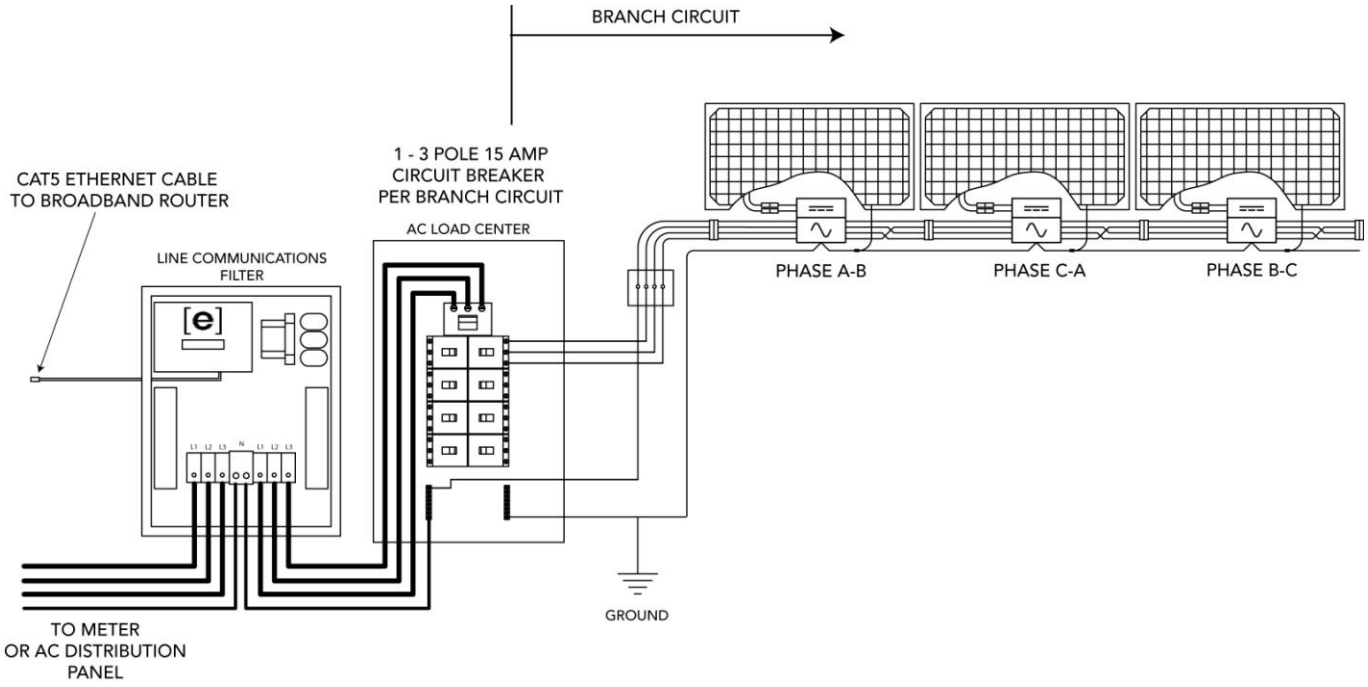
allow for network communications with the site router. Each Envoy device must be independently connected to an upstream Internet port. This often requires conduits and LAN/Ethernet cables to each LCF.

The LCF has a maximum OCPD rating of 125 amps. As per NEC 690.8(A)(1), 100 Amps of continuous inverter output current can be connected to the Inverter Sub-panel which is filtered by the LCF. The 100 Amp rating limits each communication domain to fewer microinverters than would otherwise be allowed with an Envoy. Use the chart below to determine the number of microinverters allowed per LCF.

Table 1- Microinverters per Line Communication Filter

Maximum Number of Microinverters per 125A LCF				
Microinverter Description	**Inverter Watts**	**System Voltage**	**Microinverters per LCF**	**AC System Size in kW**
M215-60 at 240	**215**	**240**	**111**	**24**
M215-60 at 208	**215**	**208**	**166**	**36**
M190-72-240	**190**	**240**	**126**	**24**
M190-72-208	**190**	**208**	**189**	**36**
M210-84-240	**210**	**240**	**114**	**24**
M210-84-208	**210**	**208**	**171**	**36**

The diagram below details a typical installation of a Line Communications Filter with M190 Microinverters in a three-phase application.



