ENPHASE.

TECHNICAL BRIEF

Power Control System integration in Enphase Energy System

Applicable regions: North America

Contents

1. 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. Power control systems can be used in a variety of cases, for example, to 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 UL 1741 Certification Requirement Decision (CRD) and UL 3141 Outline of Investigation for Power Control Systems.

Enphase Energy System (EES) has interconnected electric power production sources, such as microinverters and/or IQ Batteries. The amount of power production sources connected to a system is generally governed by various sections of the NEC.

Power Control System integration allows flexible installation of Enphase systems with minimal additional homeowners costs (for example, installing more PV or batteries) or complying with special requirements in certain jurisdictions. This technical brief describes the benefits and implementation details of Power Control System integration for real-time current monitoring and export limiting.

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

2. Supported configurations for Enphase Power Control

2.1 Overview of Enphase Energy System

An Enphase Energy System can be classified into two configurations:

- Grid-tied or non-backup systems: In a grid-tied system, Enphase microinverters and (optional) IQ Batteries will need the grid to be available to keep producing power or discharging to the loads.
- Grid-forming or backup systems: Microinverters and 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.

2.2 Enphase Power Control in a 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

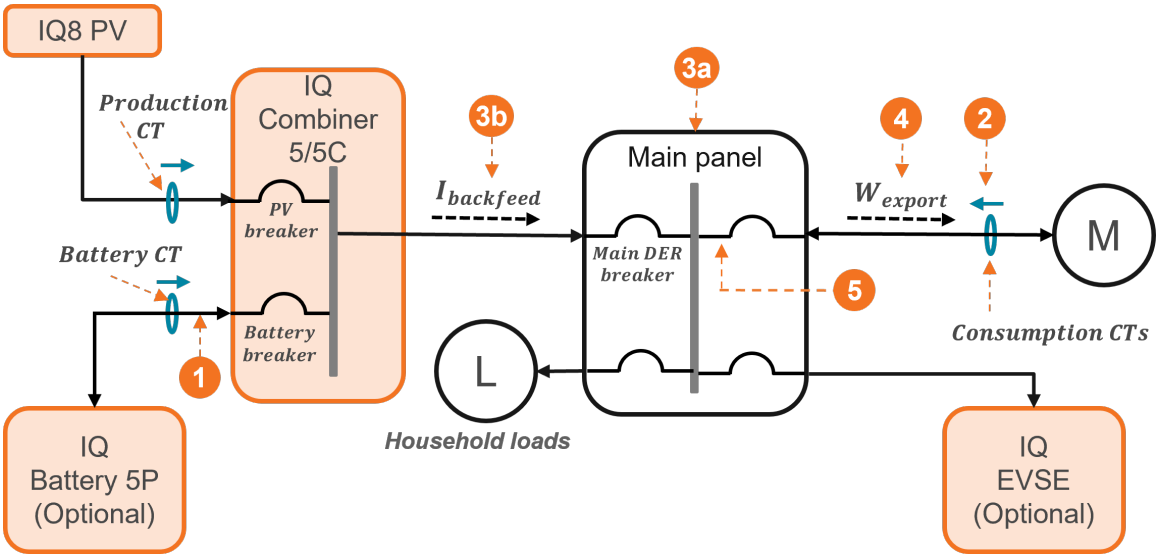


Figure 1: Example of an Enphase Energy System in the grid-tied configuration

Enphase Power Control enables six features in the grid-tied EES:

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/export only mode:
   - The import-only mode (also called non-exporting) ensures the Enphase IQ Battery never exports any power to the grid.
   - The export-only mode (also called charge from pv-only) ensures that the Enphase IQ Battery never imports any power from the grid but can export to the grid. Enphase IQ Battery can operate either in battery import-only mode or battery export-only mode.
3. Main panel upgrade avoidance (MPUA) mode with:
   - Busbar Overload Control (3a in Figure 1: Example of an Enphase Energy System in the grid-tied configuration on page 6): This feature reduces the system payback period by allowing maximum renewable energy generation and helps avoid the cost of panel upgrade for a large PV and battery systems.
   - Feeder Control (3b in Figure 1: Example of an Enphase Energy System in the grid-tied configuration on page 6): This feature enables avoiding the cost of a panel upgrade for a large PV and battery system.
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.
5. IQ EVSE main breaker trip avoidance (MBTA): This feature enables the installation of more powerful IQ EVSE to charge the electric vehicle (EV) by avoiding service upgrades and main service breaker trips when home loads are extremely high.
6. NEM integrity mode: This feature allows for expanding legacy Net Energy Metering(NEM) 1.0/2.0 systems in California with additional PV and battery capacity without losing the NEM 1.0/2.0 tariff. This is achieved by making the new system export no more than what the existing legacy system is producing. More details can be found in Appendix A.

Figure 1: Example of an Enphase Energy System in the grid-tied configuration on page 6 provides a birds-eye view of the point of current being measured and limited using Enphase Power Control for each feature.

2.3 Enphase Power Control in a grid-forming Enphase Energy System

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

- IQ8 Series Microinverters
- IQ Gateway or IQ Combiner
- IQ System Controller
- IQ Battery
- (Optional) IQ Meter Collar

Enphase Power Control enables five features for grid-forming EESs with IQ Battery 5P, as shown in the following figure.

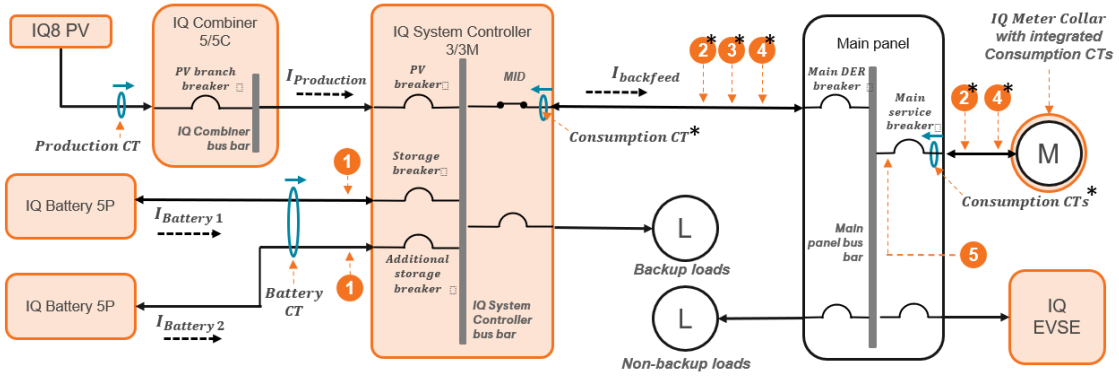


Figure 2: Example of an Enphase Energy System with IQ System Controller 3 in grid-forming configuration

NOTE: *Aggregate power export limit and battery import are applied at the Consumption CTs or IQ Meter Collar (which has integrated Consumption CTs). If Consumption CTs are used, they must be placed between the main panel and the meter by default. Consumption CTs must be placed between the IQ System Controller and the main panel if using a generator.

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: The IQ Battery oversubscription mode allows for more batteries on the storage port than allowed based on the installed breaker rating.
   - IQ System Controller 3/3M: The IQ Battery oversubscription mode allows for more batteries on the storage and DER ports than allowed based on the installed breaker rating.
2. Battery import/export only mode: The battery import-only feature ensures the Enphase IQ Battery never exports any power to the grid. The battery export-only feature ensures that the Enphase IQ Battery never imports any power from the grid but can export to the grid. Enphase IQ Battery can operate either in the battery import-only mode or the battery export-only mode.
3. MPU avoidance mode with:
   - Busbar Overload Control (3a in Figure 2: Example of an Enphase Energy System with IQ System Controller 3 in grid-forming configuration on page 7): This feature reduces the system payback period by allowing maximum renewable energy generation and helps avoid the cost of panel upgrade for a large PV and battery system.
   - Feeder Control (3b in Figure 2: Example of an Enphase Energy System with IQ System Controller 3 in grid-forming configuration on page 7): This feature enables avoiding the cost of a panel upgrade for a large PV and battery system.
4. Aggregate power export limit mode: This feature ensures that the aggregate power exported as measured at the Consumption CTs or IQ Meter Collar is limited to the power export limit (PEL) value set by the installer.

   NOTE: Enphase PV production and battery discharge ensures that the aggregate export power adheres to the limit regardless of whether the battery is in export-only or import-only mode.
5. IQ EVSE main breaker trip avoidance (MBTA) mode: This feature enables the installation of a more powerful IQ EVSE to charge the electric vehicle (EV) by avoiding Main service breaker trips when home loads are extremely high.

Figure 2: Example of an Enphase Energy System with IQ System Controller 3 in grid-forming configuration on page 7 provides a bird's-eye view of the point of current being measured/monitored and limited using Enphase Power Control for each feature.

3. Benefits of Enphase Power Control

3.1 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.

3.2 Benefit from a smaller payback period

The Enphase Power Control feature, battery export-only mode, allows homeowners in a jurisdiction with NEM 3.0 to charge their IQ Battery from the PV and discharge to their home loads and to the grid. Homeowners can benefit from a lower payback period by storing excess PV power during off-peak hours and discharging the stored energy to the grid during the time when it is most beneficial to the homeowner based on the import and export tariff rates.

The Enphase Power Control feature, MPU avoidance with busbar overload control, allows maximum utilization of available renewable energy while avoiding the cost of a main panel upgrade, reducing the payback period for the homeowner.

3.3 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. The PCS-certified Enphase Power Control features, MPU avoidance with busbar overload control and with feeder control, enable large PV and battery systems to be installed while complying with NEC code (NEC 2020 705.13 and NEC 2020 705.12 respectively).

This enables installers to avoid the cost and time due to an unplanned main panel upgrade. Enphase Power Control uses real-time current sensing to monitor and limit the current back-fed into the main panel.

3.4 Benefit from longer backup time with high-power batteries

The Enphase Power Control feature, IQ Battery oversubscription mode, enables up to twice as many batteries per site compared to systems without the Power Control System 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

	Without IQ Battery oversubscription				With IQ Battery oversubscription			
IQ System Controller type	**Max. allowed IQ Battery 5P units**	**Max. continuous output current per battery (A)**	**Aggregate power from batteries (kW)**	**Aggregate energy storage capacity of batteries (kWH)**	**Max. allowed IQ Battery 5P units**	**Max. continuous output current per battery (A)**	**Aggregate power from the batteries (kW)**	**Aggregate energy storage capacity of batteries (kWH)**
IQ System Controller 3G (SC200G111C240US01)	4 (4 on storage port[1])	16	15.36	19.84	8 on storage port[1]	8	15.36	39.68
IQ System Controller 3/3M (SC200D111C240US01/ SC200D111CMC1US01)	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
IQ Combiner 5/5C (X-IQ-AM1-240-5/5C)	3 (3 on single IQ Battery 60 A breaker)	16	11.52	14.88	6 (6 on single IQ Battery 60 A breaker)	8	11.52	29.76

NOTE: Please note that when using off-the-shelf combiner panels and an IQ Gateway, IQ Battery oversubscription maximum limits are the same as IQ System Controller 3, that is, a maximum of 16 batteries with eight batteries each on an 80 A breaker.

3.5 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.

3.6 Limit IQ EVSE charge current to avoid a main panel upgrade during load calculations

In the absence of the IQ EVSE MBTA feature, a homeowner may have to upgrade their service or their main panel when installing an IQ EV Charger to support the additional load for charging the EV. This feature adjusts the IQ EVSE charge current to ensure that the total import from the grid does not exceed the current limit per the main service breaker rating. When the current from the grid being used by the other home loads is low, the IQ EV Charger increases its charge current until the maximum

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

allowable limit as per the main service breaker rating. When the current from the grid being used by the other loads is high, the IQ EV Charger reduces its charge current to ensure that the total import from the grid is below the mentioned breaker rating.

4. Power Control System integration in the Enphase Energy System

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

4.1 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 the 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). Instead of Consumption CTs, an IQ Meter Collar (MC-200-011-V01) can be used for current sensing as well. 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. Power Control System 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 to the grid when the battery import-only mode is enabled and that the IQ Battery does not import any power from the grid to charge when the battery export-only is enabled.
4. Other balance of system components
    a. IQ Combiner: Aggregates PV branches and energy storage. Enphase Power Control can limit the backfeed into the main panel from the IQ Combiner, per NEC requirements in grid-tied systems.

        NOTE: The IQ Combiner includes an integrated IQ Gateway Power Control Systems controller, being referred to in component 2. IQ Gateway need not be repurchased if an IQ Combiner is already present at a site. However, a standalone IQ Gateway is sold separately for other use cases, such as sites with third-party off-the-shelf combiners.
    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 the backfeed into the main panel from the IQ System Controller, per NEC requirements, for partial home backup grid-forming systems.
    c. IQ EV Charger: Charges the electric vehicle (EV). It enables the Enphase Power Control feature, IQ EVSE MBTA, to control the EV charge current such that the total import current from the grid for supplying the home loads and for charging the electric vehicle together does not exceed the limit enforced by the main service breaker rating.

4.2 Supported SKUs for Enphase Power Control

For the latest PCS-supported SKUs and certification, refer to the Availability of features by System type.

4.3 Setting up Enphase Power Control

4.3.1 Installation of the Production, Battery, and Consumption Current Transformers CT(s) 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 Power Control System-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 CTs placement in a grid-forming partial home backup configuration is shown in the following figure.

NOTE: If the installer requires generator integration, the CT placement must be in between the IQ System Controller and the main panel.

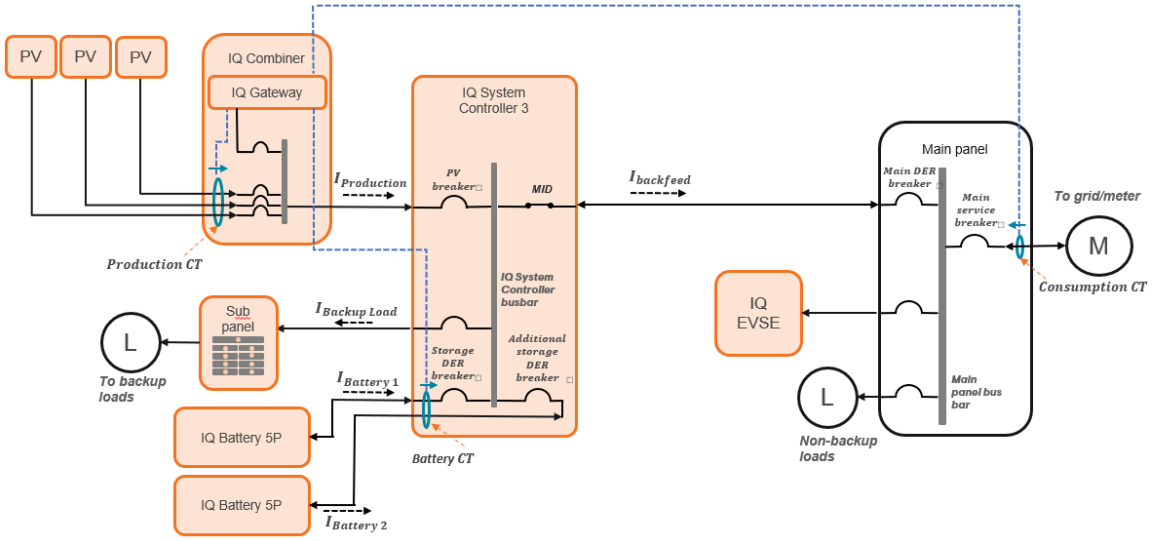


Figure 3: Bird's-eye view of Production, Battery, and Consumption CT placement in grid-forming partial home backup configuration

The high-level diagram of default Consumption CTs placement in a grid-forming whole home backup configuration is shown in the following figure.

