

Power Control System integration in Enphase Energy System

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Introduction to Enphase Power Control

Power Control Systems (PCS), as defined in NFPA 70, National Electrical Code 2020 Edition, control the output of one or more power production sources, energy storage systems (ESS), and other equipment. PCS systems limit current and loading on the busbars and conductors supplied by the power production sources and/or energy storage systems. Enphase Power Control implements power control that complies with the UL1741 Certification Requirement Decision (CRD) for Power Control System (PCS).

Enphase Energy System (EES) has interconnected electric power production sources such as microinverters and/or IQ Batteries. The amount of power production sources that can be connected to a system is generally governed by various sections of the NEC. PCS Integration allows the EES to have more batteries installed and provides features to adhere to special compliance requirements in certain jurisdictions. The tech brief describes the benefits and implementation details of PCS Integration for real-time current monitoring and export limiting to enable PCS Integration.

Distributed energy resources (DER), mentioned in this document, refer to smaller generation units that are located on the consumer’s side of the meter, such as roof-top photovoltaic (PV) units, battery storage units, third-party generators, and other units.

Supported configurations for Enphase Power Control

Overview of Enphase Energy System

An Enphase Energy System can be classified into two configurations:

1. **Grid-tied or non-backup systems:** In a grid-tied system, Enphase microinverters and IQ Batteries will need the grid to be available to keep producing power or discharging to the loads.
2. **Grid-forming or backup systems:** Microinverters and/or IQ Batteries in a grid-forming system do not depend on the grid to keep producing power or to discharge the loads. An IQ System Controller is an essential part of an Enphase grid-forming system.

Both configurations support the Enphase Power Control features. The features supported in each configuration are discussed in the following sections.

Enphase Power Control in grid-tied Enphase Energy System

An Enphase Energy System in a grid-tied configuration has the following components:

- IQ8 Series Microinverters
- IQ Battery
- IQ Gateway or IQ Combiner

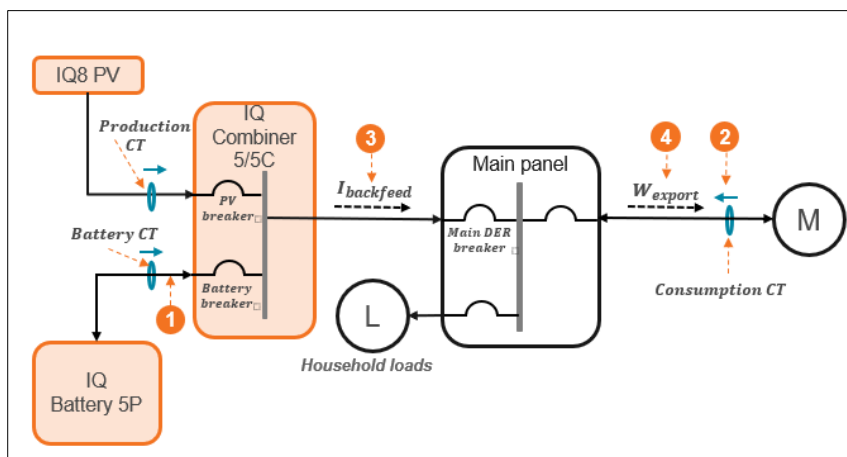


Figure 1: Example of an Enphase Energy System in the grid-tied configuration

Enphase Power Control enables four features in the grid-tied Enphase Energy System:

1. **IQ Battery oversubscription mode:** This feature limits the charge/discharge current and enables more battery capacity to be installed in grid-tied systems. The feature ensures that the total continuous output current from the batteries does not exceed 80% of the battery breaker rating.
2. **Battery import only mode:** This feature ensures the Enphase IQ Battery never exports any power to the grid. Enphase batteries always operate in Import Only mode.
3. **Main panel upgrade (MPU) avoidance mode:** This feature limits the current backfeed into the main panel and removes the need to upgrade the main panel, reducing costs for the homeowner and effort for the installer.
4. **Aggregate power export limit mode:** This feature ensures that the aggregate power exported to the grid is limited to the Aggregate Power Export Limit (PEL) defined by the installer.

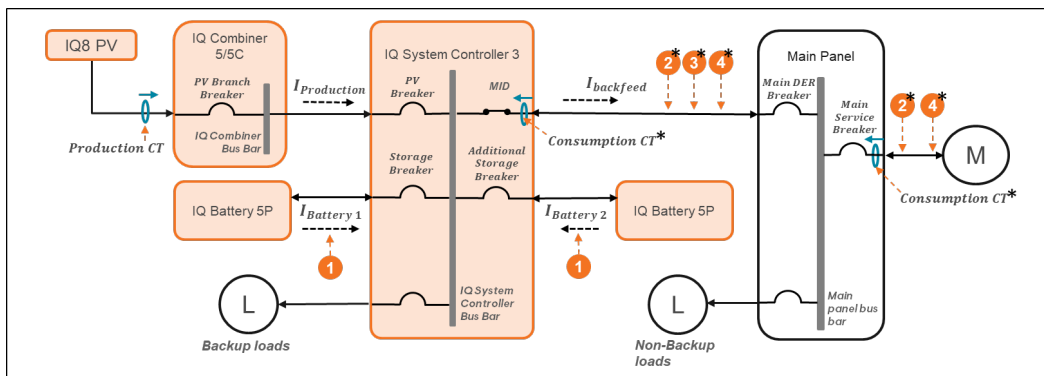
Figure 1 provides a birds-eye view of the point of current being measured and limited using Enphase Power Control for each feature.

Enphase Power Control in the grid-forming Enphase Energy System

An Enphase Energy System in a grid-forming configuration has the following components:

- IQ8 Series Microinverters
- IQ Gateway or IQ Combiner
- IQ System Controller
- IQ Battery

Enphase Power Control enables four features for grid-forming Enphase Energy Systems, which are also shown in Figure 2.



* Note that aggregate power export limit and battery import are applied at the Consumption CTs. Consumption CTs must be placed between the IQ System Controller and the main panel if using the main panel upgrade avoidance or if using a generator.

Figure 2: Example of an Enphase Energy System with IQ System Controller 3 in grid-forming configuration.

1. **IQ Battery oversubscription mode:** This feature limits the charge/discharge current and enables more battery capacity to be installed in grid-forming systems. The feature ensures that the total continuous output current from the batteries does not exceed 80% of the battery breaker rating.
 - **IQ System Controller 3G:** This feature allows for more batteries on the storage port than allowed based on the installed breaker rating.
 - **IQ System Controller 3:** This feature allows for more batteries on the storage and DER ports than allowed based on the installed breaker rating.
2. **Battery import only mode:** This feature ensures the Enphase IQ Battery never exports any power to the grid. Enphase Batteries always operate in import only mode.
3. **Main panel upgrade (MPU) avoidance mode:** This feature limits the current backfeed into the main panel, eliminating main panel upgrades due to the backfeed exceeding the allowed NEC limits.
4. **Aggregate power export limit mode:** This feature ensures that the aggregate power exported as measured at the Consumption CTs is limited to the power export limit (PEL) value set by the installer.



NOTE: The Enphase batteries do not export to the grid because the battery import only mode is always enabled. Thus, the PV production is controlled by this feature to ensure that the aggregate export power adheres to the limit.

[Figure 2](#) provides a bird’s-eye view of the point of current being measured/monitored and limited using Enphase Power Control for each feature.

Benefits of Enphase Power Control

Avoid costly interconnection equipment upgrades or installations

In the absence of the Enphase Power Control feature - Battery import only mode, utilities in California such as Pacific Gas & Electric (PG&E), San Diego Gas & Electric (SDG&E), and South California Edison (SCE) may require the installation of an additional net generation output meter (NGOM). This increases the cost of installation of the system for the homeowner. To avoid this additional cost, the homeowner may have to limit their battery to under 10 kW, which may not be sufficient for backing up their home loads. With the Enphase Power Control feature – Battery import only mode - no such trade-off is required when installing an Enphase Energy System.

Utilities such as PG&E require energy storage systems to comply with the import only mode with an open loop response time (OLRT) of less than two seconds. If the energy storage system complies with this requirement, the utility considers it non-exporting and may not require a feeder transformer upgrade in cases where the addition of an energy storage nameplate exceeds the thermal rating of the feeder transformer.

Avoid expensive main panel upgrade

The size of the PV and energy storage breakers permitted to be installed at a house may be limited by the NEC based on the size of the main panel and utility service rating. Installers may not be aware of such limits until late into the project. As a result, the system size sold to the homeowner may need an unplanned main panel upgrade, which adds significant labor and hardware costs to the project. Enphase's Power Control feature enables installers to set a software-based current limit at installation time on the backfeed into the main panel for PV and energy storage systems. This enables installers to avoid the cost and time due to an unplanned main panel upgrade. Enphase's Power Control uses real-time current sensing to monitor and limit the current back-fed into the main panel.

Benefit from higher backup time with high-power batteries

The new Enphase Power Control feature, IQ Battery oversubscription mode, enables the addition of twice as many batteries per site with PCS as the number of batteries supported without PCS enabled. The total number of batteries supported with two different SKUs of IQ System Controller with and without the IQ Battery oversubscription feature are listed in the following table:

Table 1: Maximum continuous current, aggregate power, and aggregate energy comparison with and without the IQ Battery oversubscription

IQ System Controller type	Without IQ Battery oversubscription				With IQ Battery oversubscription			
	Maximum allowed IQ Battery 5P units	Maximum continuous output current per battery (A)	Aggregate power from the batteries (kW)	Aggregate energy storage capacity of batteries (kWh)	Maximum allowed IQ Battery 5P units	Maximum continuous output current per battery (A)	Aggregate power from the batteries (kW)	Aggregate energy storage capacity of batteries (kWh)
IQ System Controller 3G (SC200G111 C240US01)	4 (4 on storage port ¹)	16	15.36	19.84	8 (8 on storage port ¹)	8	15.36	39.68

	Without IQ Battery oversubscription				With IQ Battery oversubscription			
IQ System Controller 3 (SC200D111 C240US01)	8 (4 on storage port ¹ + 4 on DER port ¹)	16	30.72	39.68	16 (8 on storage port ¹ + 8 on DER port ¹)	8	30.72	79.36

¹ Assuming that the storage breaker and the additional DER breaker are rated 80 A.

Limit PV solar power exported to the grid based on regional compliance

Utilities in certain geographies require that the power exported back to the grid is restricted to a prescribed power limit. The aggregate power export limit feature measures the aggregate power across all the phases being exported and limits the PV production to ensure that the power export at the location of the consumption current transformer (point of current measurement) does not exceed the limit specified by the installer in the Enphase Installer App.

PCS Integration in the Enphase Energy System

Enphase Power Control is a supplementary PCS. Supplementary PCS are systems or devices intended for use in circuits with an overcurrent device suitable for service, feeder, or branch circuit protection.

Components of Enphase Power Control

1. **Current transformers (CTs):** An Enphase Power Control-enabled site would require a Production CT (1 CT shipped with the IQ Gateway or IQ Combiner 5C), a pair of Consumption CTs (quantity 2 of CT-200-CLAMP, included with the IQ Combiner 5C or to be purchased separately), and a Battery CT (1 CT-200-CLAMP, included with the IQ Combiner 5C or to be purchased separately). The Production CT provides revenue-grade metering of the power generated by the PV. The Consumption CTs are installed inside the main panel to monitor the current being exported to the grid or inside the IQ System Controller cabinet to monitor the current being back-fed from the IQ System Controller to the grid or main panel in real time.
2. **PCS controller (IQ Gateway):** An Enphase Power Control-enabled site incorporates the IQ Gateway to support IQ Microinverter and IQ Battery Systems. The IQ Gateway monitors the currents as reported by the CTs and uses this information to limit PV and ESS power production as required.
3. **IQ Battery:** Enphase Power Control ensures that the IQ Battery does not export any power back to the grid.
4. **Other balance of system components**
 - a. **IQ Combiner:** Aggregates PV branches and energy storage. Enphase Power Control can limit the back feed into the main panel from the IQ Combiner, per NEC requirements in grid-tied systems.
 - b. **IQ System Controller:** Integrates a microgrid interconnect device (MID) and neutral forming transformer (NFT). It aggregates PV and energy storage for grid-forming systems. Enphase Power Control can limit back feed into the main panel from the IQ System Controller, per NEC requirements, for partial home backup grid-forming systems.