Sample Calculations for a 250 kW DC System

Designing commercial photovoltaic projects with Enphase M215 Microinverters is straightforward. The AC branch circuits can be combined using readily available components, saving material and labor costs, as well as reducing the production lost to voltage drop. The branch circuits can also be arranged to ensure high quality transmission within the power line communication domains.

We will go through the proper steps for designing a commercial 208V 3-phase photovoltaic project with Enphase M215 microinverters. As an example, we will go through the calculations for designing a 250 kW System with Enphase M215 Microinverters and 260 watt, 60 cell photovoltaic modules.

1- Determine the number of Modules/Microinverters required.

The desired system size for this example is 250 kW STC
The chosen PV module is 60 cells and is rated at 260 watts STC

250,000 W ÷ 260 W/Module = 962 modules

The total number of modules required would be 962, and the nominal AC output rating for this system would be 206.83 kW AC. The required number of microinverters would be equal to the number of PV modules:

962 photovoltaic modules = 962 M215 Microinverters

2- Determine the number of communications domains.

With Line Communication Filters

We must determine how many communication domains our 1,000 modules will be divided into. If the system is using transformers for filtering signals between communication domains, then you can use the maximum number of microinverters allowed per Envoy. However, if LCFs are used then the number of microinverters is limited by the 100A continuous rating of the LCF. From Table 1 on Page 4, we find that for a 208 volt, 3 phase system with M215 microinverters, 166 microinverter/module pairs can be installed in each communication domain using LCFs. This will require at least 6 communication domains.

(962 M215s) / (166 M215 per communication domain) = 5.8 5.8 rounded up = 6 communication domains 962 Microinverters / 6 communication domains = 160.33

When filtering is provided with LCFs, we will need six communication domains with approximately 160 Microinverters per communication domain.

Filtering With Transformers

For many commercial projects, transformers may be a preferred method of providing filtering between communication domains. This is particularly true when connecting to 480Vac and higher voltage utility services. For these applications, it is advantageous to transmit the power at a higher voltage, and located the transformers near the arrays/communication domains. Since the filtering of the communication domains is provided by the transformer, the 100A continuous limit of the LCF no longer applies. Each communication domain can now have up to 250 microinverters, which is 54kW of microinverters.

(962 M215s) / (250 M215 per Envoy/transformer) = 3.85
3.85 rounded up = 4 communication domains
962 Microinverters / 4 communication domains = 240.5

When filtering is provided with transformers, we will need four communication domains with approximately 240 Microinverters per communication domain.

Using transformers in place of LCFs can lower the total number of communication domains and Envoys installed on a site, but the cost of the transformers must be accounted for as part of the decision.

Transformers are listed based upon their primary and secondary coil voltage ratings and configuration. A common transformer for interconnecting Enphase M215 Microinverters to a 480/277Vac Utility Service would be rated as a 60kVA, 480/277Wye(Primary):208/120Wye(Secondary)

Determine the minimum number of branch circuits per communication domain.

The National Electric Code defines a branch circuit as the circuit conductors between the final Over Current Protection Device (OCPD) and the devices. The Microinverters connect in parallel on the Engage Cabling. The Microinverters, the Engage Cable, and the branch circuit wiring make up the Microinverter branch circuit. The maximum size of the circuit breaker protecting each Microinverter branch circuits is 20 amps. A 3-phase system requires a 3-pole OCPD and Three-phase, 208 Vac Engage Cabling, available in portrait or landscape.

The Enphase M215 Microinverter Datasheet and Manual specify that 25 M215 Microinverters can be installed on a three-phase, 208 Vac, 20A branch circuit.

166 M215 ÷ 25 M215 per branch circuit = 6.64 branch circuits
166 M215 ÷ 24 M215 per branch circuit = 6.92 branch circuits

7 branch circuits are required for each communication domain.

3- Finalize the Design.

To minimize installation costs, we will want to keep the number of communication domains to a minimum and we will want to keep the number of branch circuits to a minimum.