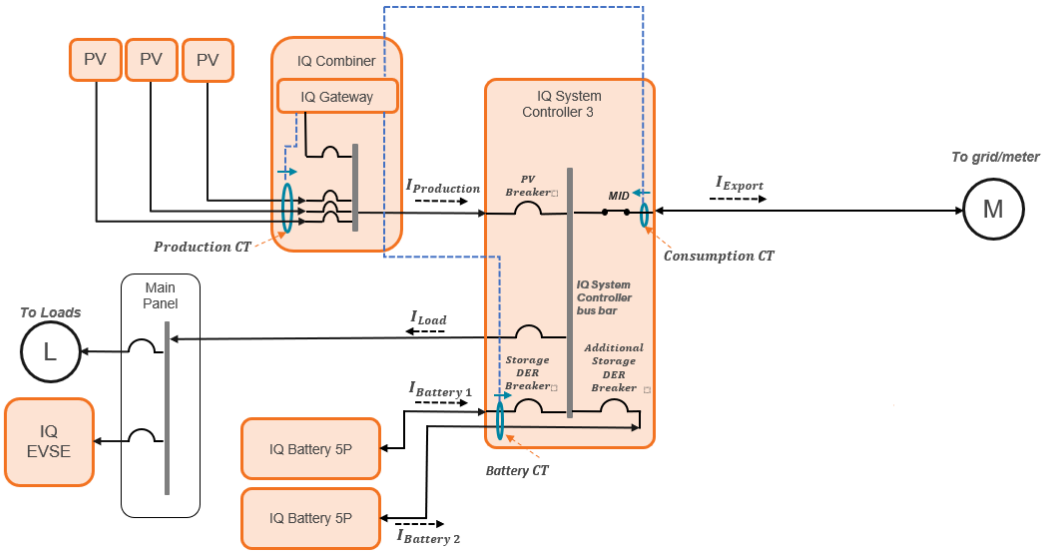


Figure 4: Bird's-eye view of Production, Battery, and Consumption CTs placement in grid-forming whole home backup configuration

NOTE: The grid-forming whole home backup with IQ System Controller 3/3G does not require a main panel upgrade because the main panel is on the load side of the IQ System Controller, and the current is back-fed into the main panel from the Enphase Energy System.

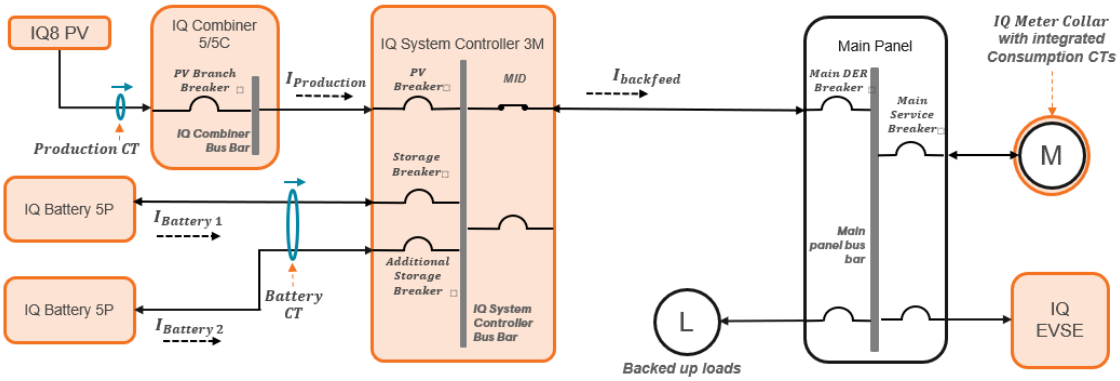


Figure 5: Bird's-eye view of production, battery, and IQ Meter Collar placement in grid-forming whole home backup configuration

4.3.2 Installation of the Production, Battery, and Consumption Current Transformers (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.

NOTE: When connecting the Battery CT on IQ Combiner 4/4C and the standalone IQ Gateway, a jumper wire must be added between the L2 and L3 terminals of the IQ Gateway. Refer to the IQ Battery metering section in Guidelines for Current Transformer (CT) installation Tech-brief for instructions on connecting the Battery CT on IQ Combiner 4/4C or standalone IQ Gateway.

4.3.3 Current transformer (CT) placement for Enphase Power Control features

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

Table 2: CT placement for Enphase Power Control features

	Grid-forming configuration		Grid-tied configuration	
Enphase Power Control feature	**CT(s) utilized**	**CT placement**	**CT(s) utilized**	**CT placement**
IQ Battery oversubscription	Battery CT[2]	Battery CT is to be placed inside the IQ System Controller[2]	Battery CT[2]	Battery CT is to be placed around all battery branch circuits[2]
Battery import-only	Production CT and Consumption CTs or Meter Collar	Production CT is placed inside the IQ Combiner Consumption CTs are placed between the main panel and utility meter (default configuration)[3] or IQ Meter Collar beneath the utility meter or in a pan Consumption CTs can also be placed between the IQ System Controller and the main panel[4]	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
Battery export-only	Production CT, Battery CT, and Consumption CTs or Meter Collar	Production CT is placed inside the IQ Combiner Consumption CTs are placed between the main panel and utility meter (default configuration) or IQ Meter Collar beneath the utility meter or in a pan Consumption CTs can also be placed between the IQ System Controller and the main panel[3] Battery CT is to be placed inside the IQ System Controller	Production CT, Battery 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 Battery CT is to be placed inside the IQ Combiner around all battery branch circuits

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

[3] Refer to the “CT wiring” section in the IQ System Controller 3/3G quick install guide (QIG) for Consumption CTs placement between the main panel and utility meter.

[4] Refer to the “CT wiring” section in the IQ System Controller 3/3G quick install guide (QIG) for Consumption CT's placement between the IQ System Controller and the main panel.

	Grid-forming configuration		Grid-tied configuration	
Enphase Power Control feature	**CT(s) utilized**	**CT placement**	**CT(s) utilized**	**CT placement**
Main panel upgrade avoidance with busbar overload control (BBoC)	Production CT, Battery CT, and Consumption CTs or Meter Collar	Production CT is placed inside the IQ Combiner Consumption CTs are placed between the main panel and utility meter (default configuration) or IQ Meter Collar beneath the utility meter or in a pan[3] Battery CT is to be placed inside the IQ System Controller	Production CT, Battery 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 Battery CT is to be placed inside the IQ Combiner around all battery branch circuits If batteries are landing outside of the combiner, then they must be placed so all battery branches are captured
Main panel upgrade avoidance with NEC 120% rule	(Default) Production CT and Battery CT	Production CT is placed inside the IQ Combiner around all PV branch circuits Battery CT is to be placed inside the IQ System Controller	Production CT and Battery CT	Production CT is placed inside the IQ Combiner around all PV branch circuits Battery CT is to be placed inside the IQ Combiner around all battery branch circuits If batteries are landing outside of the combiner, then it must be placed so all battery branches are captured.
	(In generator configurations) Consumption CTs	Consumption CTs are placed between the IQ System Controller and main panel[4]		
Aggregate power export limit	Consumption CTs or Meter Collar	Consumption CTs are placed between the main panel and utility meter (default configuration)[3] or IQ Meter Collar beneath the utility meter or in a pan Consumption CTs can also be placed between the IQ System Controller and the main panel[4]	Consumption CTs	Consumption CTs are placed between the main panel and the utility meter
IQ EVSE MBTA	Consumption CTs	Consumption CTs are placed between the main panel and	Consumption CTs	Consumption CTs are placed between the

	Grid-forming configuration		Grid-tied configuration	
Enphase Power Control feature	**CT(s) utilized**	**CT placement**	**CT(s) utilized**	**CT placement**
		utility meter (only default configuration is supported)[3]		main panel and the utility meter

NOTE: The installer can configure MPU avoidance, IQ Battery oversubscription, battery import/export-only, and aggregate power export limit Power Control System features using the Enphase Installer App or Enphase Installer Portal.

4.3.4 Wiring diagrams for Enphase Power Control

Table 3: 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 /3M	Grid-forming configuration with IQ System Controller 3G	Grid-tied configuration with IQ Combiner 5/5C
IQ Battery oversubscription	Figure 41: IQ Battery oversubscription, MPU avoidance, battery export/import only, and aggregate PEL with IQ System Controller 3 on page 52	Figure 42: IQ Battery oversubscription, MPU avoidance, battery export/import only, and aggregate PEL with IQ System Controller 3G on page 53	Figure 43: IQ Battery oversubscription, MPU avoidance, aggregate PEL, and battery export/import only with IQ Combiner 5/5C and IQ Battery 5P in the grid-tied configuration on page 53
Battery import-only			
Battery export-only			
Aggregate power export limit			
Main panel upgrade avoidance			

For wiring diagrams with IQ7 Microinverters or for older SKUs such as IQ Combiner 4/4C, IQ System Controller 1/2, and so on, refer to the Planning an Enphase Energy System technical brief.

4.3.5 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 the following:

- *IQ System Controller 3/3M/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

5. Enphase Power Control features

5.1 IQ Battery oversubscription

5.1.1 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.

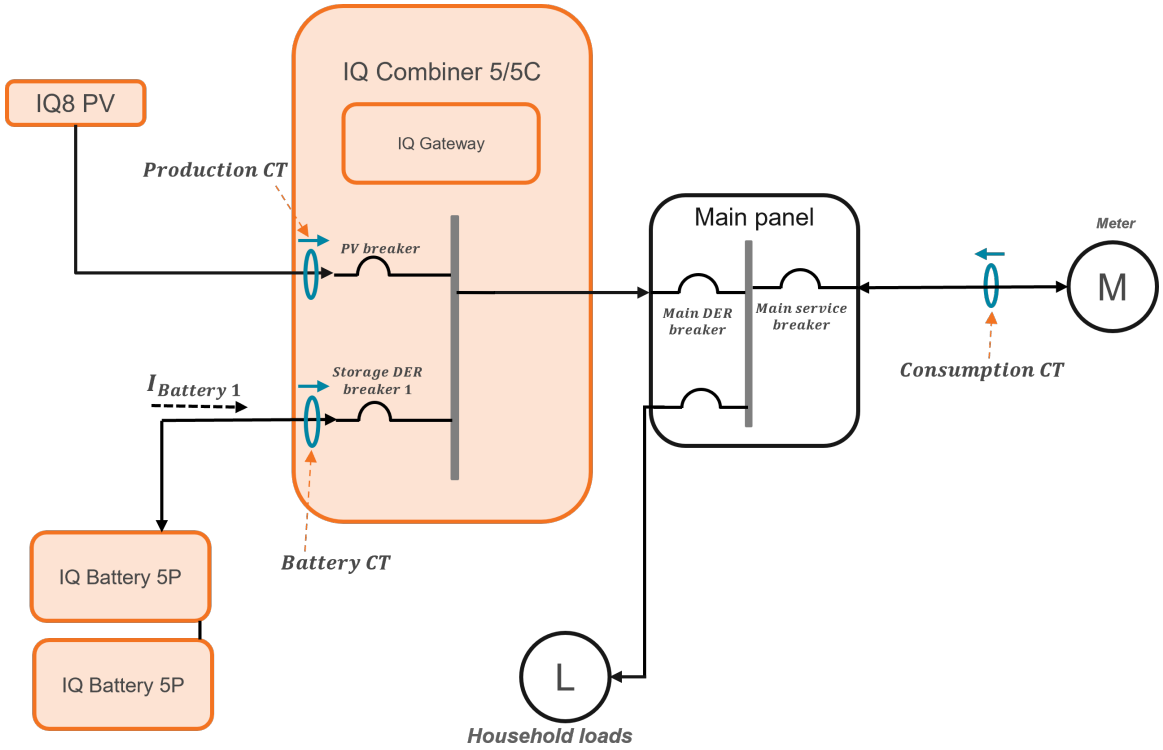


Figure 6: IQ Battery oversubscription in a grid-tied system with IQ Combiner 5/5C

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 $I_{Battery\ 1}$ 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 subpanel 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 $I_{Battery\ 1}$ and $I_{Battery\ 2}$ on the two IQ Combiner breaker slots are limited to the breaker sizes. The maximum breaker rating for the two battery breaker slots is 80 A each.

5.1.2 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.

5.1.2.1 System design and sizing: IQ Battery oversubscription with IQ System Controller 3, 3M, and 3G

As shown in Table 1: Maximum continuous current, aggregate power, and aggregate energy comparison with and without the IQ Battery oversubscription on page 10, IQ Battery oversubscription is supported with three 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.
- IQ System Controller 3M: This IQ System Controller 3Mis identical to the IQ System Controller 3 in terms of DER ports and features, with the additional functionality required to use the IQ Meter Collar product with the Enphase IQ Battery 5P.

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: Maximum continuous current, aggregate power, and aggregate energy comparison with and without the IQ Battery oversubscription on page 10.

The following figure shows the IQ Battery oversubscription in grid-forming configuration with IQ System Controller 3 and IQ System Controller 3G, respectively.