Supported SKUs for Enphase Power Control

Refer to the UL letter to see the supported Enphase SKUs for each Enphase Power Control feature in both grid-forming and grid-tied configurations, as shown in the following table:

Table 2: Supported Enphase SKUs with Enphase Power Control feature in grid-forming and grid-tied configurations

	System configuration	Systems with <ul style="list-style-type: none"> • IQ8 or IQ7/IQ6 Microinverters • IQ Battery 5P • (Optional) backup with IQ System Controller 3/3G 	Systems with <ul style="list-style-type: none"> • IQ8 or IQ7/IQ6 Microinverters • IQ Battery 3/10/3T/10T • (Optional) backup with IQ System Controller 2 	Systems with <ul style="list-style-type: none"> • IQ7 Microinverters • IQ Battery 3/10/3T/10T • (Optional) backup with IQ System Controller 1
Feature	IQ Battery oversubscription	Notice of Completion, UL Reference: File E341165, Vol. (new) Sec. 1, Project 4790806693 and 4790898396, dated Sept 2023	NA	NA
	Battery import only (ESS import only)	Notice of Completion, UL Reference: File E341165, Vol. 7, Project 4790295093, dated Feb 2022	Notice of Completion, UL Reference: File E341165, Vol. 7, Project 4790295093, dated Feb 2022	Notice of Completion, UL Reference: File E341165, Vol 7 dated Feb 2021
	Main panel upgrade avoidance	Only for IQ8 Microinverters Notice of Completion, UL Reference: File E341165, Vol. (new) Sec. 1, Project 4790806693 and 4790898396, dated Sept 2023	Only for grid-forming (backup) configurations ¹ Notice of Completion, UL Reference: File E341165, Vol. 7, Project 4790295093, dated Feb 2022	Only for grid-forming (backup) configurations ¹ Notice of Completion, UL Reference: File E341165, Vol 7 dated Feb 2021
	Aggregate power export limit		Only for IQ8 Microinverters Notice of Completion, UL Reference: File E341165, Vol. (new) Sec. 1, Project 4790806693 and 4790898396, dated Sept 2023	NA



¹ MPU avoidance is recommended with IQ8 Microinverter systems.

NOTE: Enphase Power Control supports grid-tied MPU avoidance in PV only sites. Support for MPU avoidance in grid-tied configuration with PV and IQ Battery will be available in Q4 2023.

Setting up Enphase Power Control

Installation of the Production and Consumption CTs in grid-forming configuration

Refer to the IQ System Controller Quick Install Guide (QIG) in the [documentation center](#) for detailed instructions on how to set up Enphase Power Control in a grid-forming configuration. The QIG contains detailed information required for installers to correctly set up an Enphase Power Control-enabled system and provides information on the labels required to be added to the PCS-enabling devices by the installer. These labels are shipped inside the literature kit as a part of the IQ System Controller.

In the grid-forming configuration, the IQ System Controller is required, and the installer must ensure that the CT is installed correctly between the main panel and the utility meter. The high-level diagram of default Consumption CT placement in a grid-forming partial home backup configuration is shown in Figure 3.



NOTE: If the installer requires generator integration or wants to enable MPU avoidance (applicable in partial home backup configuration), the CT placement must be in between the IQ System Controller and the main panel. Refer to the IQ System Controller Quick Install Guide (QIG) for instructions on the CT placement in this scenario.

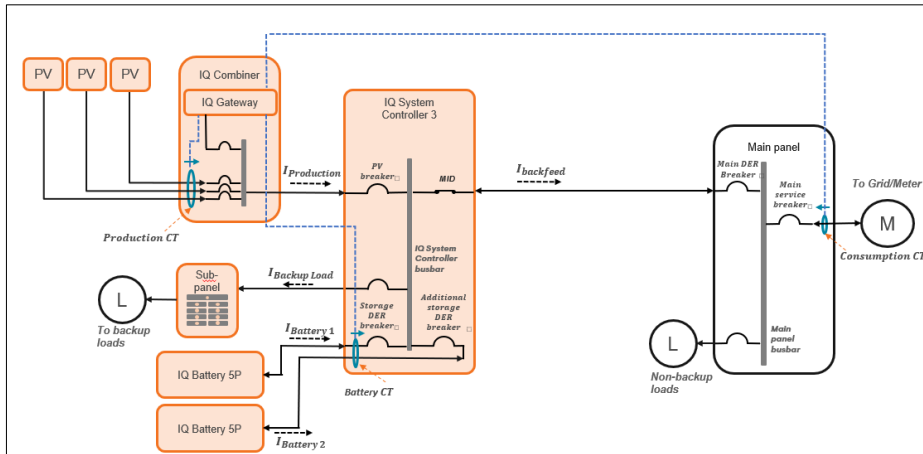


Figure 3: Bird's-eye view of Production, Battery, and Consumption CTs placement in grid-forming partial home backup configuration

The high-level diagram of default Consumption CT placement in a grid-forming whole home backup configuration is shown in Figure 4.

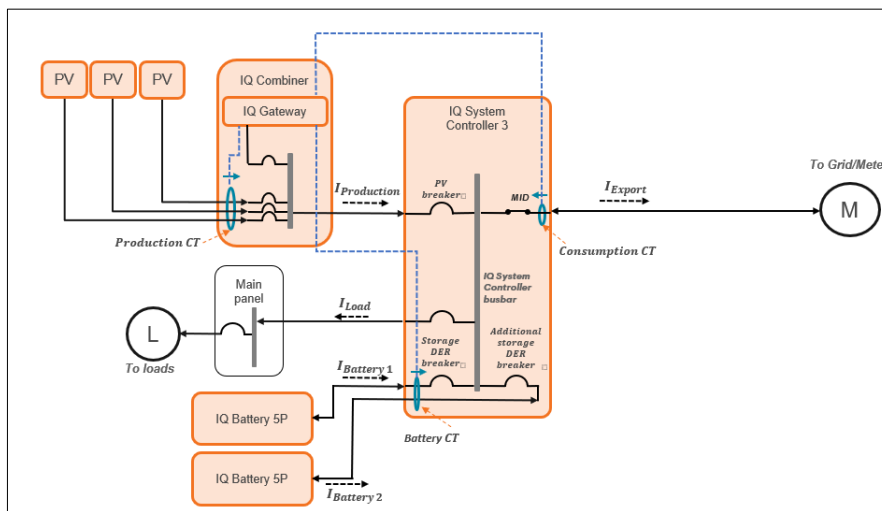


Figure 4: Bird's-eye view of Production, Battery, and Consumption CTs placement in grid-forming whole home backup configuration

NOTE: The grid-forming whole home backup does not require a main panel upgrade because the main panel is on the load side of the IQ System Controller, and there is no current being backfed into the main panel from the Enphase Energy system.

Installation of the Production and Consumption CTs in grid-tied configuration

Refer to the IQ Combiner Quick Install Guide (QIG) in the [documentation center](#) for detailed instructions on how to set up an Enphase Power Control-enabled system in a grid-tied configuration.

Current Transformer placement for Enphase Power Control features

The current transformer (CT) placement for each of the features is shown in the following table:

Table 3: CT placement for Enphase Power Control features

Enphase Power Control feature	Grid-forming configuration		Grid-tied configuration	
	Current transformer(s) utilized	CT placement	Current transformer(s) utilized	CT placement
IQ Battery	Battery CT ²	Battery CT is to be placed	Battery CT ²	Battery CT is to be placed

Enphase Power Control feature	Grid-forming configuration		Grid-tied configuration	
	Current transformer(s) utilized	CT placement	Current transformer(s) utilized	CT placement
oversubscription		inside the IQ System Controller ²		inside the IQ Combiner around all PV branch circuits ²
Battery import only	Production CT and Consumption CTs	Production CT is placed inside the IQ Combiner Consumption CTs are placed between the main panel and utility meter (default configuration) Consumption CTs can also be placed between the IQ System Controller and the main panel	Production CT and Consumption CTs	Production CT is placed inside the IQ Combiner around all PV branch circuits. Consumption CTs are placed between the main panel and the utility meter
Main panel avoidance	Consumption CTs	Consumption CTs are placed between the IQ System Controller and main panel ¹	Production CT ³	Production CT is placed inside the IQ Combiner around all PV branch circuits
Aggregate power export limit	Consumption CTs	Consumption CTs are placed between the main panel and utility meter (default configuration) Consumption CTs can also be placed between the IQ System Controller and the main panel	Consumption CTs	Consumption CTs are placed between the main panel and the utility meter

¹ Refer to the “CT wiring” section in the IQ System Controller 3/3G Quick Install Guide (QIG) for Consumption CT placement between the IQ System Controller and the main panel.

² Battery CT is not utilized for IQ Battery oversubscription but is required for other functionality of IQ Battery 5P.

³ Enphase Power Control supports grid-tied MPU avoidance in PV only sites. Support for MPU avoidance in grid-tied configuration with PV and IQ Battery will be available in Q4 2023.



NOTE: The installer can configure MPU avoidance, IQ Battery oversubscription, and aggregate power export limit PCS features using the Enphase Installer App or Enphase Installer Portal. Battery import only feature is enabled in the Enphase Energy System by default.

Wiring diagrams for Enphase Power Control

Table 4: Wiring diagrams for Enphase Power Control in grid-forming partial home backup and grid-tied configuration

Feature	Grid-forming configuration with IQ System Controller 3	Grid-forming configuration with IQ System Controller 3G	Grid-tied configuration with IQ Combiner 5/5C
IQ Battery oversubscription	Figure 27	Figure 29	Figure 30
Battery import only			
Aggregate power export limit			
Main panel upgrade avoidance	Figure 28		Figure 31

For wiring diagrams with IQ7 Microinverters or older SKUs such as IQ Combiner 4/4C, IQ System Controller 2/1, and so on, refer to the [Planning an Enphase Energy System](#) Technical Brief.

Application of the label for Enphase Power Control

The installer is required to apply relevant labels when enabling Enphase Power Control features to comply with regulations. The instructions to apply these labels are provided in:

- IQ System Controller 3/3G Quick Install Guide (QIG) in the [documentation center](#) for grid-forming configuration
- IQ Combiner 5/5C Quick Install Guide (QIG) in the [documentation center](#) for grid-tied configuration

Enphase Power Control features

IQ Battery oversubscription

IQ Battery oversubscription in grid-tied configuration

The new feature, IQ Battery oversubscription mode, allows homeowners to add more IQ Battery 5P(s) to their grid-tied systems, enabling more capacity for self-consumption or economic savings.

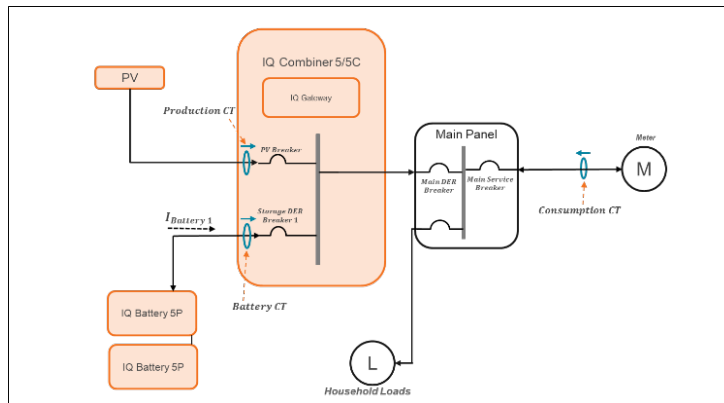


Figure 5: IQ Battery oversubscription in a grid-tied system with IQ Combiner 5/5C

In a grid-tied configuration, IQ Battery 5P(s) can be connected to the IQ Combiner on one of the four breaker slots. The installer can input the breaker size of storage DER breaker 1 through the Enphase Installer App or Enphase Installer Portal during commissioning. Enphase Power Control ensures that $I_{\text{Battery 1}}$ on the one IQ Combiner breaker slot is limited to the breaker size. The maximum breaker rating for the single battery breaker slot is 60 A, and the sum of breaker sizes for all four breaker slots (PV and battery breakers) must not exceed 80 A.

Alternatively, the installer can also use an off-the-shelf DER sub-panel to connect IQ Battery 5P up to two breaker slots. The installer can input the number of batteries and breaker sizes on storage DER breaker 1 and storage DER breaker 2 through the Enphase Installer App or Enphase Installer Portal during commissioning. Enphase Power Control ensures that $I_{\text{Battery 1}}$ and $I_{\text{Battery 2}}$ on the two IQ Combiner breaker slots are limited to the breaker sizes. The maximum breaker rating for the two battery breaker slots combined is 80 A. Refer to the Appendix for the wiring diagram for this configuration.

IQ Battery oversubscription in grid-forming configuration

The new feature, IQ Battery oversubscription mode, in grid-forming configuration allows homeowners to meet their higher energy storage requirements by adding more batteries to their Enphase Energy System, enabling them to have up to twice as much backup time as the previous generation. IQ Battery oversubscription mode limits the aggregate IQ Battery output current at the storage and DER ports by controlling the output current of each of the IQ Battery 5P(s) connected to the ports.

System design and sizing with IQ Battery oversubscription

IQ Battery oversubscription with IQ System Controller 3 and IQ System Controller 3G

As shown in Table 1, IQ Battery oversubscription is supported with two IQ System Controller SKUs:

- **IQ System Controller 3G:** This IQ System Controller 3G has only one storage port, while the other DER port is reserved to support the Generator. Homeowners who need generator backup support with the Enphase Energy System along with the IQ Battery backup must opt for the IQ System Controller 3G.
- **IQ System Controller 3:** This IQ System Controller 3 has two ports that support the addition of IQ Batteries, a storage (DER 2) port and an additional DER port (DER 3). The IQ System Controller 3 does not support the addition of a Generator. Homeowners who do not intend to have generator backup presently or in the future could opt for IQ System Controller 3, as it allows them to add twice as many IQ Batteries, making their energy storage more scalable for the future.

The maximum number of batteries with or without IQ Battery oversubscription mode in IQ System Controller 3 and IQ System Controller 3G are shown in [Table 1](#).

Figure 6 and Figure 7 show the IQ Battery oversubscription in grid-forming configuration with IQ System Controller 3 and IQ System Controller 3G, respectively.