For a 208 Vac 3-phase circuit the maximum number of M215 Microinverters allowed on a branch circuits is 25, however, using 24 will not require any additional branch circuits. In this scenario we would recommend using 24 M215 per branch circuit, because it will balance the phase currents and reduce voltage drop on the Engage Cables. One possible system design would be:

5 communication domains with 166 M215 Microinverters: 830 M215s
- 6 branch circuits of 24 M215 Microinverters, 144 M215s
- 1 branch circuit of 22 M215 Microinverters, 22 M215s

1 communication domain with 132 M215 Microinverters: 132 M215s
- 5 branch circuits of 24 M215 Microinverters, 120 M215s
- 1 branch circuit of 12 M215 Microinverters, 12 M215s

Total Number of M215 Microinverters: 962 M215s

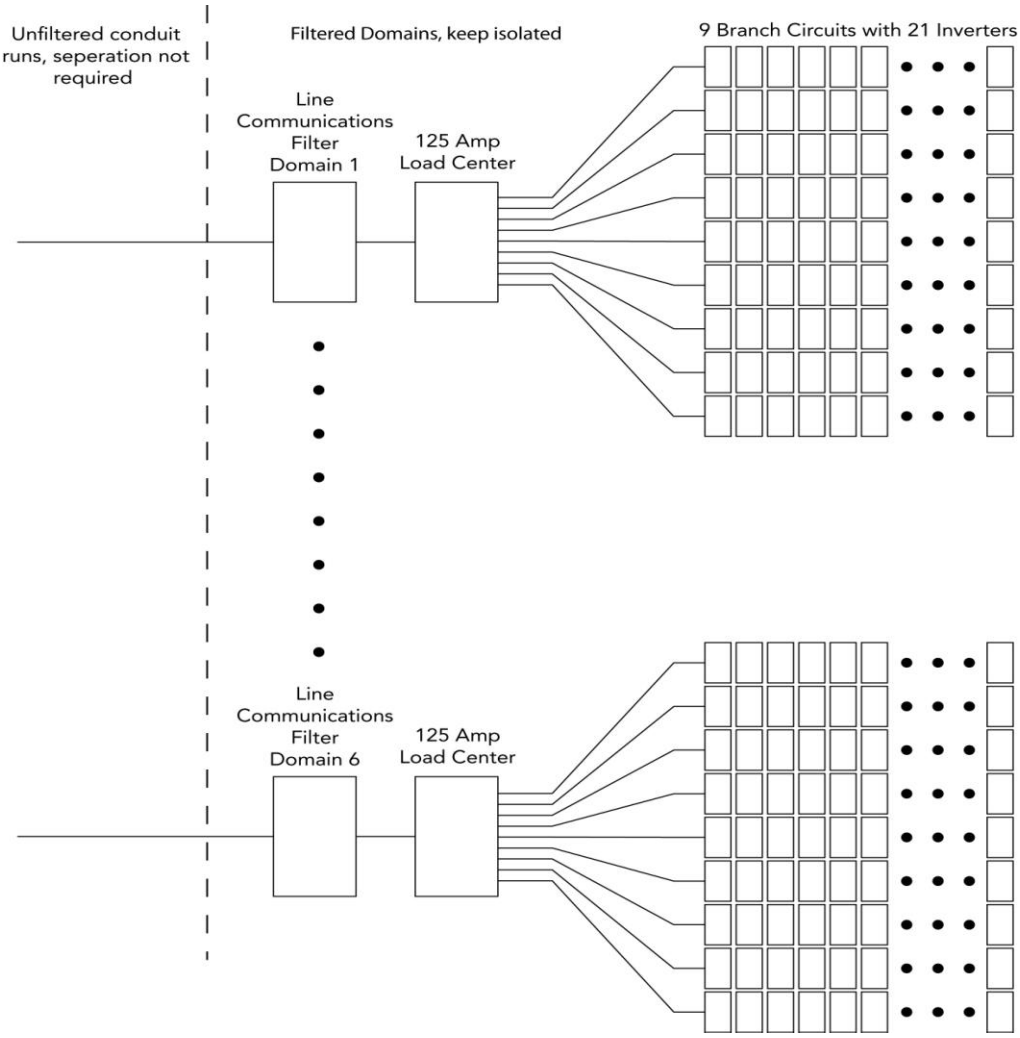
The Main Photovoltaic Load Center must accommodate 6- 125A Microinverter sub-panel circuit breakers, at 3-phase, 208Vac.