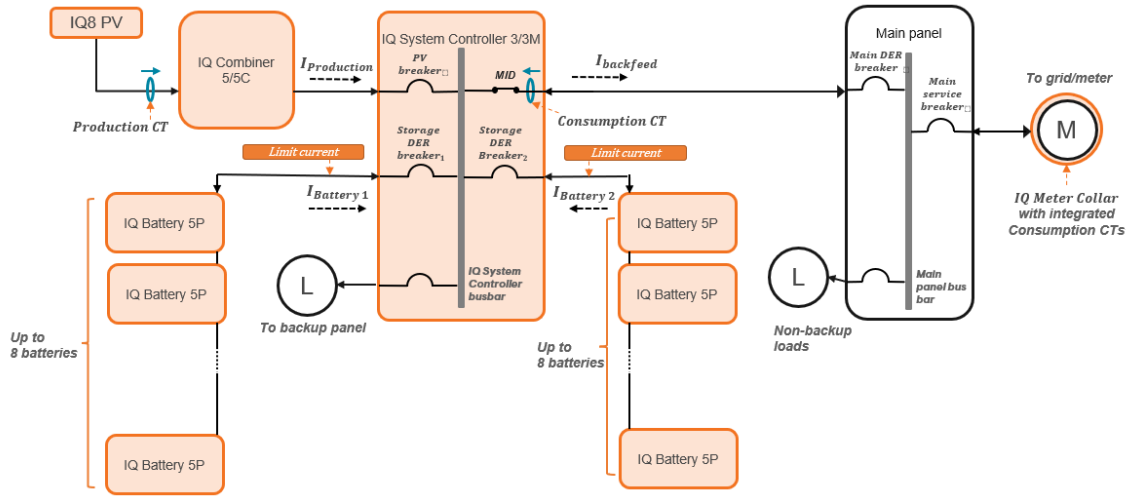


Figure 7: IQ Battery oversubscription with IQ System Controller 3/3M – supporting up to 16 IQ Battey 5P units

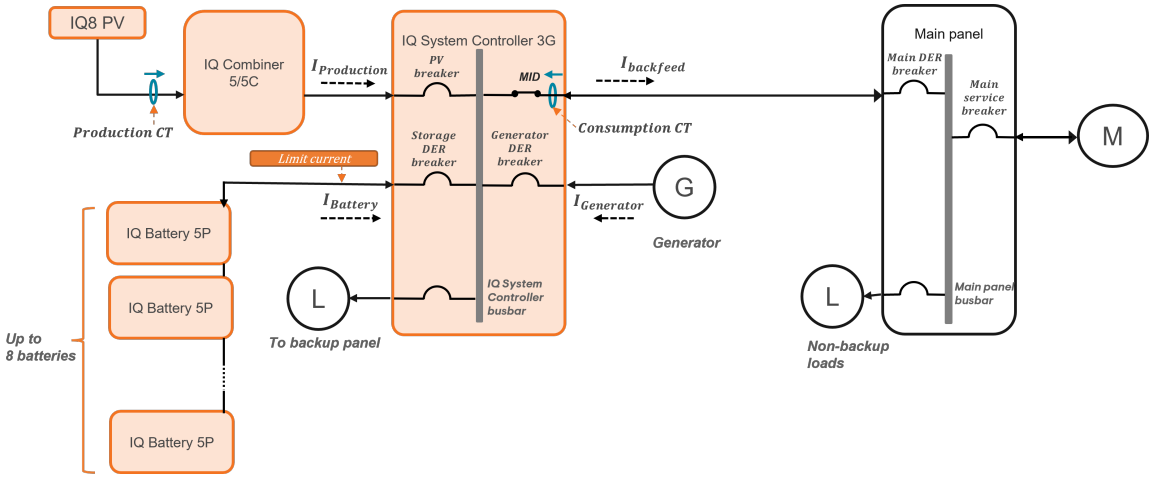


Figure 8: IQ Battery oversubscription with IQ System Controller 3G – supporting up to eight IQ Battery 5P units.

The IQ System Controller 3/3M 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 3/3M is shown in the following table, assuming that the breaker rating on each port is 80 A.

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	Maximum continuous current from port (A)	Maximum overload current from port (A)	IQ Battery oversubscription	Maximum continuous current from port (A)	Maximum overload current from port (A)	Maximum continuous current of the system (A)	Maximum overload current of the system (A)	Maximum energy of the system (kWH)
$N = N_1 + N_2$	N1	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

Figure 9: Optimal placement of the IQ Battery 5P(s) on two ports in IQ System Controller 3

The optimal placement shown in the preceding table 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.

5.1.3 Compliance with regulations

Per NFPA and NEC 2020 706.31 (B), the overprotection device rating shall not be less 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).

5.1.4 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.

5.1.5 Failure modes and resolution

The following table describes failure modes and corresponding resolutions:

Table 4: 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,

Failure mode	Resolution mechanism
	• When on-grid, IQ Battery 5P automatically falls into idle mode. That is, there is no charge or discharge. • When off-grid, IQ Battery 5P discharges up to the allowed safe limit current.

5.1.6 Configuration of IQ Battery oversubscription through 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 based Limiting** > **IQ Battery oversubscription check**.

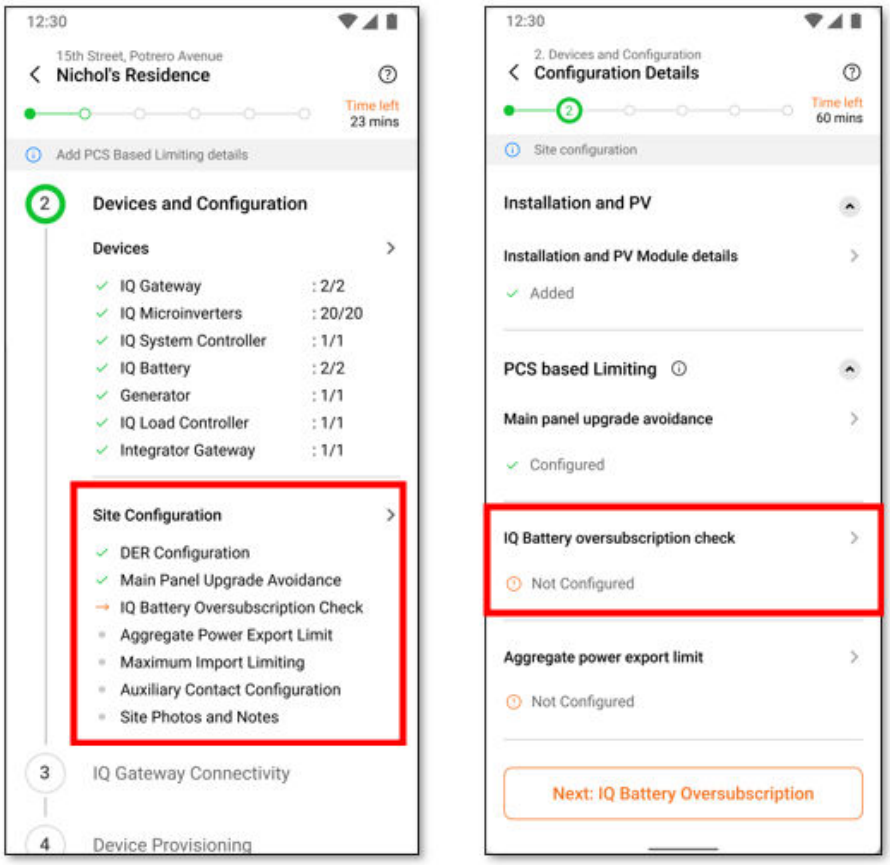


Figure 10: Enphase Power Control with IQ Battery oversubscription in Enphase Installer App

5.1.6.1 IQ Battery oversubscription configuration for grid-tied configuration

When configuring the IQ Battery oversubscription, as shown in the following figure, 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 an 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, the Enphase Installer App ensures that the maximum breaker rating for the two battery breaker slots is 80 A each.

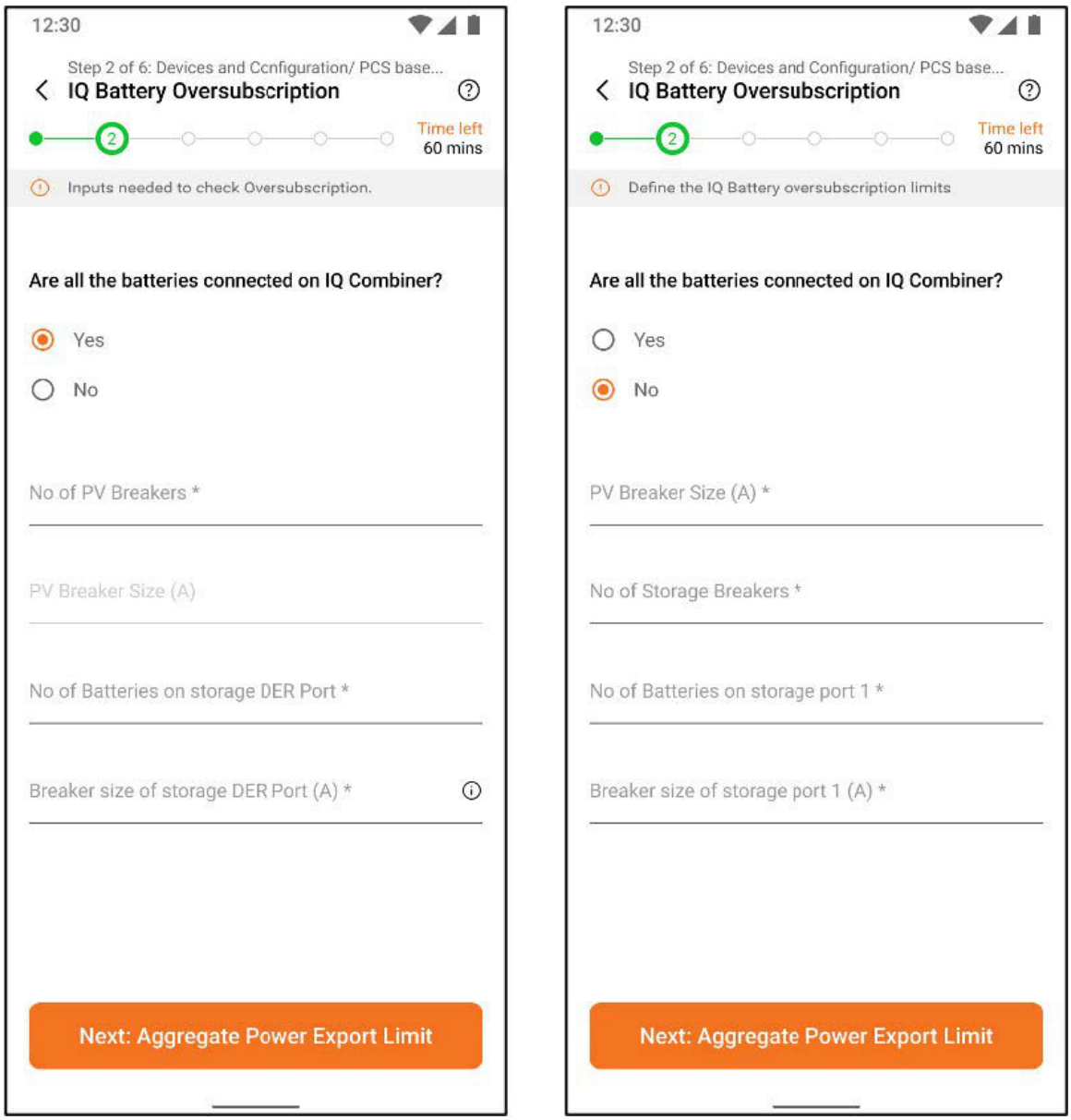


Figure 11: Configuration of IQ Battery oversubscription for grid-tied configuration in Enphase Installer App in IQ Combiner (left) and off-the-shelf subpanel (right)

5.1.6.2 IQ Battery oversubscription configuration for grid-forming configuration

The 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.

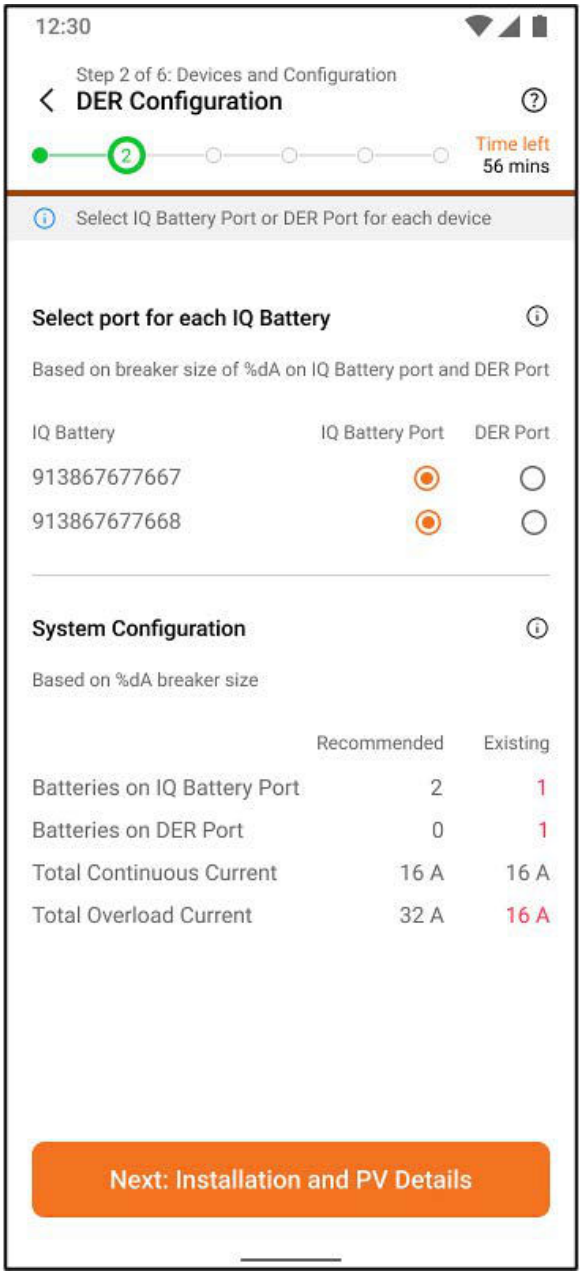


Figure 12: DER configuration

The system detects whether it requires IQ Battery 5P oversubscription based on the DER configuration step, as shown in Figure 10. When configuring IQ Battery oversubscription (as shown in the preceding figure), 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.

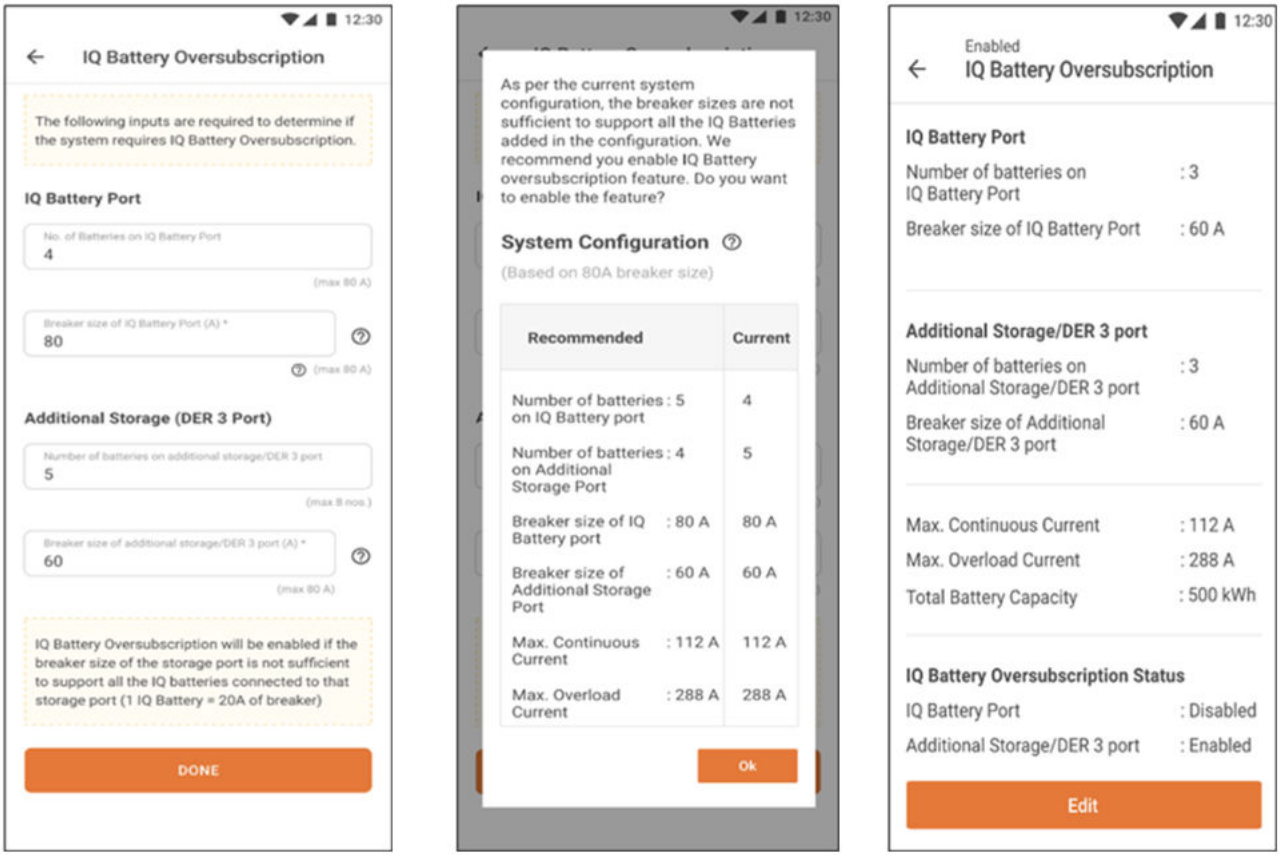


Figure 13: Configuration of IQ Battery oversubscription for grid-forming configuration

5.1.7 Configuration of IQ Battery oversubscription through 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 Based Limiting** > **IQ Battery Oversubscription**.