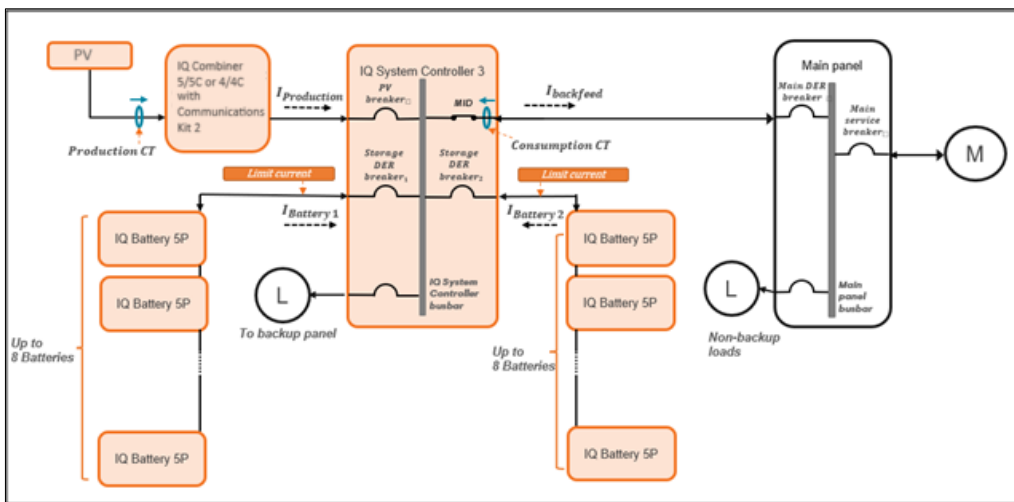


Figure 6: IQ Battery oversubscription with IQ System Controller 3 – supporting up to 16 IQ Battery 5P units.

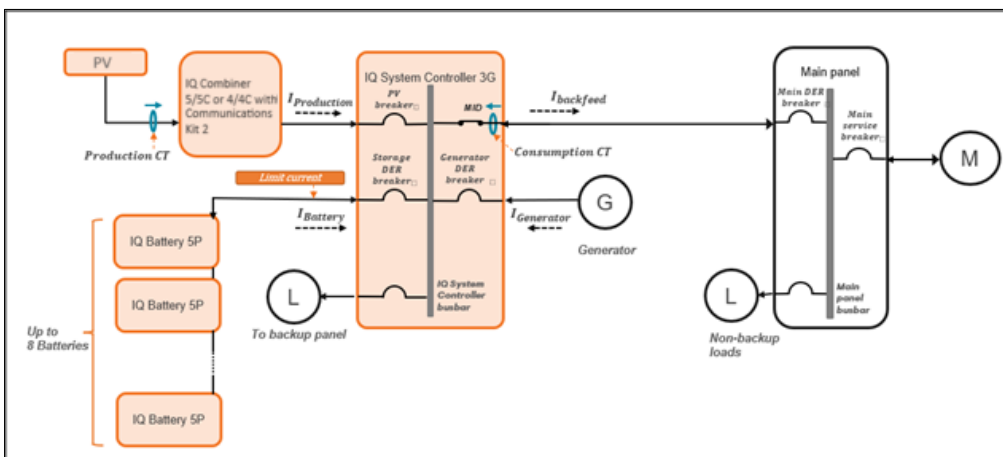


Figure 7: IQ Battery oversubscription with IQ System Controller 3G – supporting up to eight IQ Battery 5P units.

The IQ System Controller 3 has two storage DER ports, so IQ Battery 5P(s) can be connected to a storage port and/or additional DER 3 port. The placement of the IQ Batteries on each port determines the maximum aggregate continuous power available from the battery system. The ideal placement of the IQ Batteries maximizes the aggregate continuous power (kW) and aggregate overload current available from the chosen battery system with the given aggregate storage energy (kWh).

The optimal placement of IQ Battery 5P(s) on two ports per a given number of IQ Battery 5P(s) in IQ System Controller 3 is shown in Table 5, assuming that the breaker rating on each port is 80 A.

Table 5: Optimal placement of the IQ Battery 5P(s) on two ports in IQ System Controller 3

Ideal Battery Placement			At Storage Port (DER 2)			At Additional (DER 3) Port			Aggregate		
Total no. of Batteries	No of Batteries on Storage (DER 2) Port	No of Batteries on Additional (DER 3) Port	IQ Battery Oversubscription	Max Continuous Current from Port (A)	Max Overload Current from Port (A)	IQ Battery Oversubscription	Max Continuous Current from Port (A)	Max Overload Current from Port (A)	Max Continuous Current of the system (A)	Max Overload Current of the system (A)	Max Energy of the system (kWh)
$N = N_1 + N_2$	N_1	N_2	Enabled if ($N_1 > 4$ batteries)	I_1	$I_{Overload 1}$	Enabled if ($N_2 > 4$ batteries)	I_2	$I_{Overload 2}$	$I_A = I_1 + I_2$	$I_{Aggregate Overload} = I_{Overload 1} + I_{Overload 2}$	$E_A = (N_1 + N_2) * E_{Battery}$
1	1	0	Disabled	16	32	Disabled	0	0	16	32	4.96
2	2	0	Disabled	32	64	Disabled	0	0	32	64	9.92
3	3	0	Disabled	48	96	Disabled	0	0	48	96	14.88
4	4	0	Disabled	64	128	Disabled	0	0	64	128	19.84
5	4	1	Disabled	64	128	Disabled	16	32	80	160	24.8
6	4	2	Disabled	64	128	Disabled	32	64	96	192	29.76
7	4	3	Disabled	64	128	Disabled	48	96	112	224	34.72
8	4	4	Disabled	64	128	Disabled	64	128	128	256	39.68
9	5	4	Enabled	64	160	Disabled	64	128	128	288	44.64
10	6	4	Enabled	64	192	Disabled	64	128	128	320	49.6
11	7	4	Enabled	64	224	Disabled	64	128	128	352	54.56
12	8	4	Enabled	64	256	Disabled	64	128	128	384	59.52
13	8	5	Enabled	64	256	Enabled	64	160	128	416	64.48
14	8	6	Enabled	64	256	Enabled	64	192	128	448	69.44
15	8	7	Enabled	64	256	Enabled	64	224	128	480	74.4
16	8	8	Enabled	64	256	Enabled	64	256	128	512	79.36

The optimal placement shown in Table 5 ensures maximum continuous current and maximum overload current at a site. The installer can opt for configurations other than the preceding configurations, but these configurations may result in sub-optimal maximum continuous current and maximum overload current.

Compliance with regulations

In accordance with NFPA and NEC 2020 706.31(B), the overprotection device rating should not be greater than 125% of the maximum average continuous current in the circuit connected to the energy storage system. By ensuring that the aggregate output current from all the IQ Batteries connected to the storage DER port or slot (or additional DER port) does not exceed 125% of the corresponding storage DER breaker rating electronically, the feature IQ Battery oversubscription feature allows more IQ Batteries to be connected to the Enphase system while being compliant with NEC 2020 706.31(B).

Open loop response time

The maximum open loop response time (OLRT) with IQ Battery oversubscription mode is less than two seconds: that is, the Enphase Power Control ensures that the input/output current from the IQ Battery branch circuit is reduced to the set level in less than two seconds whenever there is a sudden change of load in the system.

Failure modes and resolution

The following table describes failure modes and corresponding resolutions:

Table 6: Failure modes and resolutions

Failure mode	Resolution mechanism
IQ Battery communication failure with IQ Gateway	If the IQ Gateway loses communication with the IQ Battery for more than 20 seconds, <ul style="list-style-type: none"> When on-grid, IQ Battery 5P automatically falls into Idle mode, that is, no charge or discharge. When off-grid, IQ Battery 5P discharges up to the allowed safe limit current.

Configuration of IQ Battery oversubscription via Enphase Installer App

The Enphase Installer App provides an option to enable the IQ Battery oversubscription feature using **Site Configuration** under **System Details**.

Select **Site Configuration** > **PCS Export Limiting** > **IQ Battery Oversubscription**, as shown in the following figure.

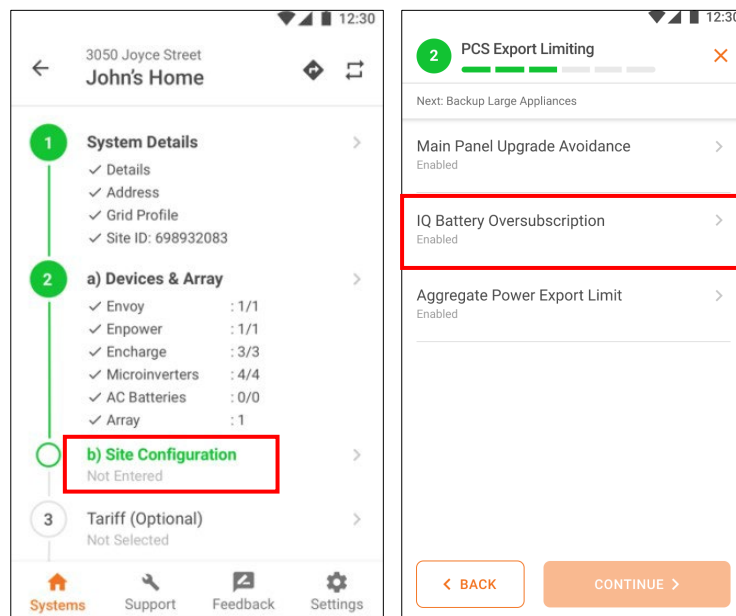


Figure 8: Enphase Power Control with IQ Battery oversubscription in Enphase Installer App

IQ Battery oversubscription configuration for grid-tied configuration

When configuring IQ Battery oversubscription (as shown in Figure 9), the installer must input the number of IQ Battery 5P(s) and breaker sizes on the port. The Enphase Installer App determines if the IQ Battery oversubscription needs to be enabled if the aggregate current from IQ Battery 5P(s) on a breaker exceeds the breaker rating.

In IQ Combiner, the Enphase Installer App also ensures that the maximum breaker rating for the single battery breaker slot is 60 A and that the sum of breaker sizes for all four breaker slots (PV breakers and battery breaker) must not exceed 80 A as required by the IQ Combiner busbar rating. In the off-the-shelf combiner, it ensures that the maximum breaker rating for the two battery breaker slots is 80 A each.

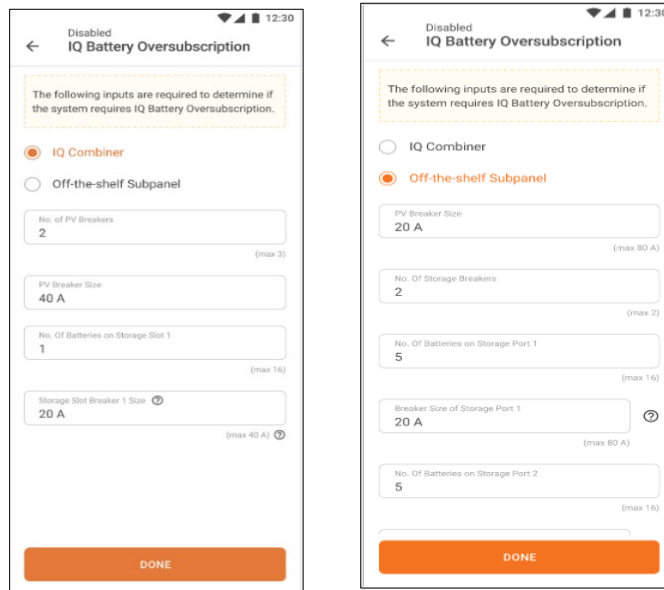


Figure 9: Configuration of IQ Battery oversubscription for grid-tied configuration in Enphase Installer App in IQ Combiner (left) and off-the-shelf sub-panel (right)

IQ Battery oversubscription configuration for grid-forming configuration

Grid-forming configuration requires IQ Battery oversubscription when the aggregate current from IQ Battery 5P on a breaker exceeds the breaker rating. For IQ System Controller 3, the DER configuration step to assign IQ Battery 5P(s) in the system to the storage or DER port must be completed before the configuration of IQ Battery oversubscription.

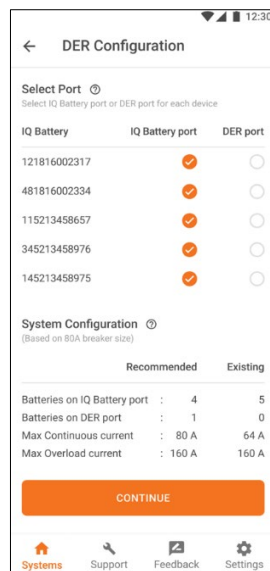


Figure 10: DER configuration

The system detects whether the system requires IQ Battery 5P oversubscription based on the DER configuration step, as shown in Figure 10. When configuring IQ Battery oversubscription (as shown in Figure 11), the installer must input the number of IQ Battery 5P(s) and breaker sizes on the port. If the breaker sizes are not sufficient to support the batteries, the Enphase Installer App prompts the installer to enable the IQ Battery oversubscription feature.

The Enphase Installer App shows the recommended number of IQ Batteries on each port to maximize the continuous and overload currents in the system.