Component Count

962- 260 watt solar modules
962- M215 Microinverters
1000- Engage Cable Connectors (spaced every 1.0m for three-phase portrait applications)
81- Engage Cable Terminators (one for each sub-branch circuit)
38- Engage Watertight Sealing Caps (for unused connectors)
3000- Engage Wire Management Clip (3 clip per connector)
6- 125A Line Communication Filters
6- 200A Rated Microinverter Subpanels with 125A Main Breakers
(The additional buss bar factor is required by the NEC code)
41- 20A, 3 Pole Circuit Breakers
6- 125A, 3 Pole Circuit Breakers in Photovoltaic Load Center

Possibly Required
1- 480-208/120 Delta-Wye Transformer

Sample Diagram



Best Practices

Locating the Microinverter Sub-Panels and Line Communications Filters

Always use Line Communication Filters when more than 2 Envoy are located at a single site or on a single utility transformer. To ensure that we have strong communication signals between the Microinverters and Envoys, we should locate the Microinverters and the Envoys as close to each other as possible. The LCFs and Microinverter sub-panels should be located on the roof and adjacent to the array. This will save on installation costs, too. Consolidating the branch circuits into a single larger circuit will reduce material costs. Using a distance of 200 feet for example, installing a single 1-½" conduit with #1 AWG instead of installing 8 ¾"

conduits with #10 AWG would save 44% on material costs. Locating the LCF and Envoy close to the array will greatly reduce the possibility of cross talk.

Physical Separation of Communication Domains

We must provide physical separation of the communication domains. Care must be taken when routing the conduits and wiring between the Microinverters, the Inverter Sub-panels, and the Line Communication Filters. This is particularly important when conduits and wires are run parallel to each other. Conduits and wiring from communication domains must be about 12" away from other conduits and wiring from other communication domains.

Metal conduit is preferred for the shielding against induced signals that it provides. Using properly grounded, metal conduits (such as EMT) can help to lower the electrical noise between conduits and conductors. For underground conduit runs, care should be taken to ensuring that soil fills the space between the conduits of separate communication domains.

In some situations, the communication signals can be inducted onto the rails of racking. For this reason, it is safest to separate the rails of multiple communication domains.

Isolate Neutrals

It is a requirement that the circuit feeding each Line Communications Filter as well as the individual branch circuits would contain a conductor for L1, L2, L3, neutral, and ground. It is important that the conductors on the inverter side of the Line Communications Filter do not come in contact with conductors from other communications domains. Even though the neutral conductors meet at the point of interconnect to the utility, it is important that they are separated once they are on the inverter side of the Line Communications Filter.

Locate the AC Junction Boxes as Close as Possible to the 1st Microinverter in the sub-branch circuit.

Layout the AC juncition boxes in a manner that enables connection to the Engage Cable with a minimum number of unused "connectors" on the Engage Cable. This can significantly lower installation costs.

Keep Voltage Rise to Less than 1%
(from the Array Located AC Junction Box to the Main Service Meter

For all photovoltaic systems, voltage drop calculations must be made to ensure quality performance. These calculations are generally referred to as 'Voltage Drop' calculations, but in reality, photovoltaic systems generate electricity, so voltage drop is seen as 'Voltage Rise" on the terminals of the utility-interactive inverter or microinverter. If the voltage rises above the allowable levels, the microinverters will cease to export electricity to the utility grid. Enphase recommends that the total voltage rise within all wiring sections does not exceed more than 2%, including the Engage Cables.

To Keep the Voltage Rise on the Engage Cable to Less than 1%, Branch Circuits must be Center-Fed

An excellent way to lower the voltage rise in the Engage Cables by nearly a quarter is to "Center-feed" the branch circuits! This is the process of separating each branch circuit into 2 or more sub-branch circuits. These sub-branches can have different numbers of microinverters on each branch circuit. *Please reference our Enphase M215 Voltage Drop Technical Brief*, which provides a comprehensive source for calculating proper wiring sizes for all sections of the AC wiring. Use the tables below to determine the voltage drop on the Engage Cables.

Internal Vrise within the 240 Vac, 4 wire, 1.0m Portrait Engage Cables for M215s

Microinverters per Branch Circuit or Sub-Branch Circuit																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Vrise	0.01	0.04	0.08	0.13	0.19	0.27	0.35	0.46	0.57	0.70	0.84	0.99	1.15	1.33	1.52	1.72	1.94
%	0.01	0.02	0.03	0.05	0.08	0.11	0.15	0.19	0.24	0.29	0.35	0.41	0.48	0.55	0.63	0.72	0.81