5.1.7.1 IQ Battery oversubscription configuration for grid-tied configuration

When configuring IQ Battery oversubscription in the Enphase Installer Portal, as shown in the following figure, 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.

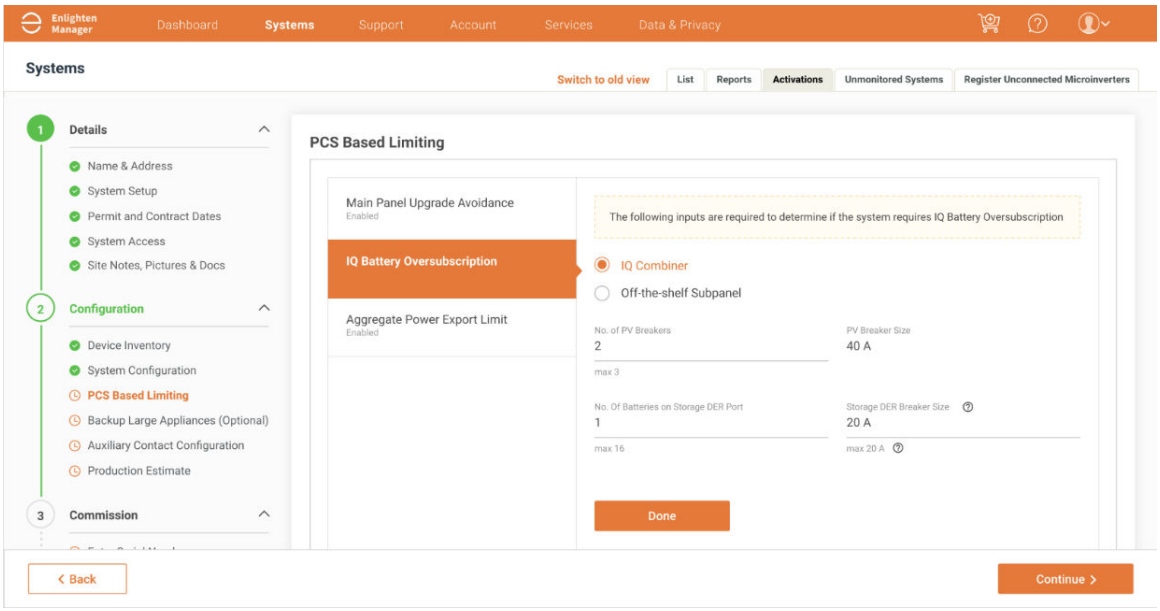


Figure 14: Configuration of IQ Battery oversubscription for grid-tied configuration

5.1.7.2 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 the following figure, the installer must input the number of IQ Battery 5P(s) and breaker sizes on each port. If the breaker sizes are insufficient to support the batteries, the Enphase Installer App prompts the installer to enable the IQ Battery oversubscription feature.

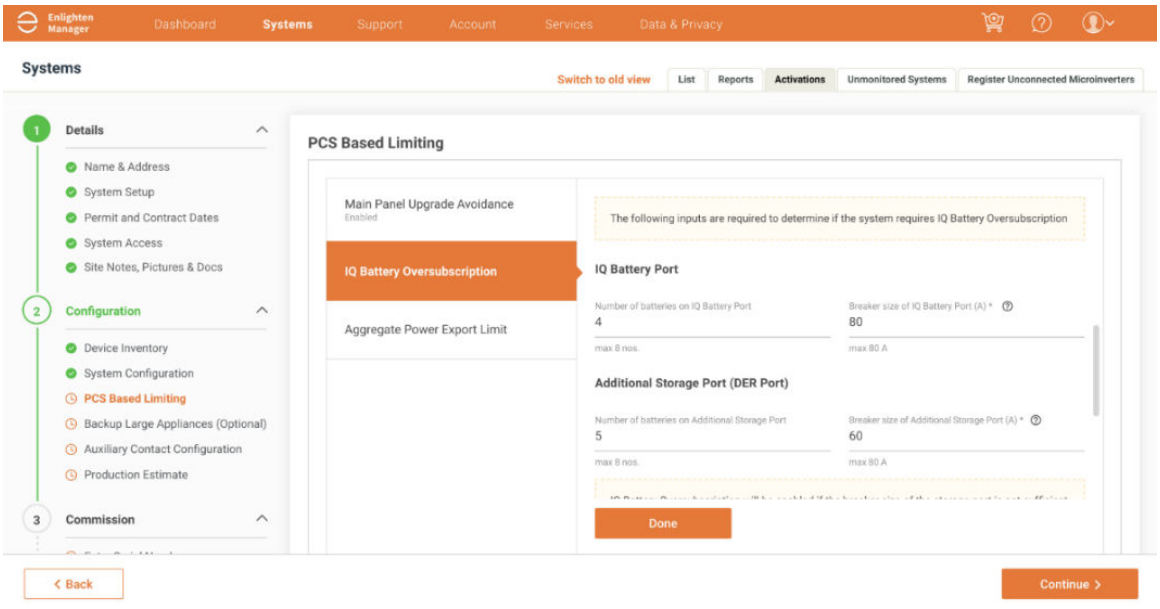


Figure 15: Configuration of IQ Battery oversubscription for grid-forming (IQ System Controller 3) in Enphase Installer App

5.2 Battery import/export-only mode for Enphase Energy System

Enphase IQ Batteries can operate either in the battery import-only mode or in the battery export-only mode.

5.2.1 Battery import-only mode

The import-only mode feature for IQ Battery 5P and IQ Battery 3T/10T/3/10 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. The IQ Battery 5P is also certified in this mode for 208 V_{AC} L-L/120 V_{AC} L-N

5.2.1.1 System sizing for battery import-only mode with IQ Battery 5P/10T/3T/10/3

Enphase Power Control with battery import-only mode 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 at the Consumption CTs never exceeds the PV production current, thus never exporting battery current past the Consumption CTs.

In the battery import-only mode, the Enphase Energy System does not export battery current past the Consumption CTs. Therefore, 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: Power Control System is covered in Article 705.13 of the NEC 2020 edition. Authorities Having Jurisdiction (AHJs) may not recognize the Power Control System feature until the 2020 NEC is adopted in their region.

5.2.1.2 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.

5.2.2 Battery export-only mode

Battery export is the only mode for IQ Battery 5P, and IQ Battery 3T/10T allows the Enphase IQ Battery to export to the grid. This feature is certified with any UL Listed PV inverters.

Homeowners can leverage this feature to lower their payback period on their solar plus battery systems as Enphase ensures that the IQ Battery stores the excess PV production and exports to the grid when it is most beneficial to the homeowner based on the import and export tariff rates.

5.2.2.1 System sizing for battery export-only mode with IQ Battery 5P/10T/3T

Enphase Power Control with Battery export-only mode ensures that the Enphase IQ Battery never imports from the grid. It is performed by ensuring that the battery charge current measured at the Battery CT is always less than the PV production current measured at the Production CT. Battery discharge is only ensured to obey other Power Control System features.

In Battery export-only mode, as Enphase Energy System exports battery current to the grid, the current from IQ Batteries must be accounted for when calculating the current exported to the grid by the system. However, the Battery export-only mode can be paired with other Enphase Power

Control features that allow for the installation of large Enphase solar plus battery systems without the need for main panel upgradation costs or additional labor costs if the Enphase system has an IQ8 Series Microinverter.

5.2.2.2 Open loop response time

The maximum open loop response time (OLRT) with battery export mode in the Enphase Energy System is less than two seconds.

5.2.3 Operation of battery import/export-only mode with other Enphase Power Control features

Battery import/export-only mode works in conjunction with other Enphase Power Control features— IQ Battery oversubscription, MPU avoidance, and Aggregate Power Export Limit. Enphase Energy System ensures that the power control limits set with respect to the other features are adhered to when the battery export or import-only modes are enabled.

5.2.4 Configuring battery import/export-only mode through the Enphase Installer App

Installers can configure battery import/export-only mode through their Enphase Installer App (EIA) during installation.

System Details Site Configuration (Additional) Battery mode, as shown in the following figure. The installer can select the battery mode as **Import Only** or **Export Only** until the battery mode selection expires in seven days, starting from the selection of the tariff structure.

The selection of mode is not possible in the Enphase Installer App if seven days have elapsed after the selection of the tariff structure.

NOTE: Battery export-only mode is currently only available in jurisdictions with Net Energy Metering 3.0 (NEM 3.0). In jurisdictions other than NEM 3.0, the battery mode is set to battery import-only mode by default.

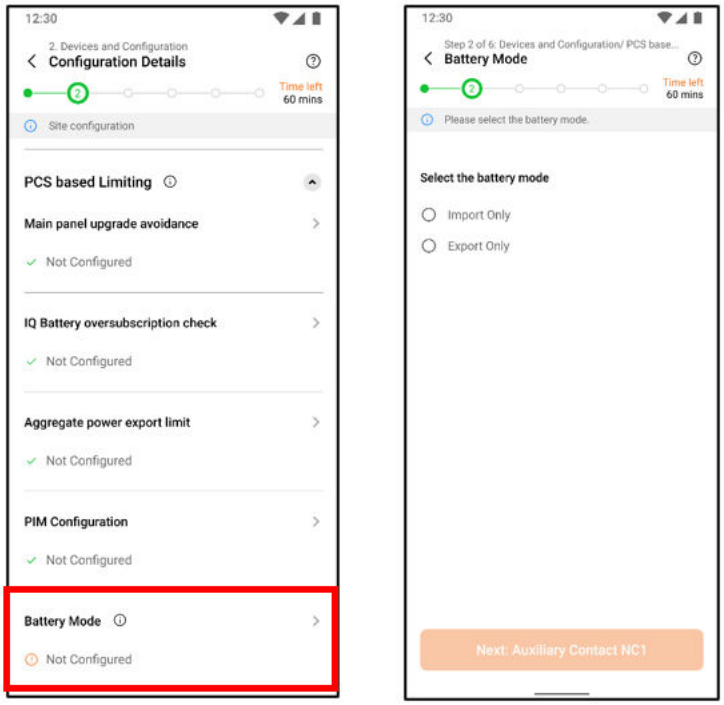


Figure 16: Battery import/export-only configuration in Enphase Installer App

NOTE: If the battery mode needs to be changed after the selection has expired in the Enphase Installer App, contact Enphase Support. The Battery mode can only be changed based on the validity of the claim.

5.3 MPU avoidance

MPU avoidance with busbar overload control: Allows maximum renewable energy generation and helps avoid the cost of panel upgrade for a large PV and battery system under National Electric Code (NEC) 2020 705.13, reducing the system payback period.

MPU avoidance with feeder control: Enables avoiding the cost of a panel upgrade for a large PV and battery system by controlling the backfeed current into the main panel as per National Electric Code (NEC) 2020 705.12.

The feature ensures that the backfeed current allowed into the main panel is limited as per the configuration provided by the installer for both grid-tied and grid-forming configurations.

The MPU avoidance feature can be configured using the below three options:

1. Using busbar overload control
2. With feeder control (using the NEC 120% rule)
3. With feeder control (using the current limit directly entered)

5.3.1 Compliance with regulations

5.3.1.1 Compliance of MPU avoidance busbar overload control with NEC 2020 705.13

Per the National Electric Code (NEC) 2020 705.13 (A) through (E), the Enphase Power Control feature, MPU avoidance with busbar overload control, controls the backfeed from the Enphase PV

and IQ Battery 5P such that the sum of the backfeed current from the DERs and the current being drawn from the grid is equal to or less than the rating or the ampacity of the busbar.

5.3.1.2 Compliance of MPU avoidance with feeder control using NEC 120% rule or current limit directly entered 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 or continuous current from DERs allowed ≤((120% of busbar rating) – ampacity of the overcurrent protection device protecting the busbar)/125%.

NOTE: The NEC 2020 705.12 section also contains other articles (such as the sum of breakers) that may be used to determine the backfeed limit, however using the above calculation is the most common. Later in this document, this rule may be referred to as the NEC 120% rule.

5.3.2 MPU avoidance using busbar overload control

When the option to use MPU avoidance using busbar overload control is selected, the feature continuously monitors the production current ($I_{production}$), battery current ($I_{battery}$), and current entering the main panel from the grid using Production CT, Battery CT, and Consumption CTs respectively. It then limits the current from PV ($I_{production}$) and current from the battery ($I_{battery}$) in real time such that the total current entering the busbar does not exceed the busbar ampacity.

NOTE: This mode does not require Consumption CT relocation for grid-forming systems thereby ensuring whole home consumption monitoring. This mode eliminates the need to use NEC120% or the current limit directly entered.

The diagram for MPU avoidance with busbar overload control in the grid-tied configuration is shown in the following figure.