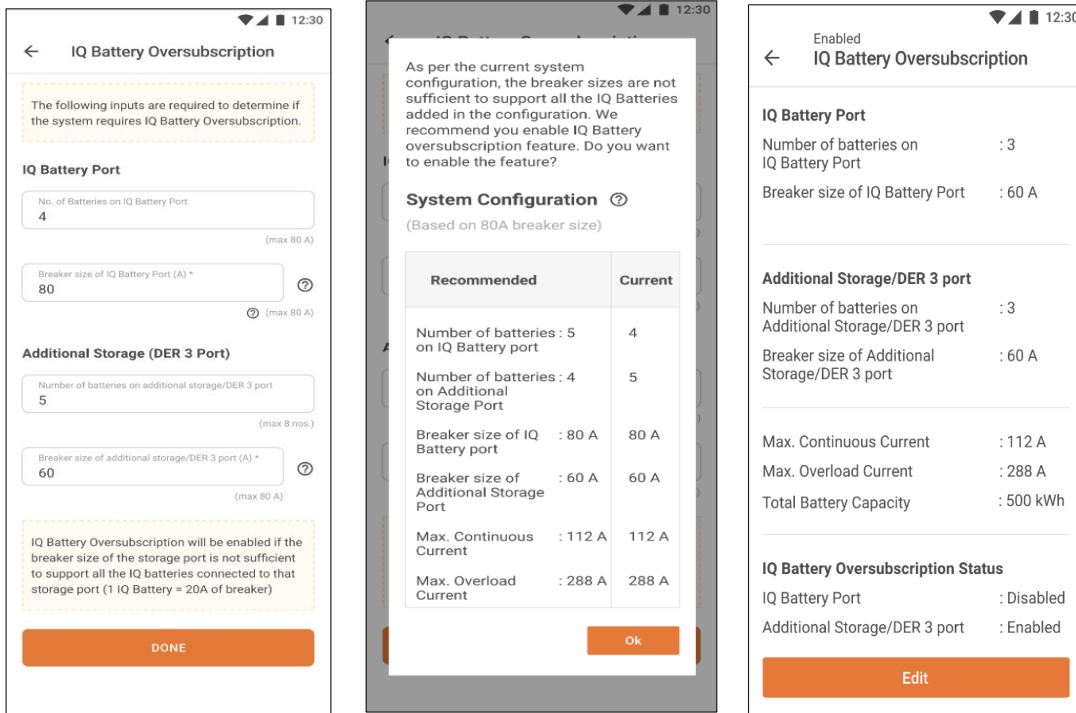


Figure 11: Configuration of IQ Battery oversubscription for grid-forming configuration

Configuration of IQ Battery oversubscription via the Enphase Installer Portal

The installer can configure the IQ Battery oversubscription feature in the Enphase Installer Portal on the Activations page.

Navigate to **Systems > Activations > Configuration > PCS Export Limiting > IQ Battery Oversubscription**.

IQ Battery oversubscription configuration for grid-tied configuration

When configuring IQ Battery oversubscription in the Enphase Installer Portal (as shown in Figure 12), the installer must input the number of IQ Battery 5P(s) and breaker sizes on the port. The Enphase Installer Portal determines if the IQ Battery oversubscription needs to be enabled if the aggregate current from IQ Battery 5P(s) on a breaker exceeds the breaker rating.

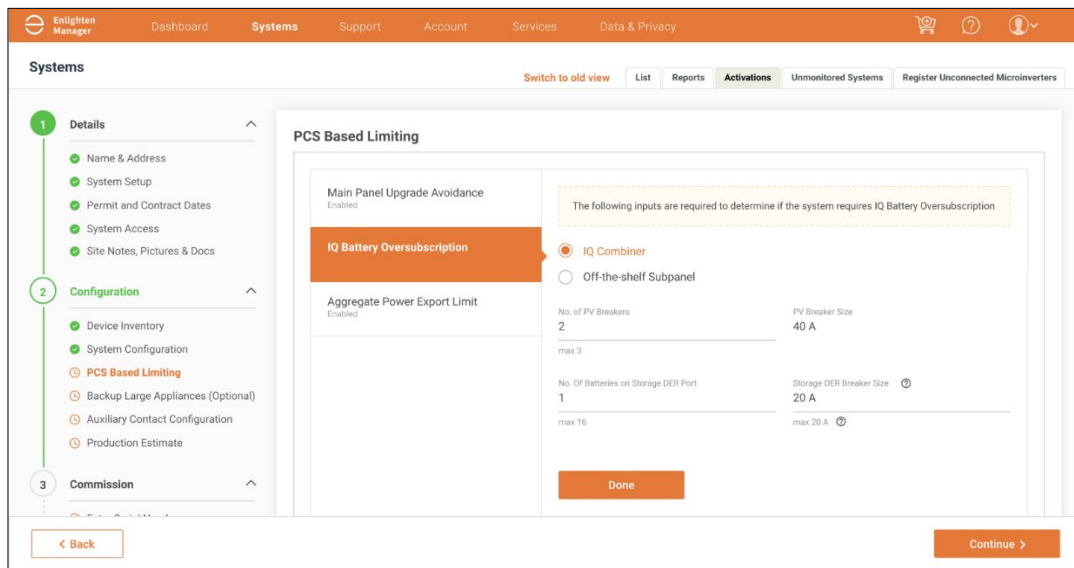


Figure 12: Configuration of IQ Battery oversubscription for grid-tied configuration

IQ Battery oversubscription configuration for grid-forming configuration

When configuring IQ Battery oversubscription in the Enphase Installer Portal for grid-forming configuration (as shown in Figure 13), the installer must input the number of IQ Battery 5P(s) and breaker sizes on each port. If the breaker sizes are not sufficient to support the batteries, the Enphase Installer App prompts the installer to enable the IQ Battery oversubscription feature.

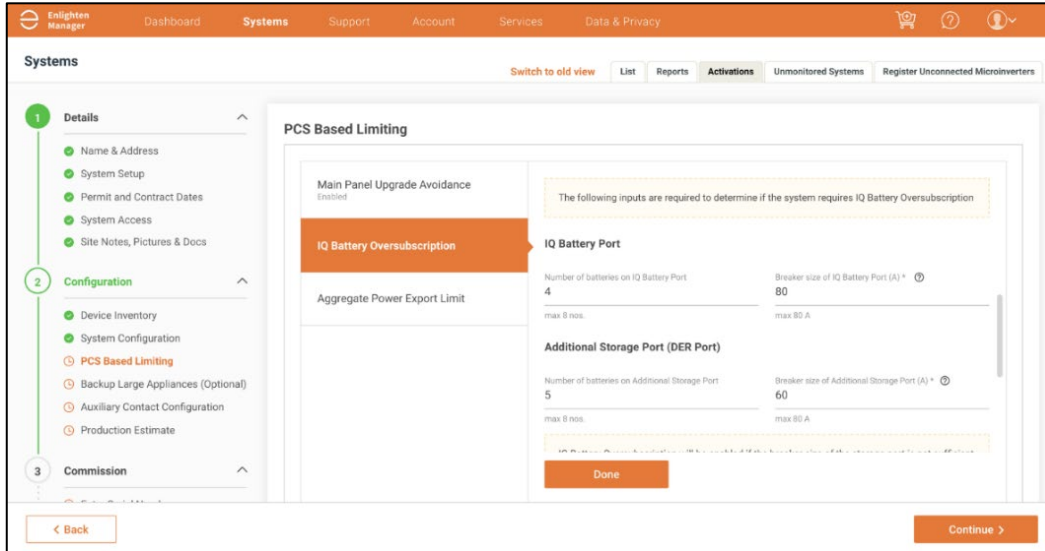


Figure 13: Configuration of IQ Battery oversubscription for grid-forming (IQ System Controller 3) in Enphase Installer App

Battery import only mode for Enphase Energy System

Import only mode for IQ Battery 5P and IQ Battery 3T/10T/3/10 is integrated into the Enphase Energy System. This feature ensures that the battery never exports power to the grid. The feature is certified for any systems that have a UL-listed PV inverter with a nameplate up to 160 A at 240 V_{AC} L-L/120 V_{AC} L-N.

System sizing with IQ Battery 5P

Enphase Power Control ensures no IQ Battery current is exported to the main panel. This is accomplished by measuring and controlling all production current and power. Enphase Power Control ensures that the current being back-fed into the main panel never exceeds the PV production current.

As Enphase Energy System does not export battery current past the Consumption CT, the current from IQ Batteries need not be accounted for when calculating the current exported to the grid by the system. As a result, installers only need to account for the size of the PV system while calculating export and need not account for the size of the IQ Battery system installed. This saves labor and upgrade costs for installers and system owners.



NOTE: PCS is covered in Article 705.13 of the NEC 2020 edition. Authorities Having Jurisdiction (AHJs) may not recognize the PCS feature until the 2020 NEC is adopted in their region.

Open loop response time

The maximum open loop response time (OLRT) with Battery import only mode in the Enphase Energy System is less than two seconds, that is, Enphase Power Control ensures that the power export from IQ Battery is curtailed at least by 90% in less than two seconds whenever there is a sudden change of load in the system.

Main panel upgrade avoidance using PV current limiting

The Enphase Power Control feature, main panel upgrade mode, allows the installer to configure the limit of the current being back-fed by the Enphase Energy System to a main panel in a grid-tied configuration or a partial home backup grid-forming configuration. The feature ensures that the backfeed current allowed into the main panel is limited to the set limit in compliance with 2020 NEC Article 705.12 for both grid-tied and grid-forming configurations.

Compliance with regulations

Compliance with NEC 2020 705.12

The National Electric Code (NEC) 2020 705.12 allows backfeed of current from solar or storage into the main panel subject to the following limit:

Backfeed allowed $\leq ((120\% \text{ of busbar rating}) - \text{ampacity of the overcurrent protection device protecting the busbar}) / 125\%$.

NOTE: This is the most common article limiting backfeed to the main panel. The NEC 2020 705.12 section also contains other articles that may be used to determine the backfeed limit. Later in this document, this rule may be referred to as the NEC120% rule.

Main panel upgrade avoidance in grid-tied configuration

Enphase Power Control feature, MPU avoidance in grid-tied configuration, continuously monitors the power being produced cumulatively by the installed PV array using Production CT and limits the produced power in real-time based on the current limit imposed by the NEC120% rule. As a result, homeowners can avoid the expensive upgrade of the main panel.

This feature in the grid-tied configuration is demonstrated in Figure 14.

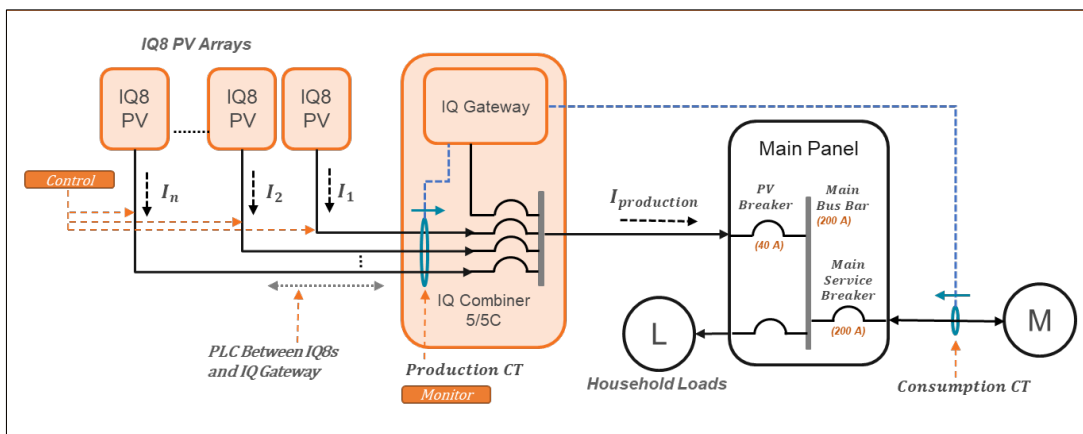


Figure 14: MPU avoidance in grid-tied configuration by curtailing PV production

NOTE: The preceding figure shows an example with IQ Combiner 5/5C.

In Figure 14, the Production CT is monitored, and the current from microinverters is controlled to limit $I_{\text{production}}$ entering the PV breaker in the main panel.

System sizing for MPU avoidance in grid-tied System

For example, as seen in Figure 14, if the main load panel busbar size is 200 A and the grid-side main service breaker size is also 200 A, the maximum continuous current backfeed allowable from the IQ Combiner to the main panel, $I_{\text{production}}$, is limited to:

$$((120\% * \text{busbar rating}) - \text{Main service breaker size}) / 125\% = \text{total DER current}$$

$$((120\% * 200) - 200) / 125\% = 32 \text{ A}$$

Thus, in this scenario, the system ensures that no more than 32 A of continuous current is exported back to the main panel. The Production CT placed inside the IQ Combiner will monitor the current being exported in real-time and feed this information to the IQ Gateway. If the current export increases beyond 32 A, the IQ Gateway sends a signal to the PV microinverters to limit their production.

Main panel upgrade avoidance in grid-forming configuration

The Enphase Power Control feature, MPU avoidance in grid-forming configuration, continuously monitors the power being back-fed from the Enphase Energy System using Consumption CTs and limits the production power in real-time based on the current limit imposed by the NEC120% rule. As a result, homeowners can avoid the expensive upgrade of the main panel.