Internal Vrise within the 240 Vac, 1.7m Landscape Engage Cables for M215s

Microinverters per Branch Circuit or Sub-Branch Circuit																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Vrise	0.02	0.06	0.13	0.21	0.31	0.44	0.59	0.75	0.94	1.15	1.38	1.64	1.91	2.20	2.52	2.85	3.21
%	0.01	0.03	0.05	0.09	0.13	0.18	0.24	0.31	0.39	0.48	0.58	0.68	0.80	0.92	1.05	1.19	1.34

Internal Vrise within the 208 Vac, 5 wire, 1.0m Portrait Engage Cables for M215s

Microinverters per Branch Circuit or Sub-Branch Circuit									
	3	6	9	12	15	18	21	24	25
Vrise	0.08	0.21	0.39	0.65	0.96	1.35	1.79	2.30	2.50
%	0.04	0.10	0.19	0.31	0.46	0.65	0.86	1.11	1.20

Internal Vrise within the 208 Vac, 1.7m Landscape Engage Cables for M215s

Microinverters per Branch Circuit or Sub-Branch Circuit									
	3	6	9	12	15	18	21	24	25
Vrise	0.12	0.32	0.63	1.05	1.58	2.41	2.95	3.78	4.14
%	0.06	0.16	0.30	0.51	0.76	1.16	1.42	1.82	2.00

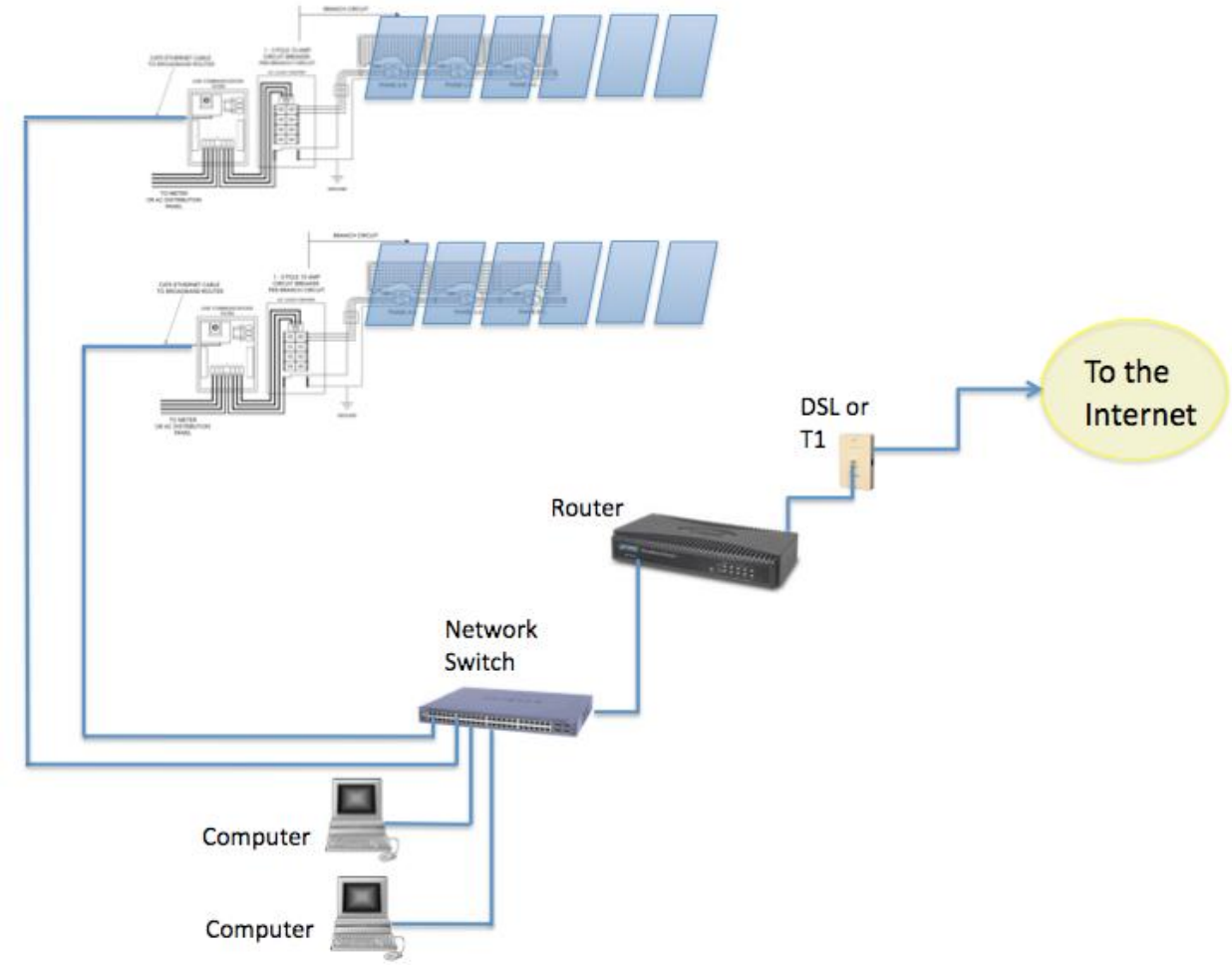
Collecting Serial Number Stickers and Preparing the Array Maps