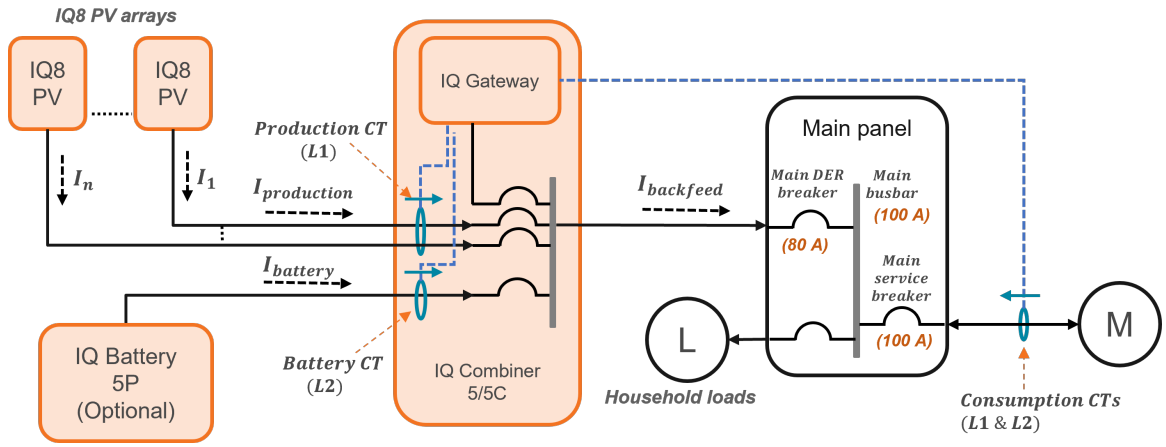
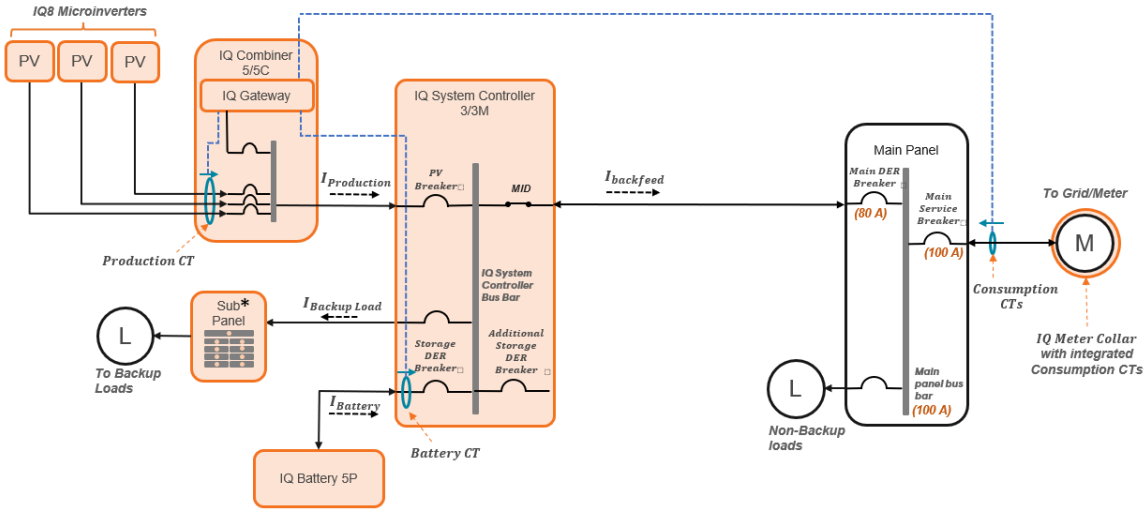


Figure 17: MPU avoidance using busbar overload control in the grid-tied configuration

The following figure shows the diagram for MPU avoidance with busbar overload control in the grid-forming configuration.



* Not present when using 3M + IQ Meter Collar

Figure 18: MPU avoidance using busbar overload control in the grid-forming configuration

NOTE: For MPU avoidance with busbar overload control in the grid-forming configuration, the Consumption CTs must be placed between the main panel and the grid.

5.3.2.1 System sizing for MPU avoidance with a busbar overload control

With the MPU avoidance option, busbar overload control, the maximum allowed main DER breaker size (backfeed breaker size) is given by:

The lower rating of the main service breaker in Amperes, 80% of the main panel busbar rating in Amperes, 150 A.

NOTE: For MPU avoidance with busbar overload control, the maximum main DER breaker size (backfeed breaker size) is limited to 150 A.

For example, as seen in Figure 17: MPU avoidance using busbar overload control in the grid-tied configuration on page 29 and Figure 18: MPU avoidance using busbar overload control in the grid-forming configuration on page 30, if the main load panel busbar size is 100 A and the grid-side main service breaker size is also 100 A, the maximum continuous current backfeed allowable from the IQ Combiner to the main panel is limited to:

Min (100 A, 80% of 100 A, 150 A) = 80 A

Therefore, in this scenario, the main DER breaker can be sized up to 80 A. The system ensures that the production and battery current is limited such that the current in the busbar never exceeds 100 A by monitoring the Production CT, Battery CT, and Consumption CTs.

5.3.3 MPU Avoidance with Feeder control (using NEC 120% or current limit directly entered)

5.3.3.1 In grid-tied configuration

When selecting the option to use MPU avoidance using the NEC 120% rule or current limit directly entered in grid-tied configuration, the feature continuously monitors the power being produced cumulatively by the installed PV array and the IQ Battery using Production CT and Battery CT,

respectively. It then limits the produced power in real time based on the current limit imposed by the NEC 120% rule. The following figure shows this grid-tied configuration feature.

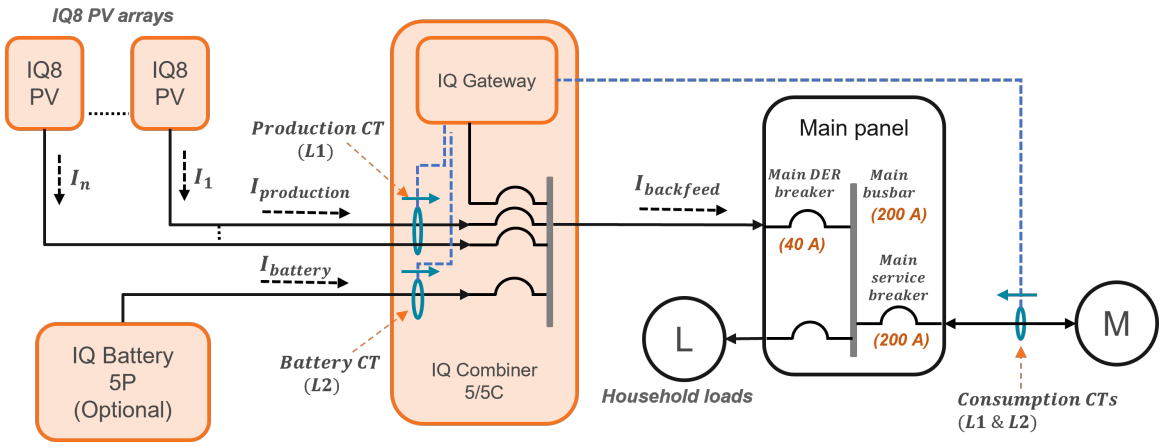


Figure 19: MPU avoidance in the grid-tied configuration

NOTE: The preceding figure shows an example with IQ Combiner 5/5C. MPU avoidance in the grid-tied configuration with IQ Battery 3T/10T and IQ Combiner 4/4C is shown in Figure 44: MPU avoidance in grid-tied configuration with IQ Combiner 4/4C on page 54. Connecting a Battery CT in IQ Combiner 4/4C or standalone IQ Gateway requires connecting a jumper wire between the L2 and L3 terminals of IQ Gateway. Refer to the IQ Battery metering section in the Guidelines for Current Transformer (CT) installation tech brief for instructions on connecting the Battery CT on IQ Combiner 4/4C or standalone IQ Gateway.

In Figure 19: MPU avoidance in the grid-tied configuration on page 31, both Production CT and Battery CT are monitored, and the battery discharge is controlled first, followed by the PV production current to limit $I_{backfeed}$ entering the main DER breaker in the main panel. The main DER breaker must be sized to the PCS limit as per NEC 2020 705.13 (C).

System sizing for MPU avoidance with NEC 120% rule and with current limit directly entered in a grid-tied system

For example, as seen in Figure 19: MPU avoidance in the grid-tied configuration on page 31, 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, $I_{production}$, is limited to:

((120% * busbar rating) – Main service breaker size)/125% = total DER current

((120% * 200)-200)/125% = 32 A

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 and the Battery CT placed inside the IQ Combiner will monitor the current being backfed into the main panel in real time and feed this information to the IQ Gateway. If the current being backfed to the main panel increases beyond 32 A, the IQ Gateway sends a signal to PV microinverters and the battery to limit their production and discharge, respectively.

NOTE: The PV branch breakers in the IQ Combiner cannot be oversubscribed and must be sized to the nameplate of the PV on the respective branches.

MPU avoidance in grid-tied configuration supports a maximum PV nameplate rated output of 64 A and a maximum battery nameplate output (to limit per-phase backfeed levels to the main panel) of 64 A.

Operation with IQ Battery oversubscription

In systems with IQ Battery 5P, MPU avoidance in grid-tied configuration works in conjunction with IQ Battery oversubscription.

For example, in Figure 19: MPU avoidance in the grid-tied configuration on page 31, the $I_{backfeed}$ allowed is 32 A. If $I_{production}$ is 0 A, the maximum allowed $I_{battery}$ is 32 A. However, consider a scenario in Figure 19: MPU avoidance in the grid-tied configuration on page 31 where IQ Battery oversubscription is enabled with the Battery breaker on IQ Combiner as 20 A. $I_{backfeed}$ allowed remains 32 A, but if $I_{production}$ is 0 A, the maximum allowed $I_{battery}$ is 16 A.

5.3.3.2 In grid-forming configuration

MPU avoidance in grid-forming configuration, when the option for NEC 120% rule or the current limit directly entered is selected, supports two configurations depending on the locations of Consumption CTs.

- Figure 20: MPU avoidance in grid-forming configuration, Consumption CTs placed between the main panel and utility meter on page 32 shows the default configuration, where the Consumption CTs are placed between the main panel and the utility meter. The system continuously monitors the production current from the PV using Production CT and the discharge current from the battery using Battery CT and curtails them in real-time to ensure that the back-fed current does not exceed the limit imposed by the NEC 120% rule. As a result, homeowners can avoid the expensive upgrade of the main panel.
- In the second configuration, as shown in Figure 21: MPU avoidance in grid-forming configuration, Consumption CTs placed between IQ System Controller and main panel on page 33, the Consumption CTs are placed between the System Controller and the main panel (refer to the section Installation of the Production, Battery, and Consumption Current Transformers CT(s) in grid-forming configuration on page 12). The system continuously monitors the back-fed current at the Consumption CTs location and curtails them in real time to ensure that the back-fed current does not exceed the limit imposed by the NEC 120% rule.

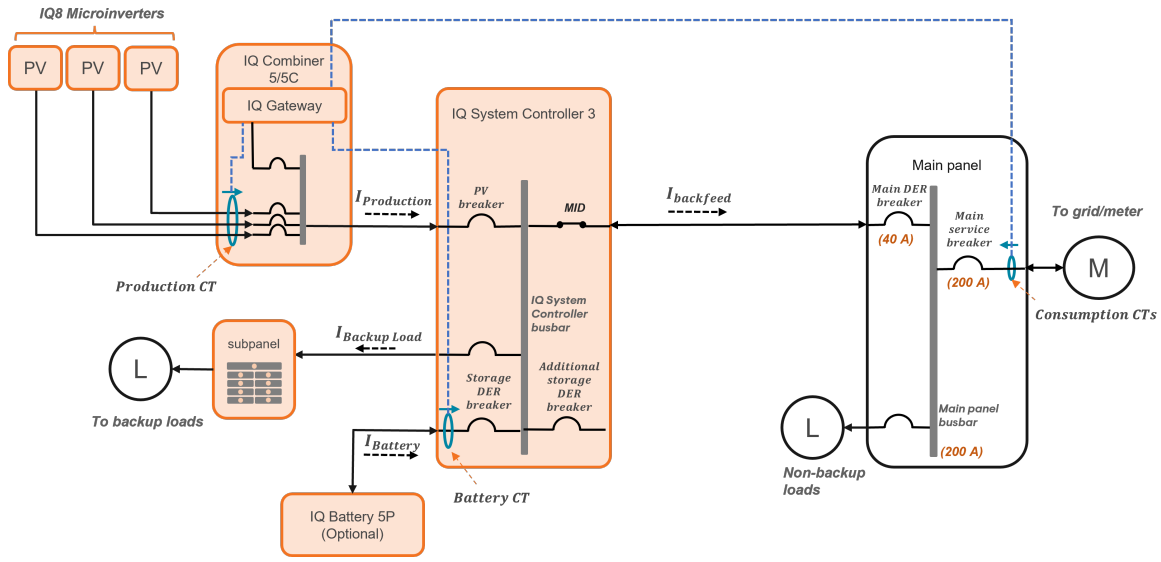


Figure 20: MPU avoidance in grid-forming configuration, Consumption CTs placed between the main panel and utility meter

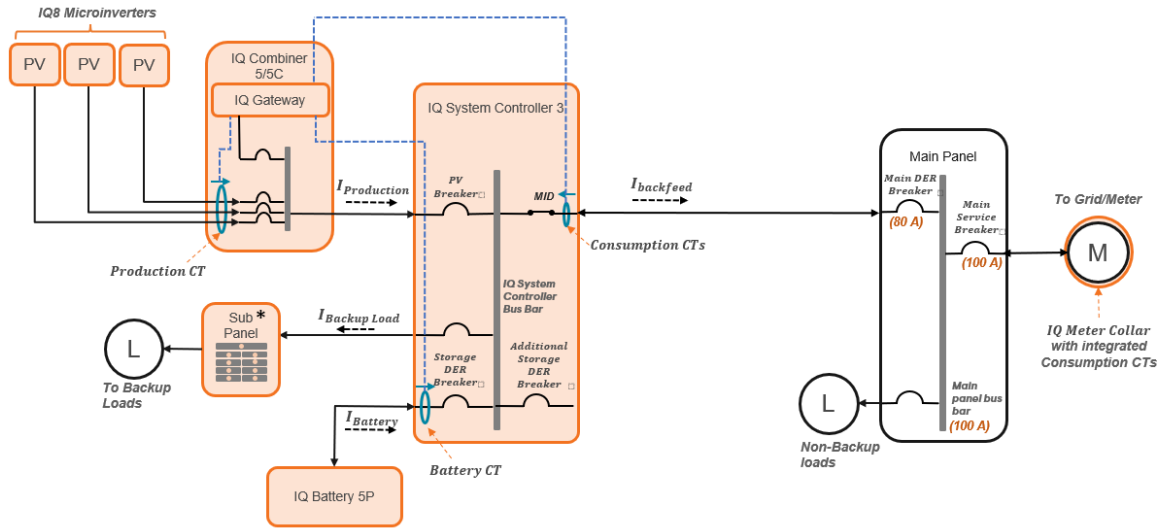


Figure 21: MPU avoidance in grid-forming configuration, Consumption CTs placed between IQ System Controller and main panel

NOTE: The grid-forming configuration can also have an IQ System Controller 3M with a meter collar, but for MPU Avoidance without busbar overload control; this meter reading is unused.

In the configuration shown in Figure 20: MPU avoidance in grid-forming configuration, Consumption CTs placed between the main panel and utility meter on page 32 and Figure 21: MPU avoidance in grid-forming configuration, Consumption CTs placed between IQ System Controller and main panel on page 33, the back-fed current ($I_{backfeed}$) to the main panel is monitored by the System using the appropriate CTs. The current produced by the PV system ($I_{production}$) and the current discharged by the battery ($I_{battery}$) are controlled appropriately to keep the $I_{backfeed}$ level adhered to the NEC 120% limit.