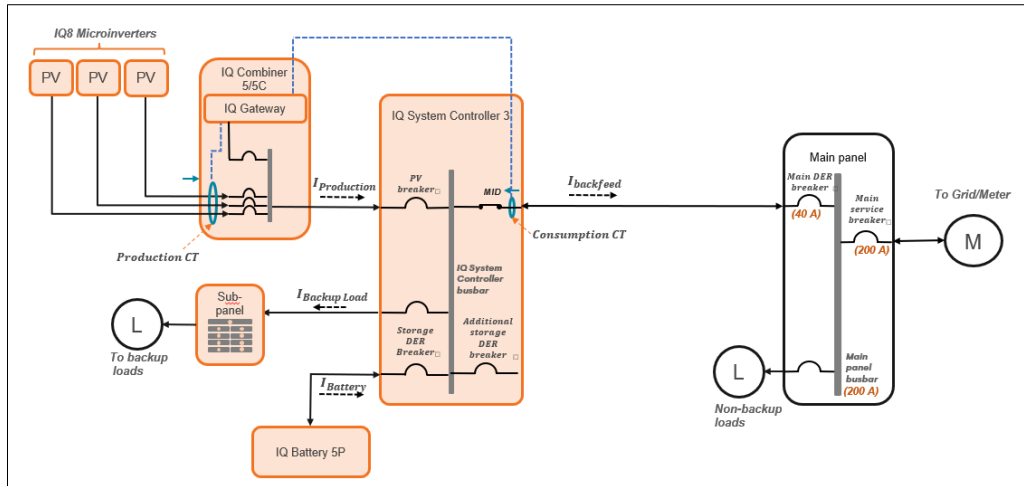


Figure 15: Main panel avoidance in grid-forming configuration, Consumption CT placed between IQ System Controller and main panel



NOTE: The preceding figure shows an example with IQ Combiner 5/5C, IQ Battery 5, and IQ System Controller 3.

In the configuration shown in Figure 15, the back-fed current ($I_{backfeed}$) to the main panel is monitored by the Consumption CTs placed between the IQ System Controller and the main panel. The current produced by the PV system ($I_{production}$) is controlled appropriately to keep $I_{backfeed}$ level adhered to the NEC 120% limit.


System sizing with MPU avoidance in grid-forming System

For example, as seen in Figure 15, if the main load panel busbar is 200 A and the grid size breaker is also 200 A, the maximum continuous current backfeed allowable from the IQ System Controller to the main panel is limited to

$$((120\% * \text{busbar rating}) - \text{main breaker size}) / 125\% = \text{total DER current } ((120\% * 200) - 200) / 125\% = 32 \text{ A}$$

Thus, in this scenario, the system ensures that no more than 32 A of continuous current is exported back to the main panel. The Consumption CTs placed inside the IQ System Controller cabinet (refer to the section *Installation of the Production and Consumption CTs in grid-forming configuration* mentioned previously) monitor the current being exported in real-time and feed this information to the IQ Gateway. The IQ Batteries never export past the Consumption CTs because of the default battery import only mode. If the current export increases beyond 32 A, the IQ Gateway sends a signal to the PV microinverters to limit their production.

It is a good idea to estimate the baseline usage of the backup loads and account for the installation of IQ Batteries when determining the size of the PV system to be installed on a site. For example, consider a scenario where the baseline usage of the backup loads is 1500 W. If IQ8+ PVs are being installed on a site that has a maximum individual continuous AC output of 290 W, we can effectively have $1500/290$, that is, five IQ8+ Microinverters installed on the site with little risk of clipping. Further, PV arrays installed at a site facing different directions lead to a nameplate rating that is mathematically higher than the allowed backfeed current according to NEC 120% rule, but the arrays never produce at peak power at the same time as they face different directions. Even more, PVs can be installed in grid-forming configuration with the IQ System Controller, as the battery would consume a portion of the generated current for charging. Thus, the maximum allowable backfeed should not be solely taken as a limiting factor in determining the size of the PV array.

 **NOTE:** For this MPU Avoidance use case to be accepted by an AHJ, the AHJ needs to recognize PCS. PCS is part of the 2020 edition of the NEC. The edition of NEC in effect in various states can be found on the [NFPA](#) website.

Refer to Table 3 for the placement of Consumption CTs to enable MPU avoidance. The following are the details of trade-offs with the placement of CTs for MPU avoidance.

Trade-offs of the Consumption CT placement for MPU avoidance in grid-forming system

When enabling MPU avoidance, the installer must keep in mind the following trade-offs for Consumption CT placement:

Table 7: Consumption CT placement for MPU avoidance

Consumption CT is placed between the IQ System Controller and the main panel (for MPU avoidance)	Consumption CT is placed between the main panel and the utility meter or main grid (default)
✓ MPU avoidance mode can be enabled in grid-forming partial home backup configuration in this CT placement.	✗ MPU avoidance mode in grid-forming configuration cannot be enabled in grid-forming partial home backup configuration. A main panel upgrade might be required.
✓ Generator integration supports this Consumption CT placement.	✗ Generator integration does not support this Consumption CT placement.
✗ The excess PV power over the PEL limit cannot be used for loads on the main panel because power limiting to comply with the power export limit (PEL) happens at Consumption CTs placed between the IQ System Controller and the main panel. Similarly, the IQ Batteries do not discharge to loads on the main panel due to battery import only power control at the Consumption CTs location.	✓ The excess PV power over the PEL limit can be used for loads on the main panel because power limiting to comply with the power export limit (PEL) happens at Consumption CTs placed between the main panel and utility meter. Similarly, the IQ Batteries can discharge loads on the main panel due to battery import only power control at the Consumption CTs location.
✗ This Consumption CT placement does not provide whole home consumption data on loads connected to the main panel in this placement, that is, consumption data on loads connected to the main panel is not available in this placement.	✓ This Consumption CT placement provides whole home consumption data.

Failure mode and resolution for MPU avoidance

Enphase Power Control is designed for robustness. The system ensures adherence to the NEC guidelines of current backfeed even when one or more devices have stopped communicating with the IQ Gateway.

Table 8: Failure mode and solution mechanism

Failure mode	Resolution mechanism
IQ Battery communication failure	If the IQ Gateway loses communication with the IQ Battery for more than 20 seconds, the IQ Battery discharge is completely curtailed.
Microinverter communication failure	If IQ Gateway loses communication for more than 10 seconds with the microinverter, PV production will be curtailed to the safe limit.
PCS controller or IQ Gateway failure	If the IQ Gateway loses communication with the microinverters for more than 10 seconds and with the IQ Battery for more than 20 seconds, all PV and IQ Battery discharges are curtailed to a safe limit.
Consumption CT not reporting correct value/missing Consumption CT	PV production will be curtailed to a safe limit.

Configuring MPU avoidance via the Enphase Installer App

Installers can configure Enphase Power Control for main panel upgrade avoidance through their Enphase Installer App (EIA). The MPU avoidance use case can be enabled via EIA during installation at:

Navigate to **System Details > Site Configuration > PCS Export Limiting > Main Panel Upgrade Avoidance**, as shown in the figure.

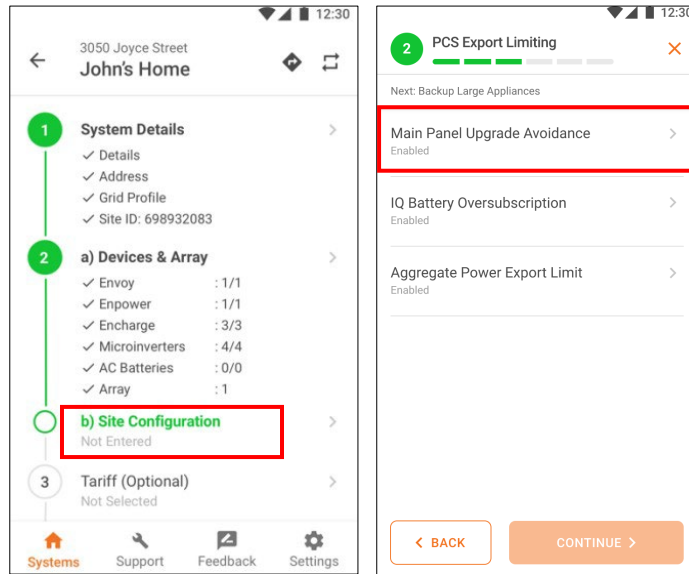


Figure 16: MPU avoidance in the site configuration



NOTE: In a grid-forming system, MPU avoidance can only be enabled in the partial home backup mode. The installer must first select **System Details > Site Configuration > Select Backup Type > Partial Home Backup**. Once this is done, the installer can move to the **PCS Export Limiting** section.

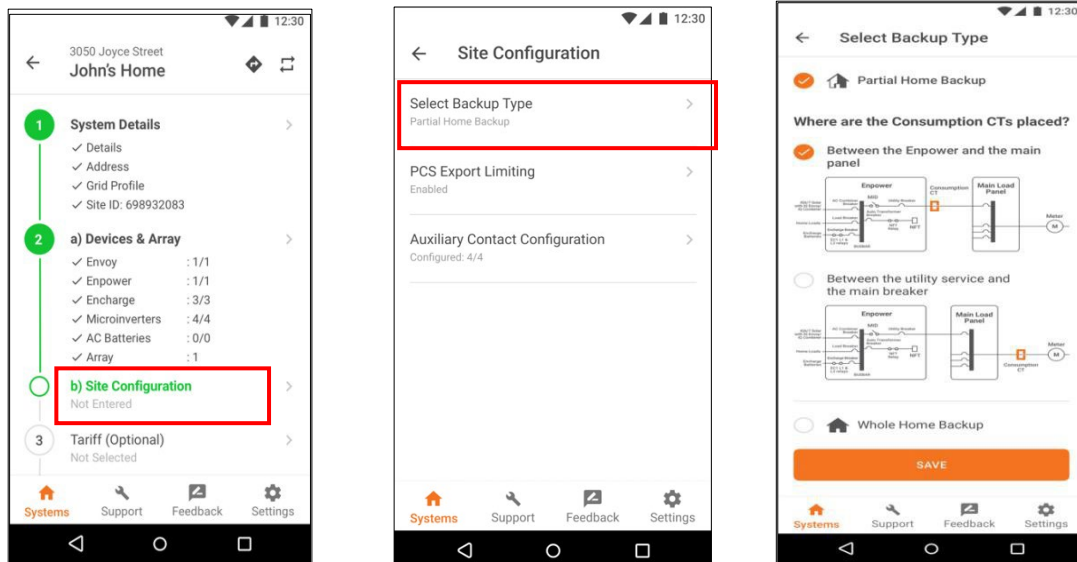


Figure 17: Partial backup configuration in site configuration in grid-forming configuration

In the **PCS Export Limiting > Main Panel Upgrade Avoidance** section, the installer has two ways of setting up the feature:

- **Current Limit with NEC 120% Rule:** In this option, the installer adds information on the rating of the main load panel busbar and the main service breaker rating. The system then auto-calculates the export current limit based on the 2020 NEC 705.12 (B) (2) or (4) rule.

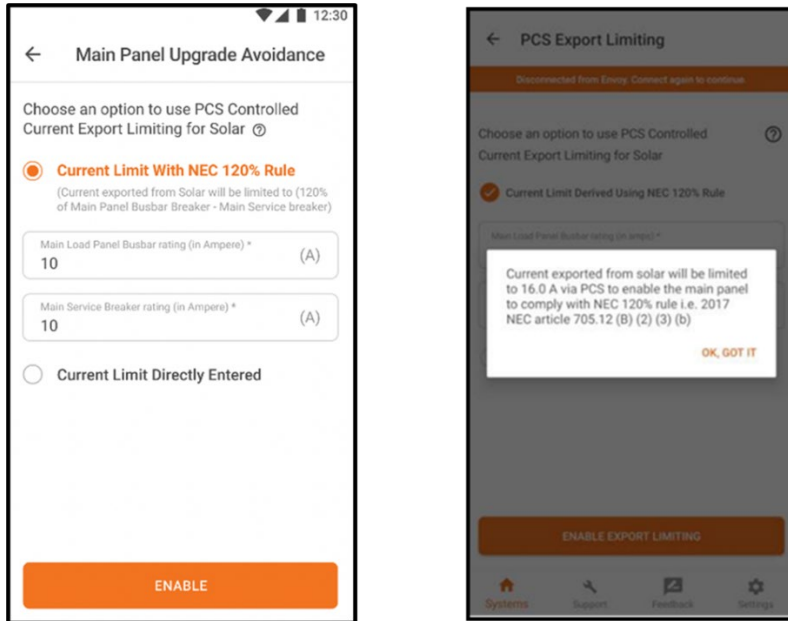


Figure 18: MPU avoidance configuration using NEC 120% rule

- Current Limit Directly Entered:** There may be situations where a homeowner may have an additional DER system connected to the main panel that is not monitored by Enphase Power Control. This could be a DER from another manufacturer or Enphase’s legacy microinverters. In either case, it is important for the installer to account for the current being back-fed from such a system and ensure they limit the maximum current export value of the Enphase storage system so that the total current exported back to the grid remains compliant with the NEC guidelines.

Also, there may be other situations where the site may be compliant with one of the subsections of the 2020 NEC 705.12 rule other than the 2020 NEC 705.12 (B) (2) or (4) rule that Enphase Power Control uses for auto-calculating the maximum backfeed current allowable.