To accurately monitor each module/microinverter, it is important to collect the serial number stickers from each microinverter. Each microinverter has removable labels which lists its serial number. The stickers should be peeled off of the microinverters and placed onto an array map. This should be done before the modules have been installed! Enphase Energy provides blank array maps at the back of the microinverter manuals, but for some large systems, custom maps may be preferred. When collecting the stickers, it is important to detail the orientation and tilt angle of the arrays, as well as detailing if the modules are installed in a portrait or landscape orientation. It is also important to label which array is associated with each array map.

Commercial Networking with Multiple Envoys

Hardwired Network

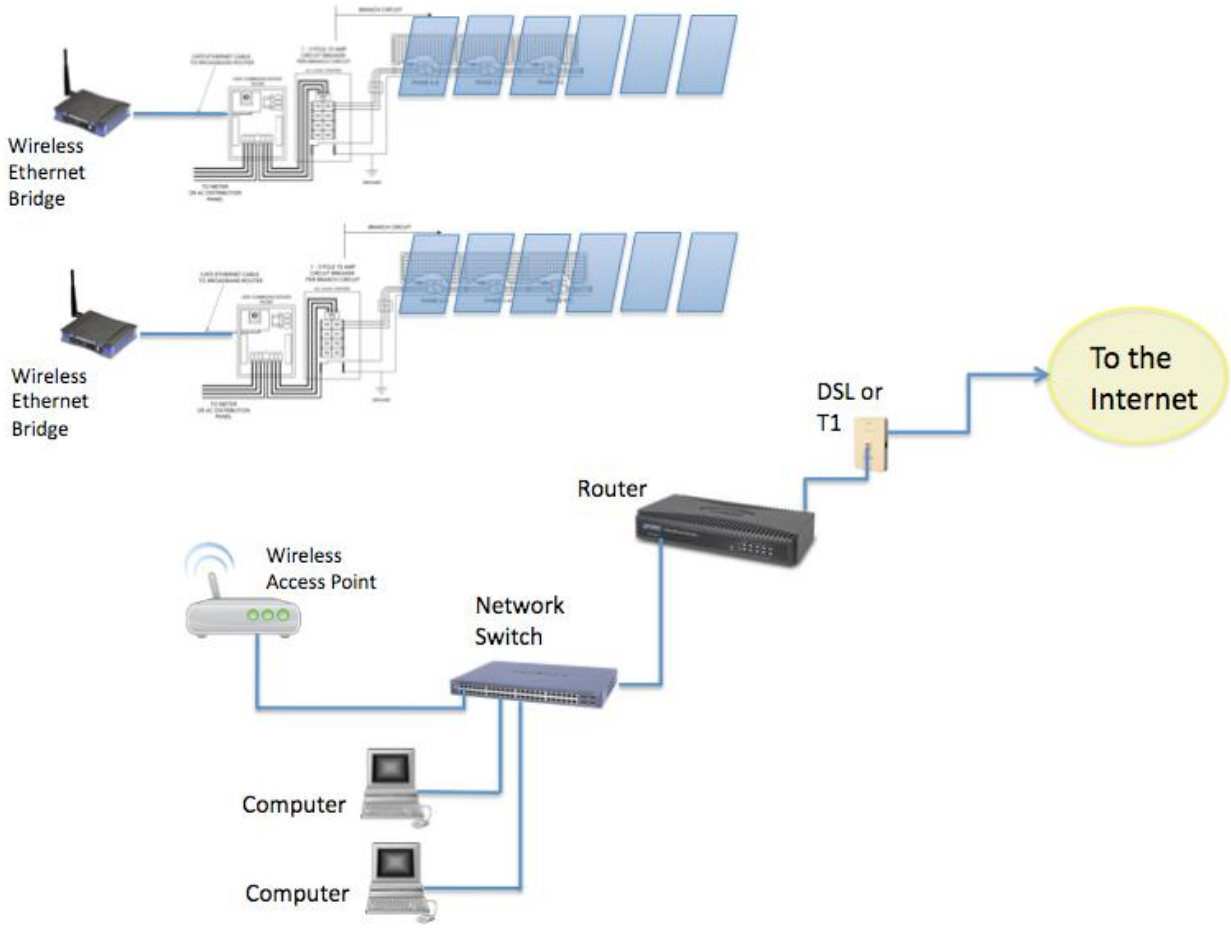
When multiple LCF/Envoys are installed at a single router, each LCF will require a dedicated LAN/Ethernet network connection. This model can scale as large as needed.