System sizing with MPU avoidance using the NEC 120% rule or using the current limit directly entered in the grid-forming system

For example, as seen in Figure 20: MPU avoidance in grid-forming configuration, Consumption CTs placed between the main panel and utility meter on page 32, 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% * busbar rating) - main breaker size)/125% = total DER current ((120% * 200)-200)/125% = 32 A

Therefore, in this scenario, the system ensures that no more than 32 A of continuous current is backfed to the main panel.

NOTE: The PV breaker in the IQ System Controller cannot be oversized and must be sized to the PV nameplate rating.

It is recommended 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. Further, in the presence of a battery, more PVs can be installed 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 must 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.

5.3.4 Failure mode and resolution for MPU avoidance

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

Table 5: Failure mode and solution mechanism

Failure mode	Resolution mechanism
Production, Battery, or Consumption CTs not reporting correct value/ missing	PV production current and IQ Battery current will be curtailed to a safe limit
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 with the microinverter for more than 10 seconds, 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

5.3.5 Configuring MPU avoidance through the Enphase Installer App

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

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

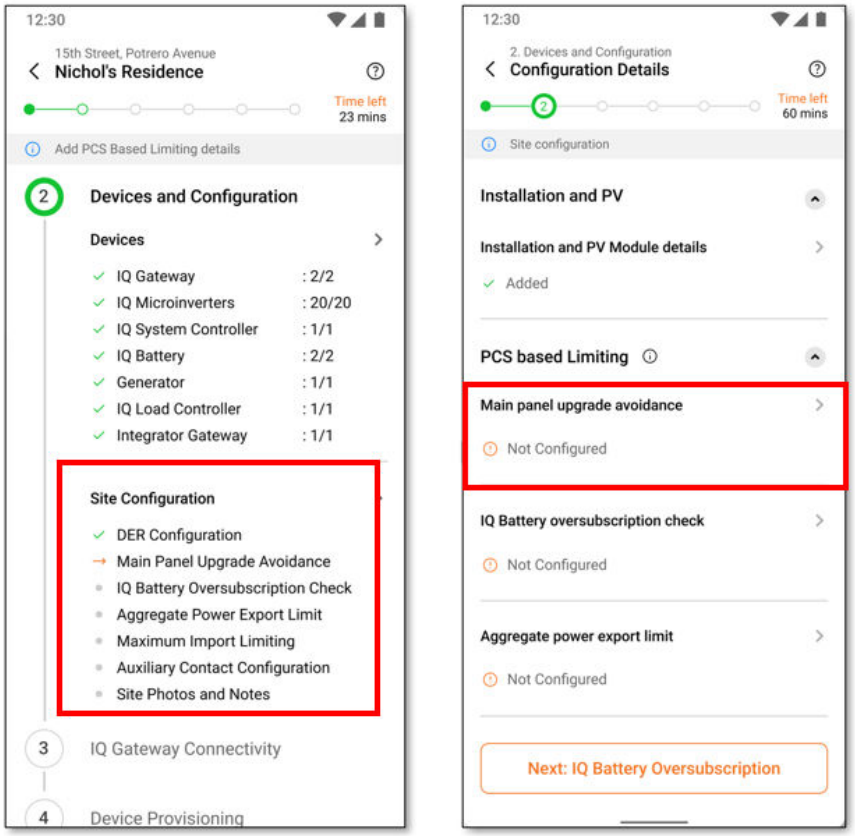


Figure 22: MPU avoidance in the site configuration

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** > **Home Backup** > **Partial**. Once this is done, the installer can move to the **PCS based Limiting** section.

NOTE: For MPU avoidance with busbar overload control, Consumption CTs must be placed between the main panel and the utility meter. For MPU avoidance with feeder control (using NEC 120% or the current limit directly entered), Consumption CTs can be placed in either of two locations.

NOTE: For generator integration, Consumption CTs must be placed between the IQ System Controller and the main panel.

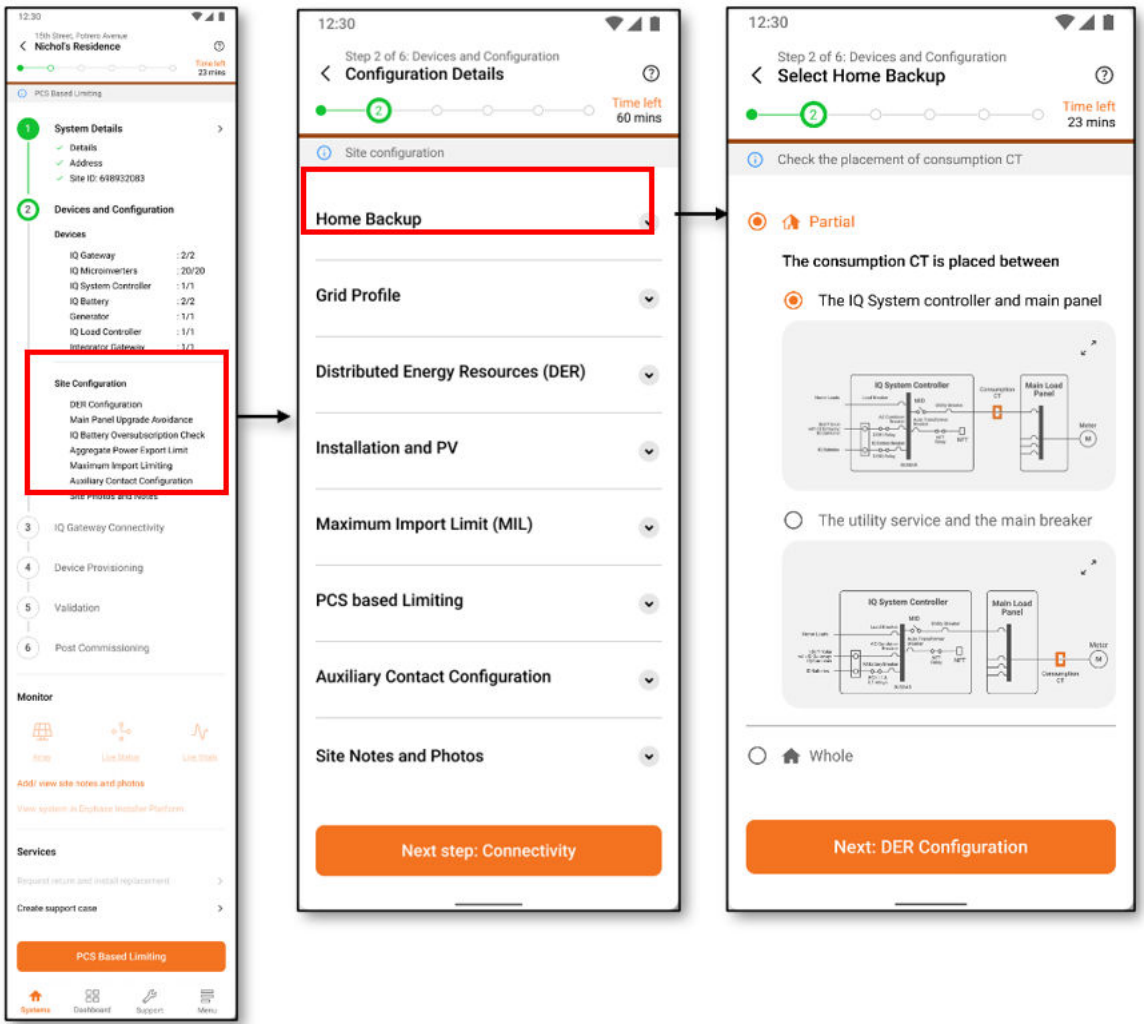


Figure 23: Partial backup configuration in site configuration in the grid-forming configuration

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

- Busbar overload control: In this option, the installer adds information on the rating of the main load panel, the main service breaker, and the main DER breaker. The system utilizes these inputs to configure the busbar overload current feature, complaint with 2020 NEC 705.13 (A) through (E).
- 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.
- 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 the Enphase Power Control feature. This could be a DER from another manufacturer or Enphase's legacy microinverters. In either case, the installer needs to account for the current being backfed 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.

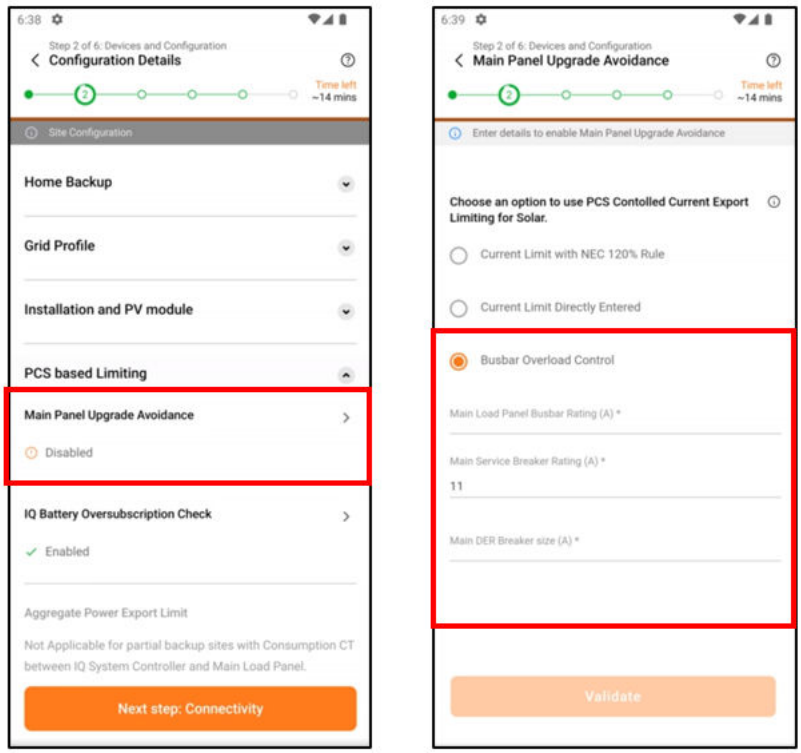


Figure 24: MPU avoidance configuration with busbar overload control

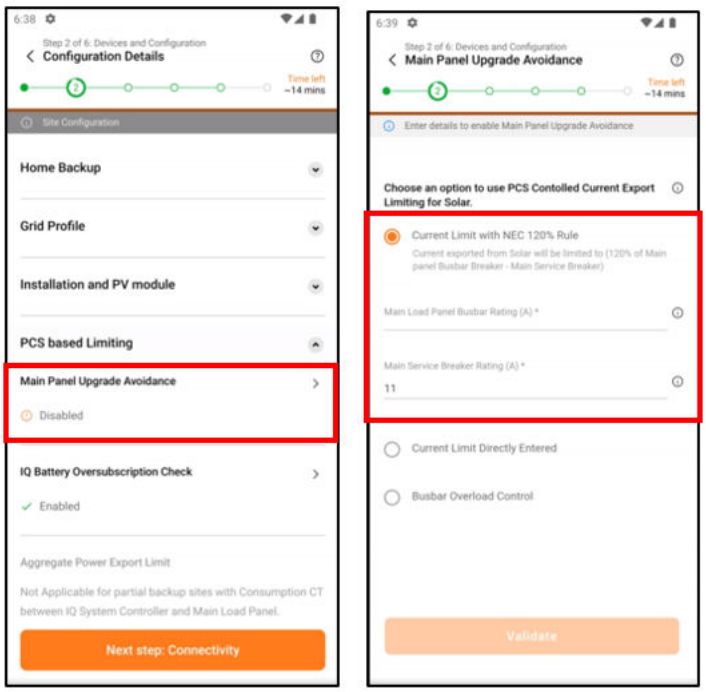


Figure 25: MPU avoidance configuration with NEC 120% rule

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 the Enphase Installer App. 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 NEC 120% rule. As shown in Figure 26: MPU avoidance configuration using direct current limit input on page 38, the installer can directly set the PCS export current limit based on their discretion with this option.

NOTE: For safety, the current limit directly entered parameter must still comply with NEC 705.12 rules to keep the main panel within safe limits. See busbar overload control if you need to increase the backfeed current limit.

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 the Enphase Energy System to 16 A, that is, 32 A–16 A using the current limit directly entered parameter in Enphase Installer App.

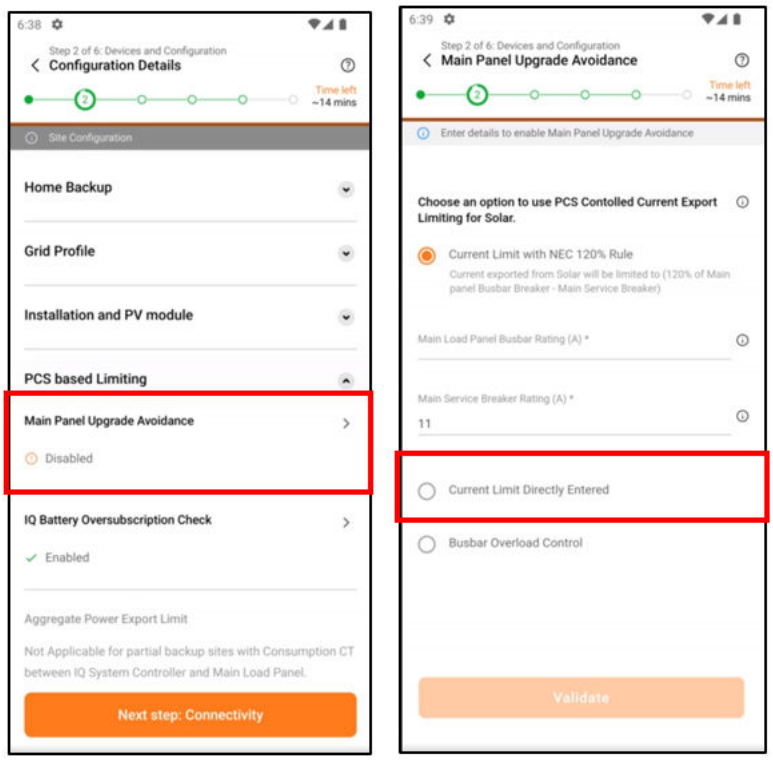


Figure 26: MPU avoidance configuration using direct current limit input

The Enphase Power Control feature does not start functioning until the meters are enabled and the site is commissioned in the Enphase Installer App. If the main DER breaker has the risk of tripping before the commissioning has finished, turn off the breakers on 1 or 2 PV branches while enabling the main panel upgrade avoidance feature and turn the PV breakers back on after successful commissioning.

NOTE: When setting up the storage meter with IQ Battery 3T/10T during commissioning with the Enphase Installer App as per the steps provided in the section Setting up Enphase Power Control on page 12, if the IQ Battery 3T/10T (s) is not charging/discharging at the required power for storage meter validation, reset the DC switch on the IQ Battery 3T/10T (s) batteries and retry.

5.3.6 Configuring MPU avoidance through the 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**.

The following figure shows the configuration screen of the Enphase Power Control feature in the Enphase Installer Portal.