To account for such situations, the Enphase Installer App provides installers with the ability to define the maximum allowable backfeed current by setting the **Current Limit Directly Entered** parameter in EIA. If the **Current Limit Directly Entered** parameter is set, the system uses this value and does not auto-calculate backfeed current limits based on the NEC120% rule. As shown in Figure 19, the installer can directly set the PCS export current limit based on their discretion with this option.

For example, if a site has an Enphase Energy System and a third-party PV system connected to a main panel, the main service breaker rating is 200 A, and the main panel busbar rating is 200 A. The maximum allowed continuous current from both the PV systems is 32 A. If the third-party PV system supplies a maximum continuous current of 16 A, then the installer can manually set the maximum continuous current for Enphase Energy System to 16 A, that is, 32 A–16 A using the **Current Limit Directly Entered** parameter in EIA.

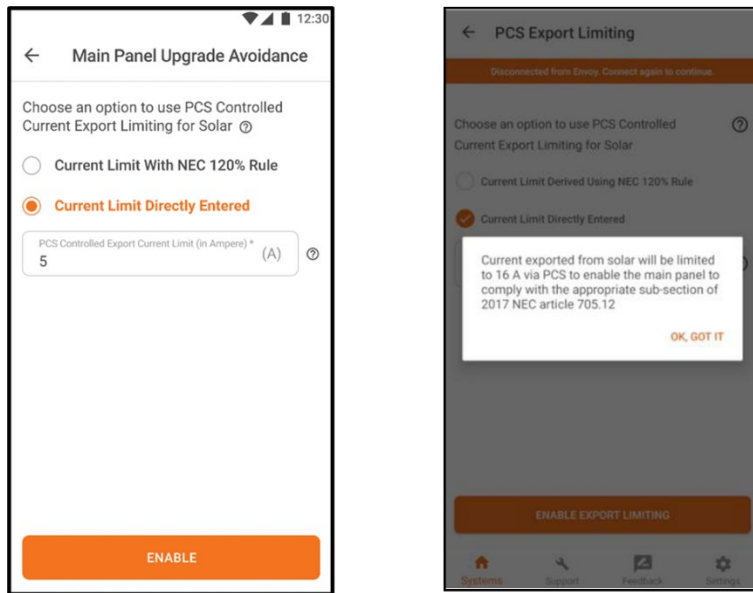


Figure 19: MPU avoidance configuration using direct current limit input

Configuring MPU avoidance in grid-forming configuration via Enphase Installer Portal

The installer can enable the Main Panel Upgrade Avoidance feature in the Enphase Installer Portal on the Activations page at the following location:

Navigate to **Systems > Activations > Configuration > PCS Export Limiting > Main Panel Upgrade Avoidance**.

Figure 20 demonstrates the configuration screen of the Enphase Power Control feature in the Enphase Installer Portal.

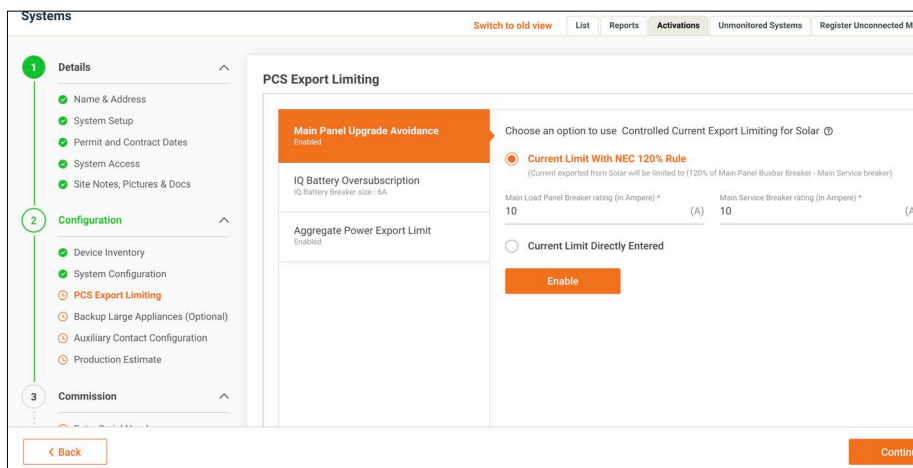


Figure 20: Enphase Power Control feature- MPU avoidance configuration in Enphase Installer Portal

Accounting for currents due to reactive power in the system

There is always a certain amount of reactive power generated in the system due to the presence of capacitors inside the PV microinverters present in the system. Due to the presence of this reactive power in the system, the current from the system can never be completely curtailed down to 0.

This does not impact our functionality of limiting export to the grid in any way because reactive power is not accounted for by utilities when measuring the export from DER to the utility grid. Utilities calculate exports based on the active power component. However, this current due to reactive power must be considered when using Enphase Power Control to control the export current from the DER to the main panel to avoid a main panel upgrade.

Handling reactive power when the current limit is derived based on the NEC 120% rule

If the installer enters a system configuration such that the total current in the system due to reactive power will exceed the limit to which the export current needs to be curtailed based on the NEC 120% rule, the installer will see a pop-up such as the one mentioned in the following Figure 21.

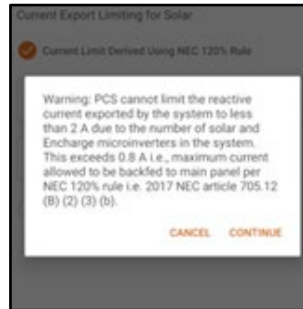


Figure 21: Warning pop-up for MPU avoidance configuration using the NEC 120% rule

The installer will have the option to click **CANCEL** and re-enter the system configuration if required or click **CONTINUE** and proceed. If the installer chooses to proceed, then the system limits the export current to the current generated due to the reactive power generated in the system and cannot limit it to any value below that. Therefore, there is a possibility of the system not being compliant with the NEC 120% rule.

Handling reactive power when the current limit is directly entered by the installer

We need to account for the presence of currents due to reactive power in the system. If the installer enters a value that is lower than the total current generated by reactive power in the system, the pop-up is displayed as shown, asking the installer to re-enter an appropriate value.



Figure 22: Warning pop-up for MPU avoidance configuration using direct current limit input

Aggregate power export limit

The Aggregate power export limit feature ensures that the power exported by the Enphase Energy System across all phases, that is, aggregate power, to the grid does not exceed the power export limit set in the Enphase Installer App by the installer. The Enphase Energy System continuously monitors the aggregate exported power at the point of measurement, i.e., at the Consumption CT, and controls the power produced from the PV system to keep the exported power below the limit set by the installer.

Aggregate power export limit can be supported in two configurations: grid-tied configuration and grid-forming configuration. For all supported SKUs with Aggregate power export limit, refer to Table 2.

Aggregate power export limit in the grid-tied configuration

Figure 23 shows the aggregate power export limit in grid-tied and grid-forming configurations, respectively.

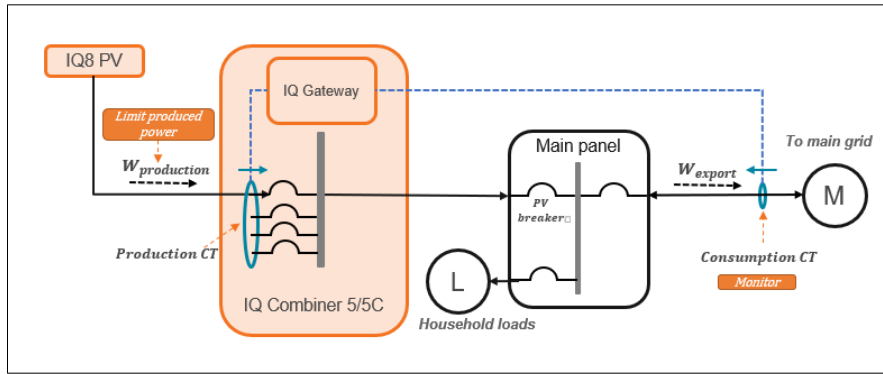


Figure 23: Aggregate Power Export Limit in the grid-tied configuration

In the configuration shown in Figure 23, the aggregate export power (W_{export}) to the utility grid is monitored through the Consumption CT placed on the utility/grid side of the main panel. The power produced by the PV system ($W_{production}$) is controlled appropriately to keep the W_{export} less than or equal to the set limit.

Aggregate power export limit in the grid-forming configuration

In the configuration shown in Figure 24, the aggregate export power (W_{export}) to the utility grid is monitored by the Consumption CT placed between the main panel and the utility meter. The power produced by the PV system ($W_{production}$) is controlled appropriately to keep W_{export} less than or equal to the set limit.

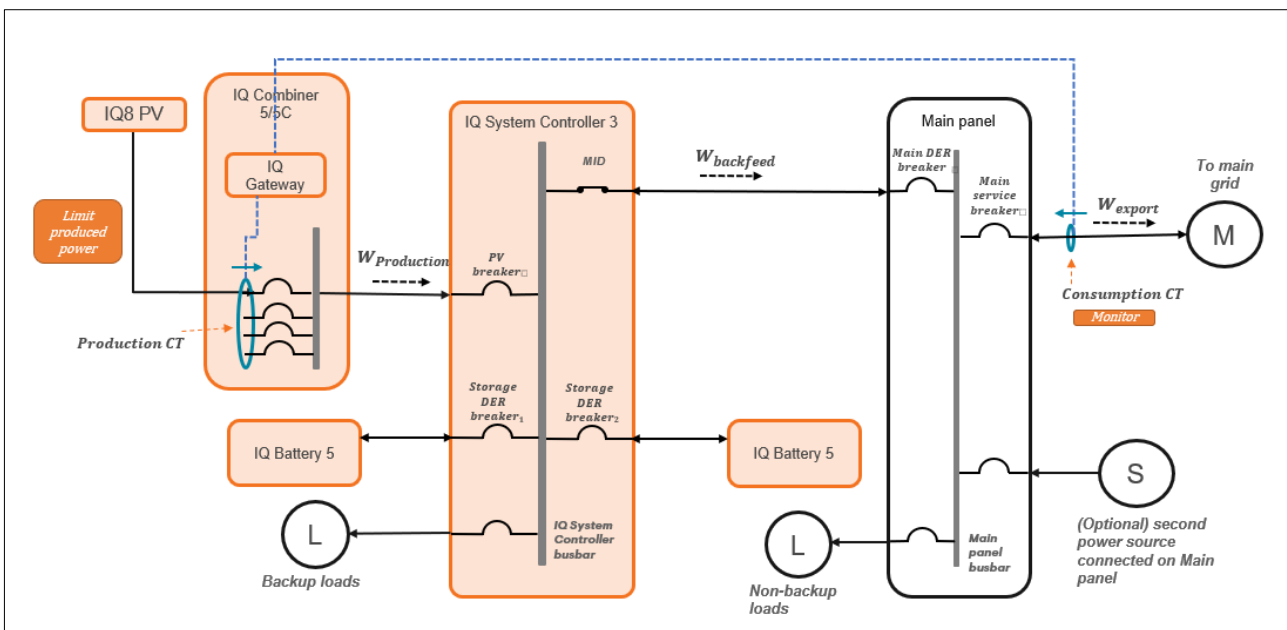


Figure 24: Aggregate power export limit in grid-forming configuration, Consumption CT placed between main service breaker and the meter

Compliance with regulations

Utilities in certain geographies require solar energy systems to limit their aggregate export power sent back to the utility grid. In such regions, the Enphase installers can configure the aggregate export power limit equal to or below the level required by the utility using the Enphase Installer App or Enphase Installer Portal. The Enphase Energy System automatically curtails PV production to ensure compliance with the local jurisdiction by adhering to the set aggregate power export limit.

The aggregate power export limit feature set by the installer during commissioning overrides the power export limit set in the specific Enphase grid profile; that is, when an aggregate power export limit is entered by the installer in the Enphase Installer app, the power export limit present in the grid profile is not utilized.

Note that power export limiting works on an aggregate basis for all phases by default. But, when the main panel upgrade avoidance is enabled, the export limiting of the current from PV production and IQ Batteries is limited per phase.

Failure modes and resolution

In case of communication failure or any unintended behavior from the Enphase Energy System, the following resolution mechanism would be employed, as shown in the following table:

Table 9: Failure modes and resolution

Failure mode	Resolution mechanism
One or more microinverters failed or stopped communicating with the IQ Gateway	If the IQ Gateway loses communication with the PV microinverter for more than 10 seconds, the PV microinverter automatically curtails its output current to the static safe limit (80% of the least of PV breaker size, power export limit, and main panel breaker size).
Consumption CT not reporting the correct value or missing Consumption CT	The PV production from each of the microinverters automatically defaults to the safe limit, such that the aggregate PV production is set to a static limit of 80% of the PV breaker on the main panel or the IQ System Controller.
PCS controller or IQ Gateway failure	If the PCS controller or IQ Gateway fails, the PV production curtails its output current to the static safe limit within 10 seconds of losing communication from the PCS controller. The homeowner can contact Enphase Support.

Configuring Aggregate PEL feature via Enphase Installer App (EIA)

During installation, the installer can enable the aggregate power export limit feature during the site configuration. The installer can navigate to the feature as shown:

Select **Site Configuration > PCS Export Limiting > Aggregate Power Export Limit**.

On the Configuration screen for the feature, as shown in Figure 25, the installer must input the **Aggregate Power Export Limit (W)** and press the **Enable** button to enable the feature.