Wireless LAN Configuration

A Wireless Access Point may be used to provide internet connectivity to one or more of the Envoys inside of an LCF Enclosure. In this configuration, only the Wireless Access Point needs the hard-wired connection to an Internet switch/router. In turn, it provides WIFI services to each of the Envoys.

The Envoy does not have wireless capability built-in, so each one would require its own Wireless Ethernet "Bridge" to pass data from the Envoy to the Wireless Access oiubt as shown it the following diagram. These can be sourced from most consumer electronics and office supply stores.



Start-up Procedure for Sites with Multiple Envoys

When commissioning a commercial system, it is important to turn on each communication domain individually, and allow the microinverters to connect to the Envoy which is providing monitoring for that communication domain.

When an Envoy is initially provided AC power, it begins a 7 day "Device Scan". During this process, the Envoy populates its database with the serial numbers of all microinverters that it communicates with. The Envoy and Microinverters will pair together after the initial "handshake" between the two devices. For this reason, it is important that the Envoy is only communicating with Microinverters from its own communication domain. The best way to ensure this, is to shut of the disconnects or circuit breakers feeding the other communication domains.

Once the Envoy has established communications with all of the microinverters associated with that communication domain, then you can turn off the device scan. This can be done by holding down the button located on side of the Envoy until the display screen reads, "Disable Device Scan". When the Device Scan has ended, you can then move to commission the next communication domain's array.

Activating Commercial Projects in Enlighten

Once the system has been installed or is nearing completion, you can activate your system on the Enphase Energy Enlighten website. For projects over 125 KW, multiple activations may be needed. Each activation will become a single 'system' in Enlighten, with a recommended maximum of 500 modules/microinverters per activation. For our 250 KW sample system, at least 2 'Systems' should be activated in Enlighten. Each 'System' will need a unique system name, such as 'Acme Motors West Array' and 'Acme Motors East Array'

If this is your first time to activate a system in Enlighten, select 'Register A New Enphase System', then select 'Add New Activation.'

If you already have an account in Enlighten; login to your account, select 'Activations', and then select 'Add New Activation'.

To complete the activation, you will need to provide the following:

- Owner Name (*if the system has been financed with a PPA, the holder of the PPA is the owner)
- If the system is financed with a PPA, check the PPA box
- Owners email address and phone
- Site Address
- Envoy Serial Numbers
- Number of Branch Circuits
- Number of modules
- Module Manufacturer and Model Number
- Utility company, rate schedule, and service voltage
- Scanned array maps.

For Additional Support Documents, please reference:

http://enphase.com/support/downloads/

Enphase Application Note- M215 Installation

Enphase Application Note- Performance-Based Incentives

Enphase Application Note- Voltage Drop Calculations

Enphase Application Note- Networking in Commercial Applications

Enphase Application Note- Multi-tenant Installations

Enphase Datasheet- Line Communications Filter

Enphase Energy provides free design review and design support for commercial systems. Contact your sales representative or send an email to commercial@enphaseenergy.com.

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Commercial Design and Installation Checklist

	Are the modules and microinverters compatible?
	How many modules/microinverters are required?
	How many communication domains are required?
	Have LCFs or transformers been installed at each communication domain?
	Have the conduits/wiring been separated between communication domains?
	Has the total voltage drop been kept to less than 2% for all wiring sections?
	Has a LAN/Internet connection been provided to each communication domain?
	Have the array maps been made before the modules have been installed?
	Have the 'Systems' in Enlighten be kept to 500 modules or less?
	Has Enphase Energy been contacted for design review services?

Date: **Signature:**

_____ _____