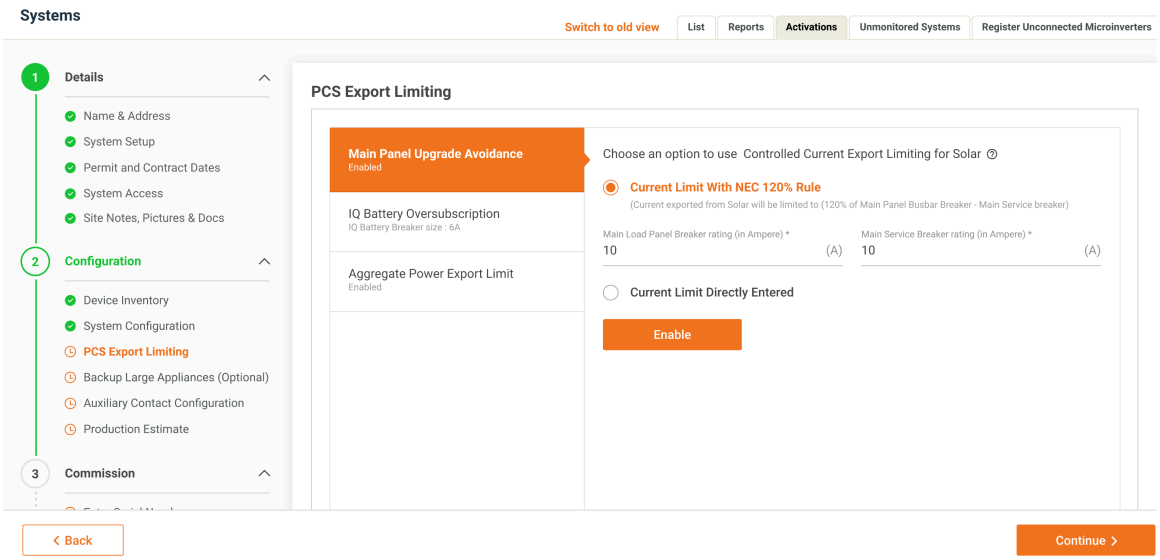


Figure 27: Enphase Power Control feature-MPU avoidance configuration in Enphase Installer Portal

5.3.7 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. 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.

5.3.7.1 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.

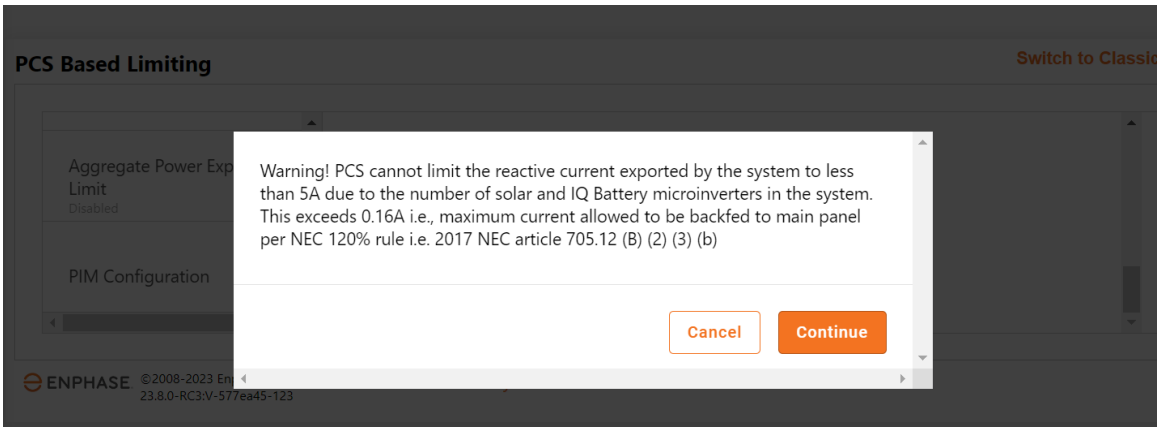


Figure 28: Warning pop-up for MPU avoidance configuration using the NEC 120% rule

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.

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

We must 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.

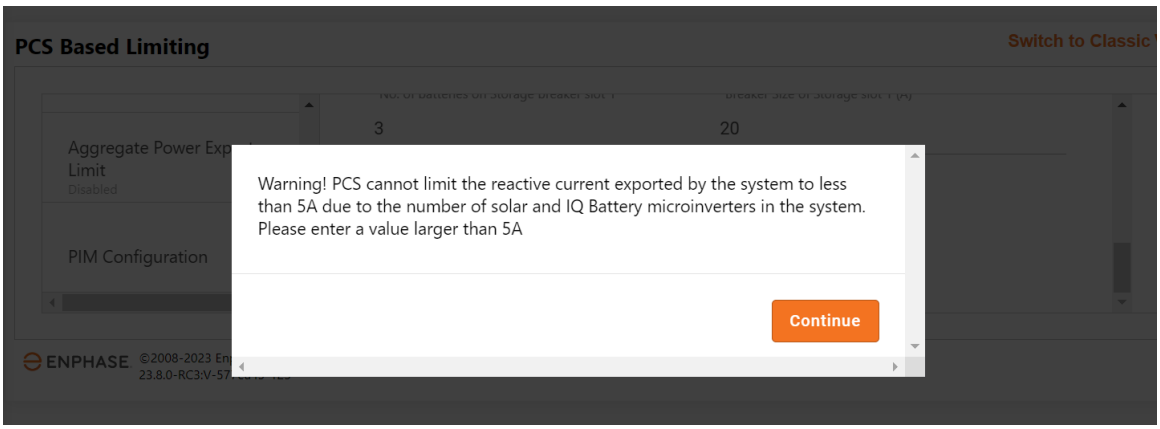


Figure 29: Warning pop-up for MPU avoidance configuration using direct current limit input

5.4 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, that is, at the Consumption CTs, and controls the power produced from the PV system to keep the exported power below the limit set by the installer.

The maximum open loop response time of the aggregate power export limit feature is two seconds for a maximum PV capacity of 80 A and battery capacity of 80 A simultaneously.

Aggregate power export limit can be supported in two configurations: grid-tied configuration (Solar + Battery or Solar only) and grid-forming configuration (Solar + Battery or Solar only). For all supported SKUs with aggregate power export limit, refer to Table 2.

5.4.1 Aggregate power export limit in the grid-tied configuration

The following figure shows the aggregate power export limit in grid-tied and grid-forming configurations, respectively.

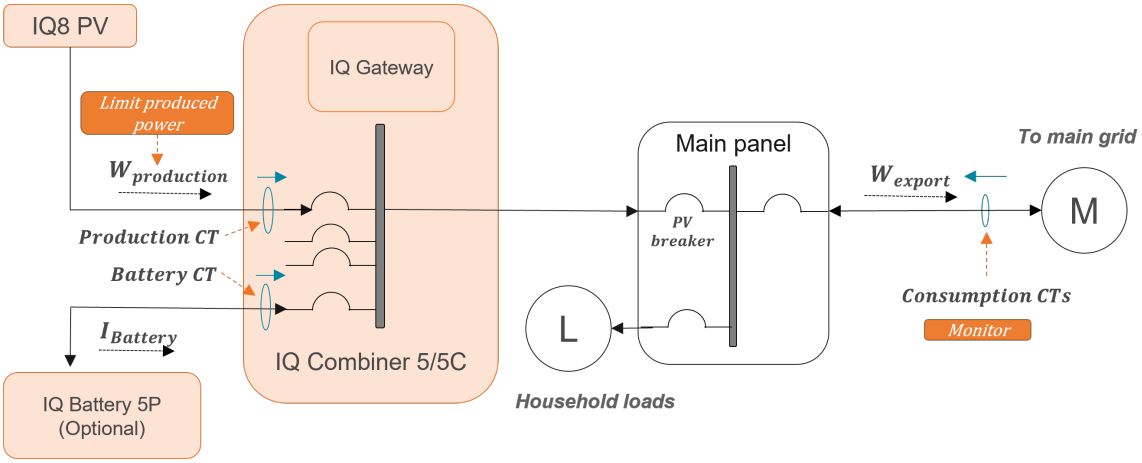


Figure 30: Aggregate power export limit in the grid-tied configuration

In the configuration shown in the Aggregate power export limit in the grid-forming configuration on page 41, the aggregate export power (W_{export}) to the utility grid is monitored through the Consumption CTs are 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.

5.4.2 Aggregate power export limit in the grid-forming configuration

In the configuration shown in Figure 31: Aggregate power export limit in grid-forming configuration, Consumption CTs placed between the main service breaker and the meter on page 42, the aggregate export power (W_{export}) to the utility grid is monitored by the Consumption CTs 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.

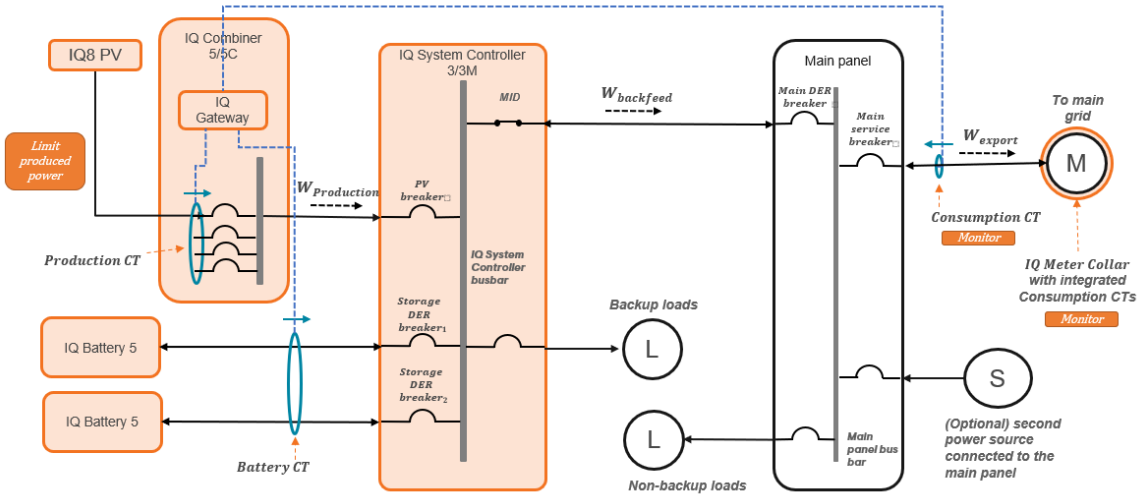


Figure 31: Aggregate power export limit in grid-forming configuration, Consumption CTs placed between the main service breaker and the meter

5.4.3 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: 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.

5.4.4 Failure modes and resolution

Table 6: 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 CTs not reporting the correct value or missing Consumption CTs	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

Failure mode	Resolution mechanism
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

5.4.5 Configuring aggregate power export limit feature through the Enphase Installer App

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 the following figure, the installer must input the **Aggregate Power Export Limit (W)** and press the **Next** button to enable the feature.

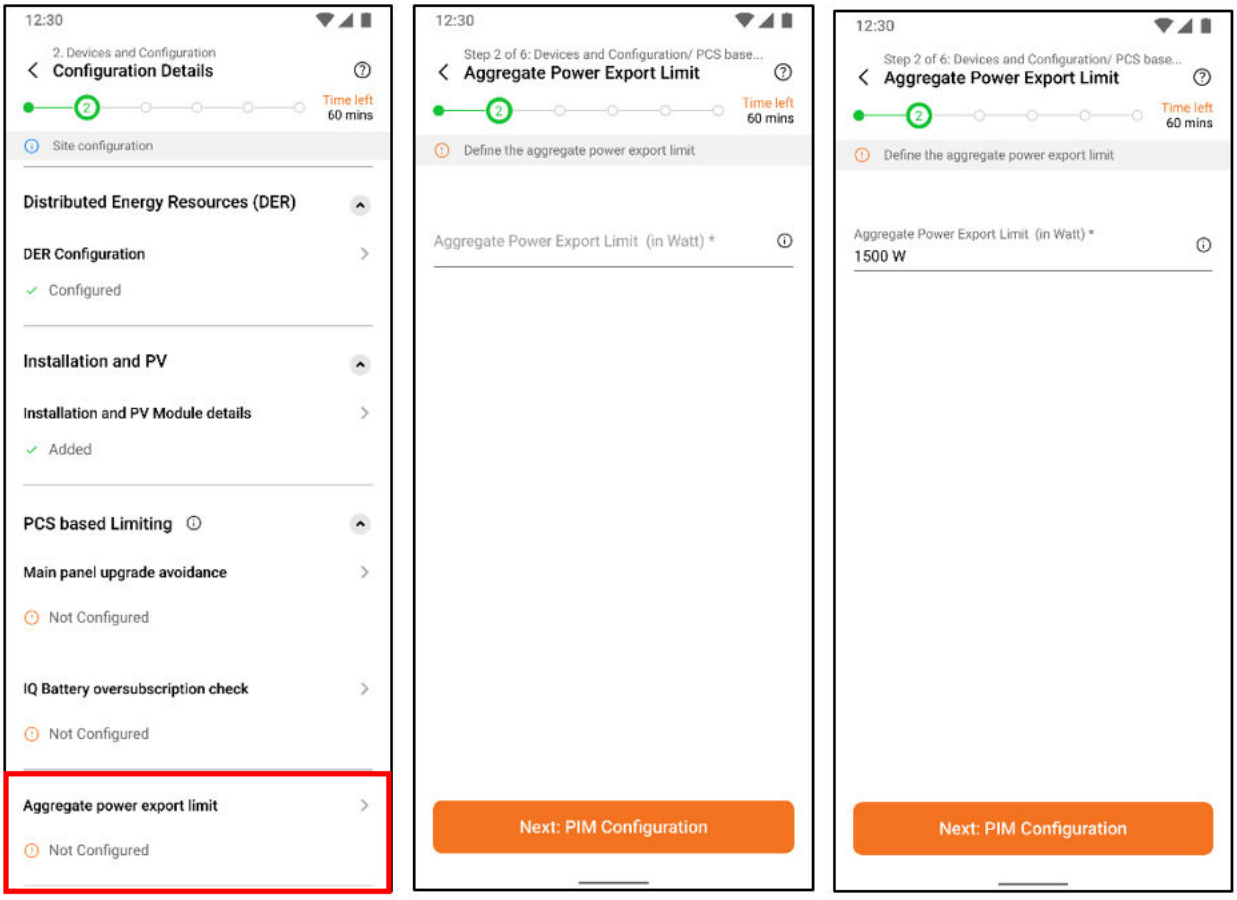


Figure 32: Aggregate Power Export Limit configuration

5.4.6 Configuring aggregate PEL feature through the 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 Based Limiting** > **Aggregate Power Export Limit** > **Enable**

The following figure shows the configuration screen of the Enphase Power Control feature in the preceding location.