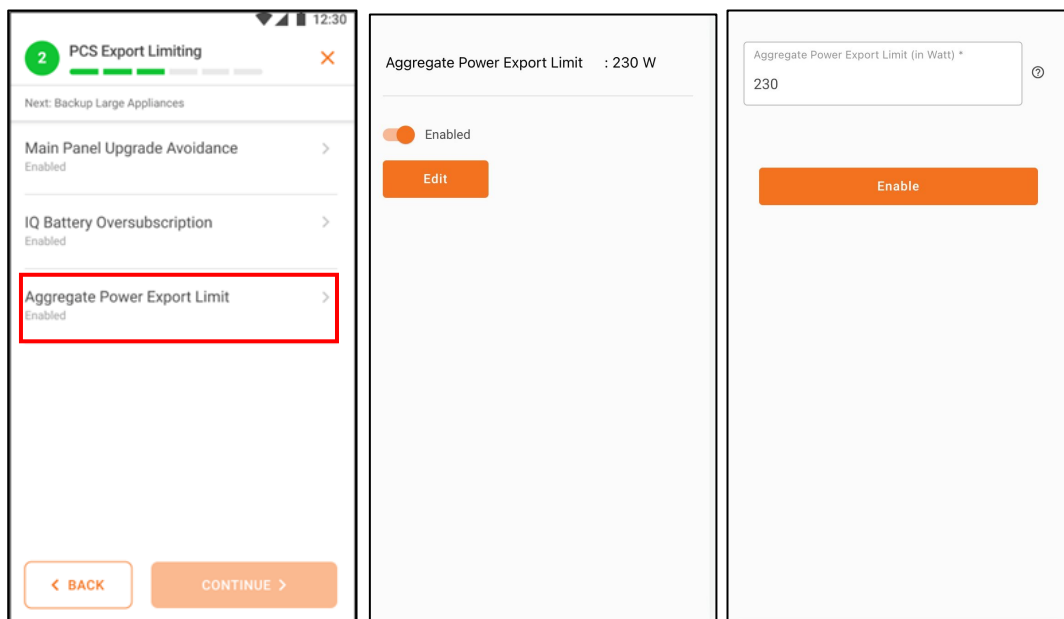


Figure 25: Aggregate Power Export Limit configuration

Configuring Aggregate PEL feature via Enphase Installer Portal

The installer can configure the aggregate power export limit feature using the Enphase Installer Portal on the Activations page for the site at the following location:

Select **Systems > Activations > Configuration > PCS Export Limiting > Aggregate Power Export Limit > Enable**

Figure 26 demonstrates the configuration screen of the Enphase Power Control feature in the above location.

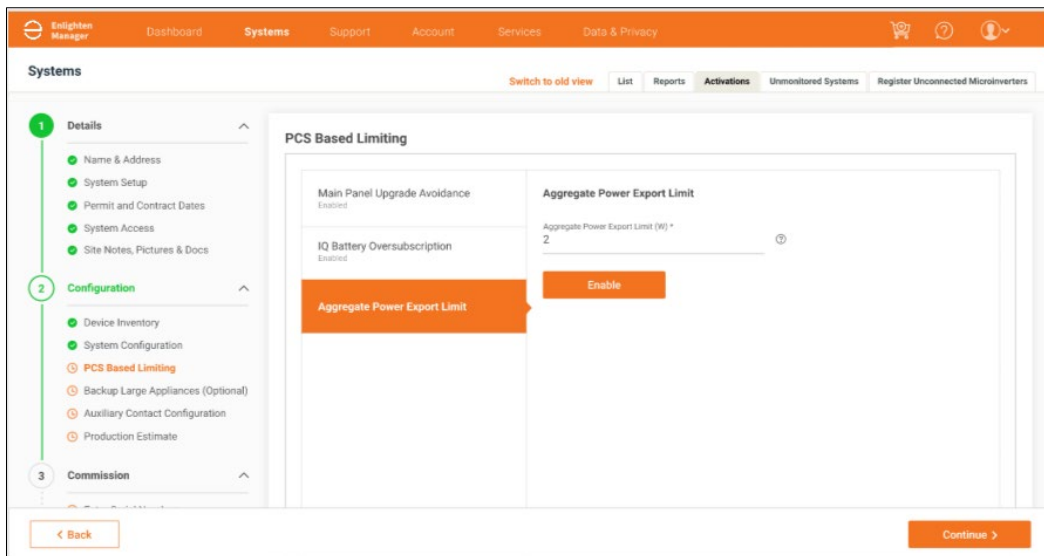


Figure 26: Aggregate power export limit in Enphase Installer Portal

On the Configuration screen, the installer must input the **Aggregate Power Export Limit (in W)** and press the **Enable** button to enable the Enphase Power Control feature.

Appendix

IQ Battery oversubscription, battery import only, and aggregate PEL with IQ System Controller 3 in partial home backup grid-forming configuration

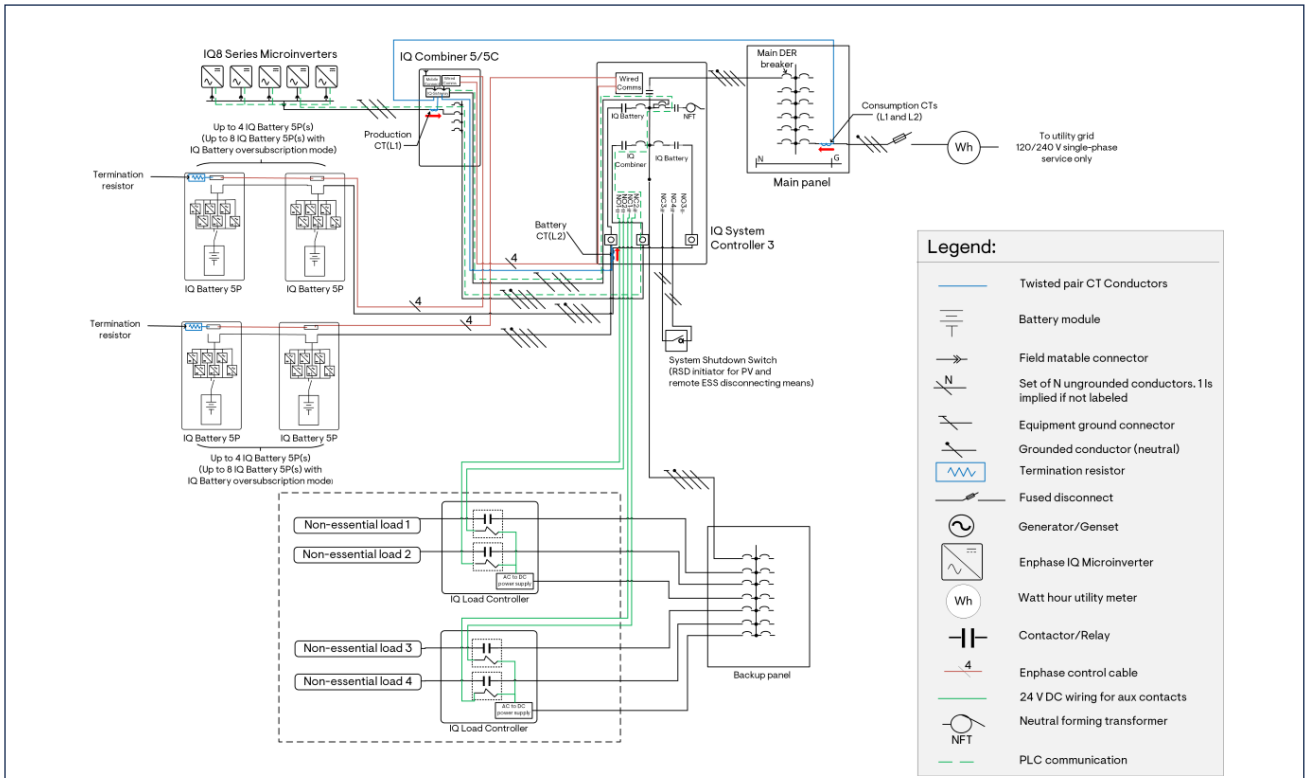


Figure 27: IQ Battery oversubscription, battery import only, and aggregate PEL with IQ System Controller 3

MPU avoidance with IQ System Controller 3 in partial home backup grid-forming configuration

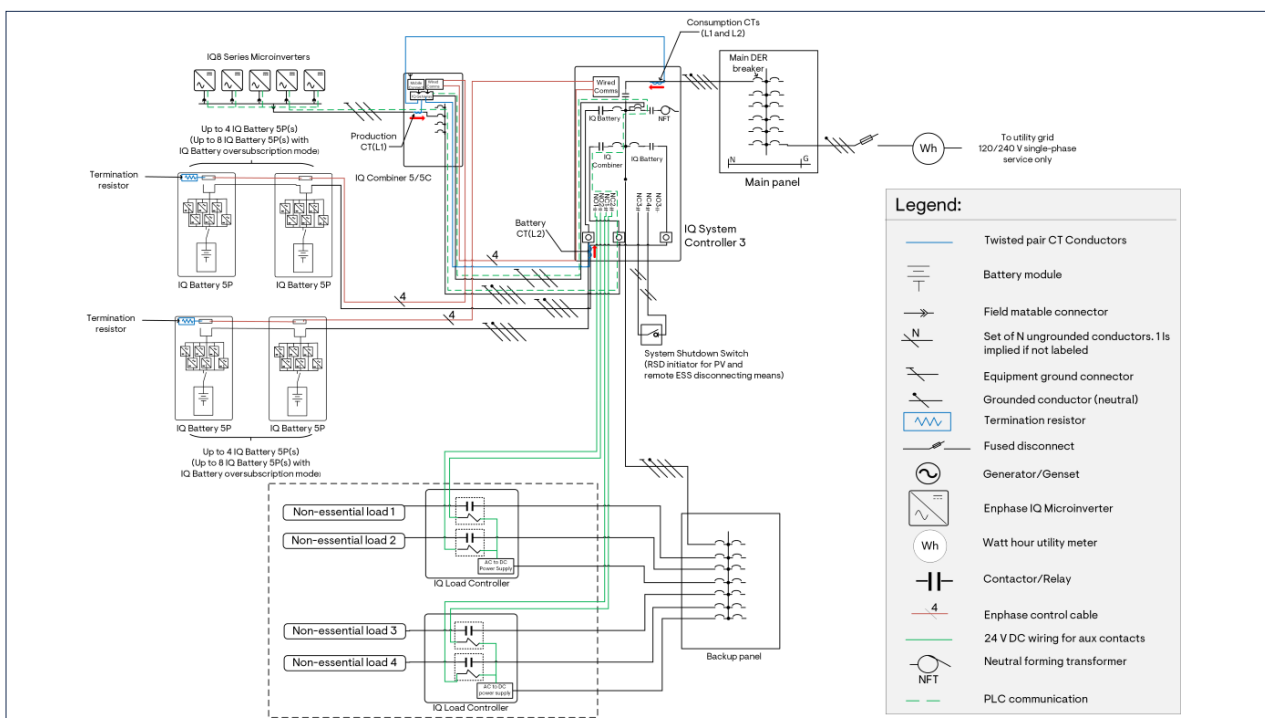


Figure 28: MPU avoidance with IQ System Controller 3

IQ Battery oversubscription, MPU avoidance, battery import only, and aggregate PEL with IQ System Controller 3G in partial home backup grid-forming configuration

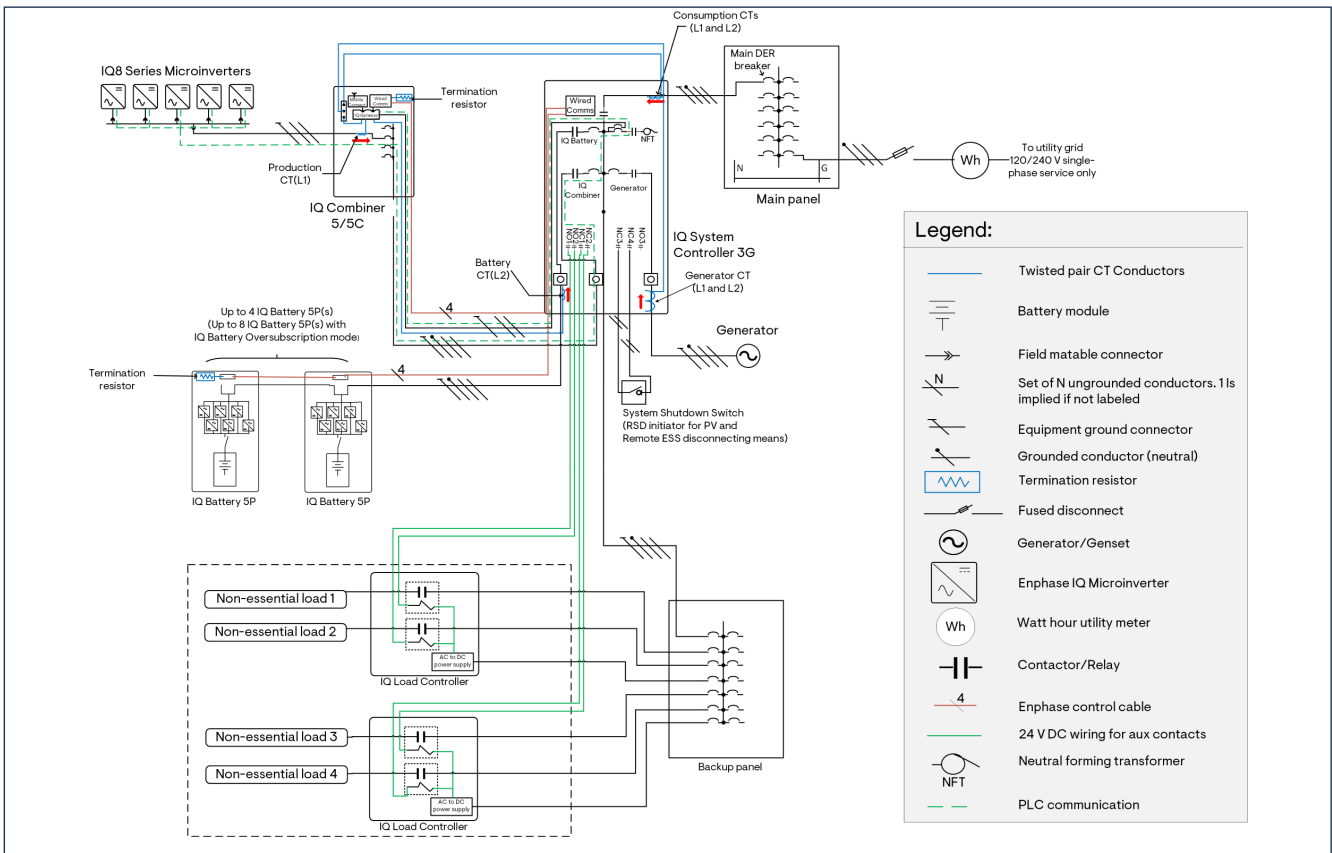


Figure 29: IQ Battery oversubscription, MPU avoidance, battery import only, and aggregate PEL with IQ System Controller 3G

IQ Battery oversubscription, aggregate PEL, and battery import only in grid-tied configuration with IQ Combiner 5/5C

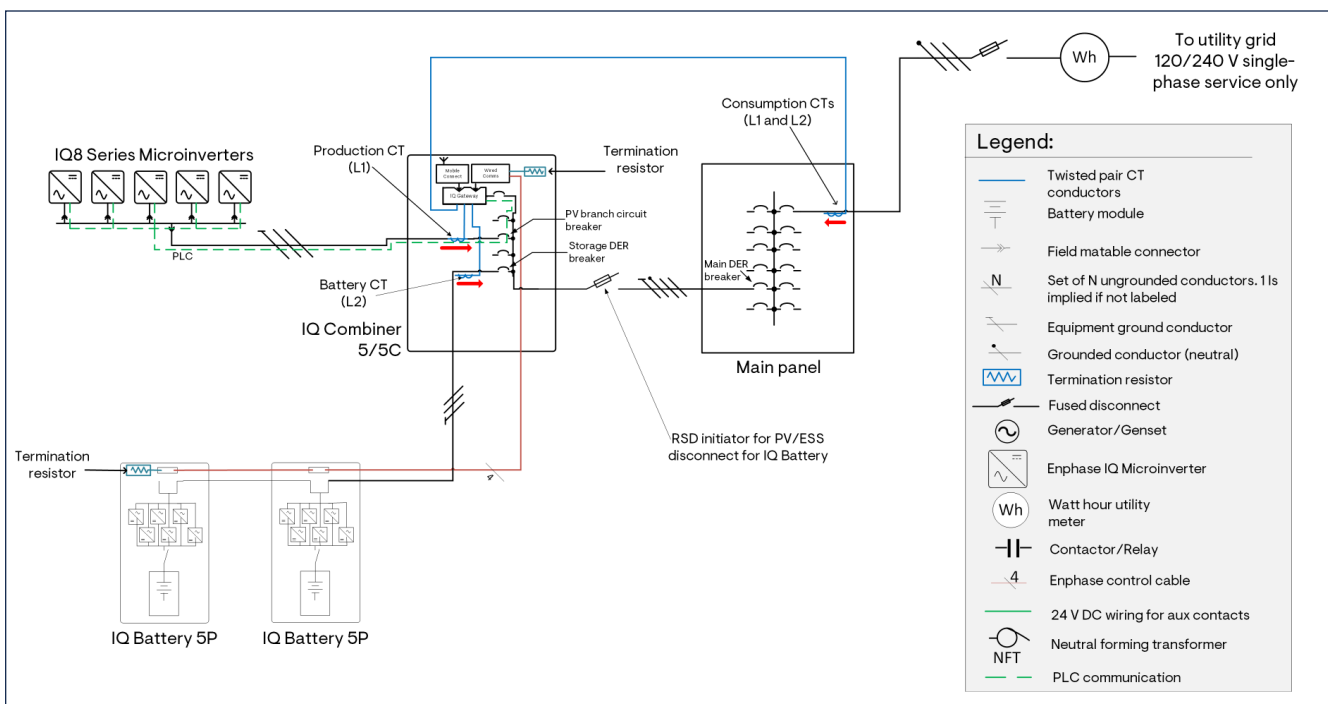


Figure 30: IQ Battery oversubscription, aggregate PEL, and battery import only with IQ Combiner 5/5C in grid-tied configuration

MPU avoidance in grid-tied configuration with IQ Combiner 5/5C

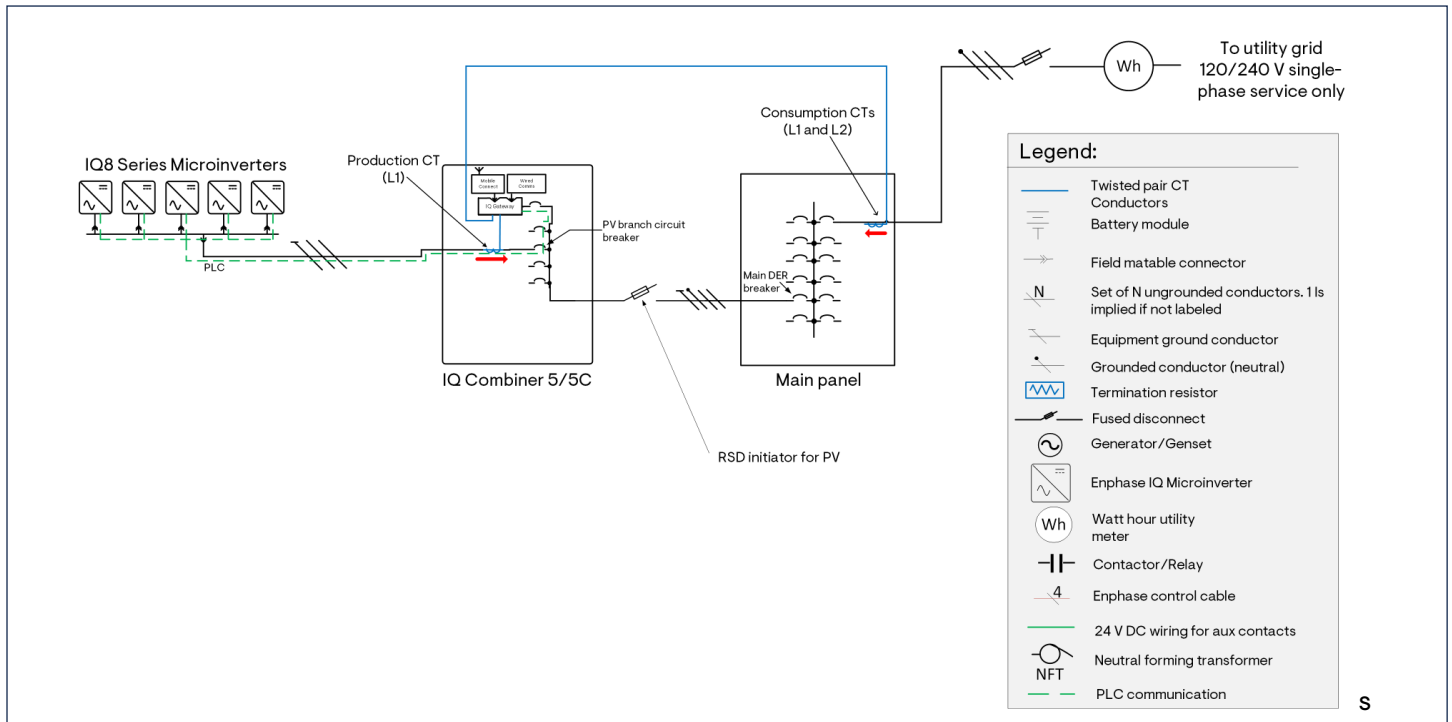


Figure 31: MPU avoidance in grid-tied configuration with IQ Combiner 5/5C



NOTE: The Enphase Power Control supports grid-tied MPU avoidance in PV only sites. Support for MPU avoidance in grid-tied configuration with PV and IQ Battery will be available in Q4 2023.

IQ Battery oversubscription, aggregate PEL, and battery import only in grid-tied configuration with off-the-shelf sub-panel

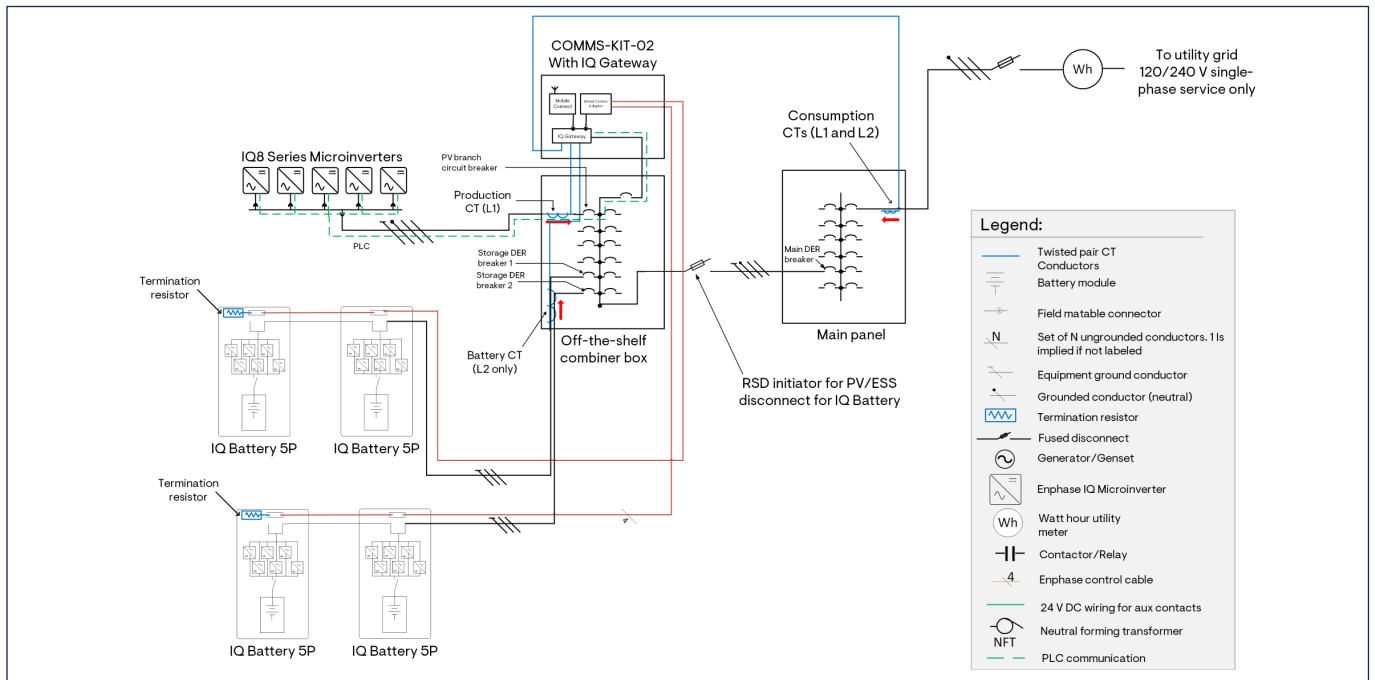


Figure 32: IQ Battery oversubscription, aggregate PEL, and battery import only in grid-tied configuration with off-the-shelf sub-panel

Revision history

Revision	Date	Description
TEB-00049-2.0	September 2023	<ul style="list-style-type: none"> Updated Table 2 “Supported SKUs for added support on older SKUs”. Updated diagrams to demonstrate support of features over older SKUs in the “IQ Battery Oversubscription” section. Updated the “Aggregate PEL” section. Updated the “Wiring diagrams” section.
TEB-00049-1.0	August 2023	<ul style="list-style-type: none"> Updated “Enphase Storage System” to “Enphase Energy System”. Updated “Introduction to Power Control System” section. Added “Supported configurations for Enphase Power Control” section. <ul style="list-style-type: none"> Added “Overview of Enphase Energy System” section. Added “Enphase Power Control in grid-tied Enphase Energy System” section. Added “Enphase Power Control in grid-tied Enphase Energy System” section. Updated “Benefits of Enphase Power Control” section. Updated “PCS Integration in Enphase Energy System” section. <ul style="list-style-type: none"> Updated “Components of Enphase Power Control” section. Updated “Supported SKUs for Enphase Power Control” section. Updated “Setting up Enphase Power Control” section. Added “IQ Battery oversubscription” section. Updated “Battery import only mode for Enphase Energy System (EES)” section. Updated “Main panel upgrade avoidance using PV current limiting” section. Added “Aggregate power export limit” section. Added “Appendix” section with wiring diagrams for Enphase Power Control features enabled.
Previous release		