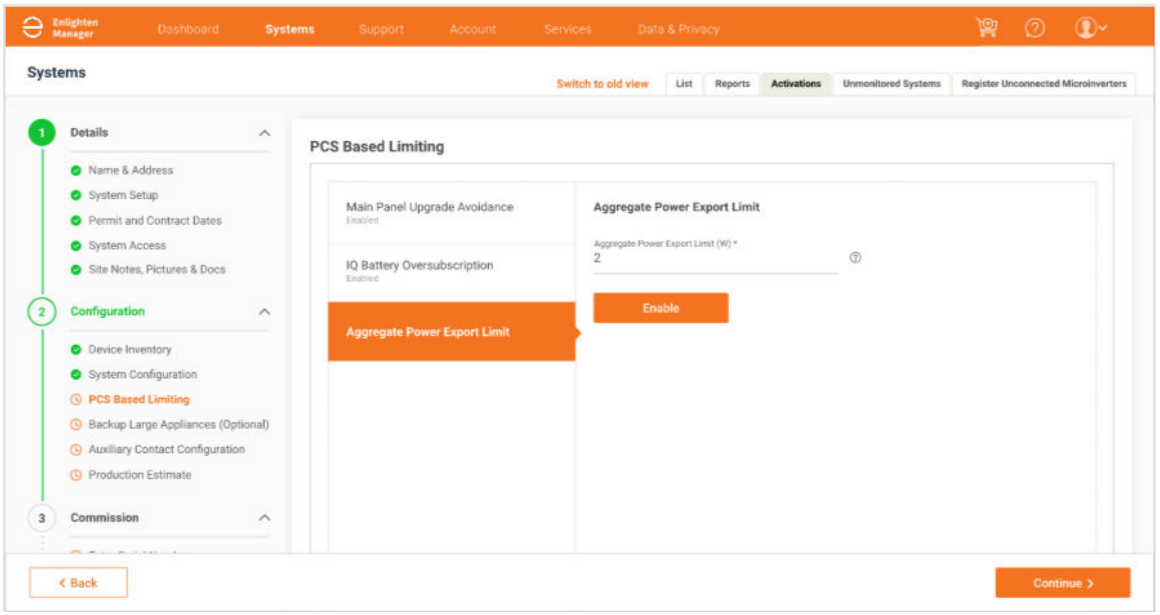


Figure 33: Aggregate power export limit in Enphase Installer Portal

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.

5.5 IQ EVSE main breaker trip avoidance (MBTA)

The IQ EVSE MBTA feature continuously monitors the total import current, I_{import} from the grid at the Consumption CTs location, and controls the IQ EV Charger charge current, I_{EV} current, to ensure that I_{import} does not exceed the main service breaker rating configured by the installer. This feature provides flexibility to the installers during load calculations to install the IQ EV Chargers without needing to upgrade the main panel.

NOTE: Refer to the *IQ EV Charger Installation technical brief* in the Enphase documentation center for more details.

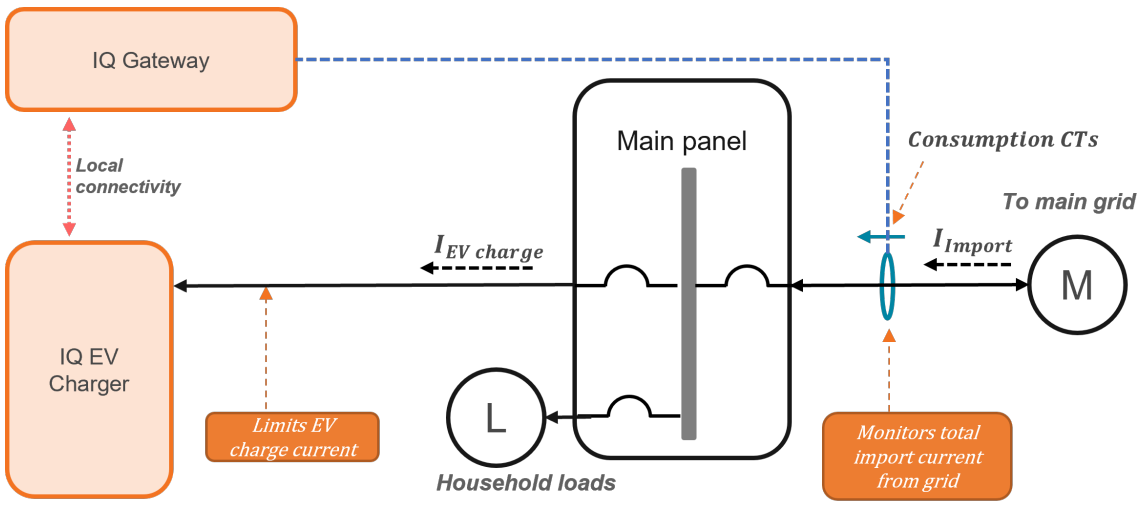


Figure 34: IQ EVSE MBTA in Enphase Energy System

5.5.1 Compliance with regulations

IQ EVSE MBTA complies with UL 3141 Outline of Investigation for Power Control Systems. As per UL 3141 Load Control PCS (PCS-LC), Enphase Power Control feature, the IQ EVSE MBTA is designed to provide current limiting for main service breaker overload control via load control of Power Control System controlled loads (IQ EV Charger).

5.5.2 System sizing

To understand where IQ EVSE MBTA can be utilized, consider an example of a home with a 100 A utility service.

Case 1

If the total load from all the appliances in the home is 22,000 VA. Perform the following steps for load calculation as per NEC 2020, Section 220.83:

1. Calculate the total existing load at home = 22,000 VA
2. Calculate the load by IQ EVSE (for example, with 40A IQ EVSE) = 240 V × 40 A = 9,600 VA
3. Calculate the following:
   - Perform load calculation as per NEC 2020, Section 220.83:
     - Add First 8 kVA at 100% = 8,000 VA
     - Add the rest of the load at 40% = (22,000–8,000) * 40% VA = 5600 VA
     - Add IQ EVSE at 100% = 9,600 VA
   - Calculated load as per 220.83 = (8000 + 5600 + 9600) VA = 23,200 VA
   - Calculated load in Amperes = 23,200 VA/240 V = 96.667 A
4. Is the existing service capable?
   - Calculated load (96.667 A) < Service rating (100 A)
   - IQ EVSE will not require a service upgrade. IQ EVSE MBTA need not be configured

Case 2

If the total load from all the appliances in the home is 26,000 VA. The load calculation as per NEC 2020, Section 220.83 is done as follows:

1. Calculate the total existing load at home = 26,000 VA
2. Calculate the load by IQ EVSE (for example, with 40A IQ EVSE) = 240 V × 40 A = 9,600 VA
3. Calculate the following:
   - Perform load calculation as per NEC 2020, Section 220.83:
     - Add First 8 kVA at 100% = 8,000 VA
     - Add the rest of the load at 40% = (26,000–8,000) * 40% VA = 7,200 VA
     - Add IQ EVSE at 100% = 9,600 VA
   - Calculated load as per 220.83 = (8000 + 7200 + 9600) VA = 24,800 VA
   - Calculated load in Amperes = 24,800 VA/240 V = 103.33 A
4. Is the existing service capable?
   - Calculated load (103.33 A) > Service rating (100 A)
   - IQ EVSE will require a service upgrade. IQ EVSE MBTA can be configured to avoid a service upgrade

5.5.3 Failure modes and resolution

Table 7: Failure modes and resolution

Failure mode	Resolution mechanism
Loss of local connectivity between IQ EV Charger and IQ Gateway.	IQ EV Charger limits the charge of the EV to 25% of its total capacity.
PCS controller or IQ Gateway failure.	IQ EV Charger limits the charge of the EV to 25% of its total capacity.

5.5.4 Configuring IQ EVSE MBTA through the Enphase Installer App

During installation, the installer can enable this feature in the Enphase Installer App during site configuration.

In the case of a grid-forming system, an additional pre-requisite step to choose the **home backup type** is required. If the home backup type is a partial home backup, the Consumption CTs must be placed between the utility service and the main breaker, as shown in Figure 23: Partial backup configuration in site configuration in the grid-forming configuration on page 36.

Select **Configuration details** > **Home backup type** > **Select Whole home backup/Partial home backup** with the Consumption CTs placed between the utility service and the main breaker.

The installer can navigate to the feature as shown:

Configuration details > **PCS based Limiting** > **Main Breaker Trip Avoidance**

On the Configuration screen for the feature, as shown in the installer must input the **Main Service Breaker Rating** in Amperes and press the **Enable** button to enable the feature.

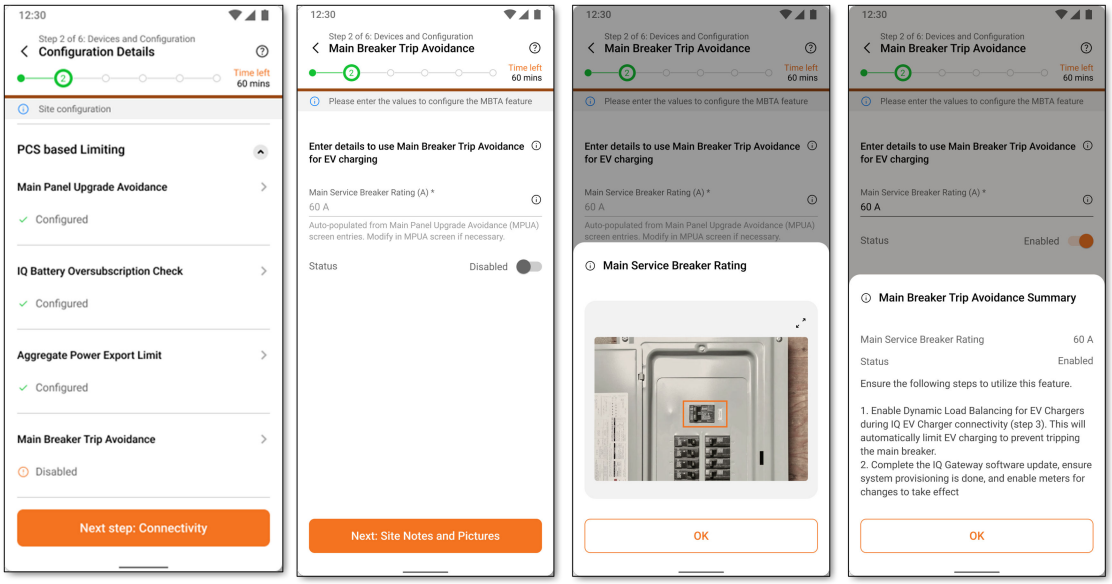


Figure 35: Configuration of MBTA in Enphase Installer App

The feature requires an additional set after IQ Gateway Commissioning is complete, and after the meters are enabled and the summary report is generated, to set up the connectivity of the IQ EVSE on the same Wi-Fi network as IQ Gateway and enable dynamic load balancing:

In **Step 3 – Connectivity Status** > **Ensure IQ EVSE is connected to IQ Gateway** > **Enable Dynamic Load Balancing.**

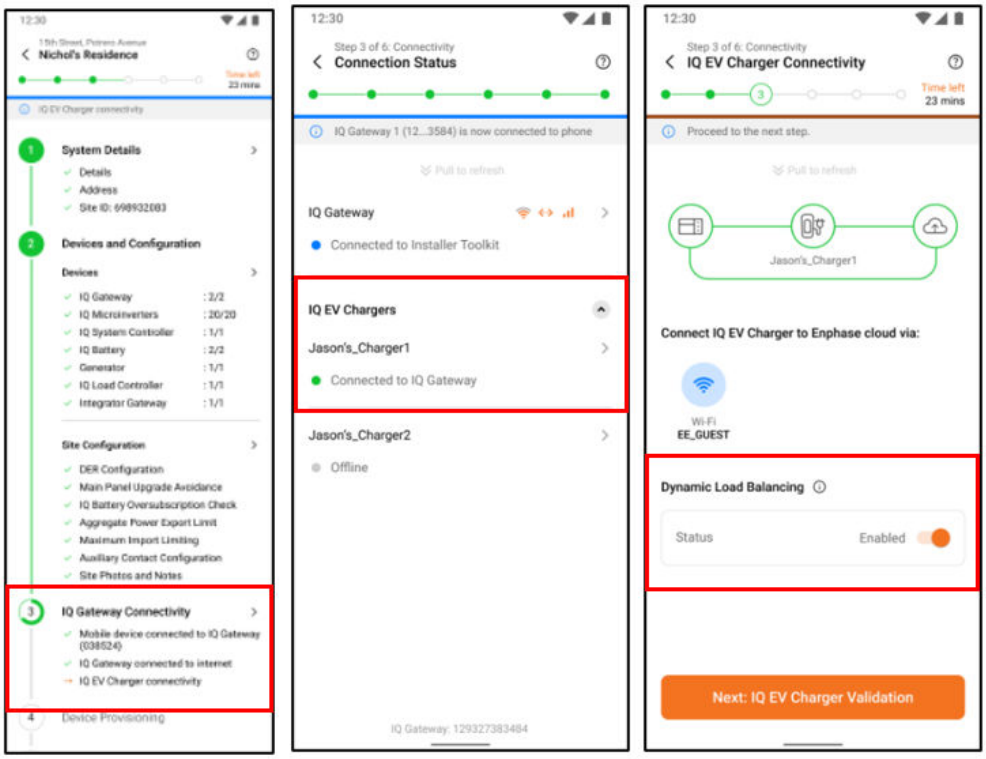


Figure 36: Configuration of MBTA in Enphase Installer App

NOTE: Refer to the *IQ EV Charger Installation technical brief* in the Enphase documentation center for more details.

Appendix A

Expansion with NEM 2.0 systems

If a homeowner with an existing Enphase or Non-Enphase Solar-only system would like to expand their system further with Enphase microinverters or batteries, they can retain the NEM 2.0 tariff structure on their legacy system and utilize the NEM Multiple tariff structure for the newer/expanded system.

There are currently three utility-accepted configurations for this,

1. Enable Enphase Power Control with NEM integrity mode such that the new system will never export more than what the legacy/existing Solar-only produces in real-time
2. Enable Enphase Power Control for the added system on a separate sub-panel in zero export mode

The supported legacy solar-only systems can be Enphase IQ8, IQ7/IQ6, M Series Microinverters, or non-Enphase systems.

To add a grid-tied or grid-forming system to the legacy systems with added parallel Consumption CTs, the following steps can be followed:

1. The expanded system must be installed as per the table below, with a dedicated IQ Gateway/ IQ Combiner. A Power line filter must be installed on the legacy system.

Legacy system	New expansion system type	Option to expand	Diagram
Legacy Enphase system with IQ8 or IQ7/IQ6 or M Series or non-Enphase systems	Grid-tied	Option 1: Added parallel Consumption CTs on the legacy system	Figure 37: Grid-tied system expansion of Legacy Solar-only systems with added parallel Consumption CTs on page 49
		Option 2: Added subpanel	Figure 38: Grid-tied system expansion of Legacy Solar-only systems with an added subpanel on page 50
	Grid-forming	Option 1: Added parallel Consumption CTs on the legacy system	Figure 39: Grid-forming system expansion of Legacy Solar-only systems with added parallel Consumption CTs on page 50
		Option 2: Added subpanel	Figure 40: Grid-forming system expansion of Legacy Solar-only systems with an added subpanel on page 51

2. Configure the Aggregate Power Export limit to Zero Watts as shown in the sections Configuring aggregate power export limit feature through the Enphase Installer App on page 43 or Configuring aggregate PEL feature through the Enphase Installer Portal on page 43.

Grid-tied expansion for legacy NEM 2.0 PV Only system

Option 1: Grid-tied system expansion with added parallel Consumption CTs on legacy system

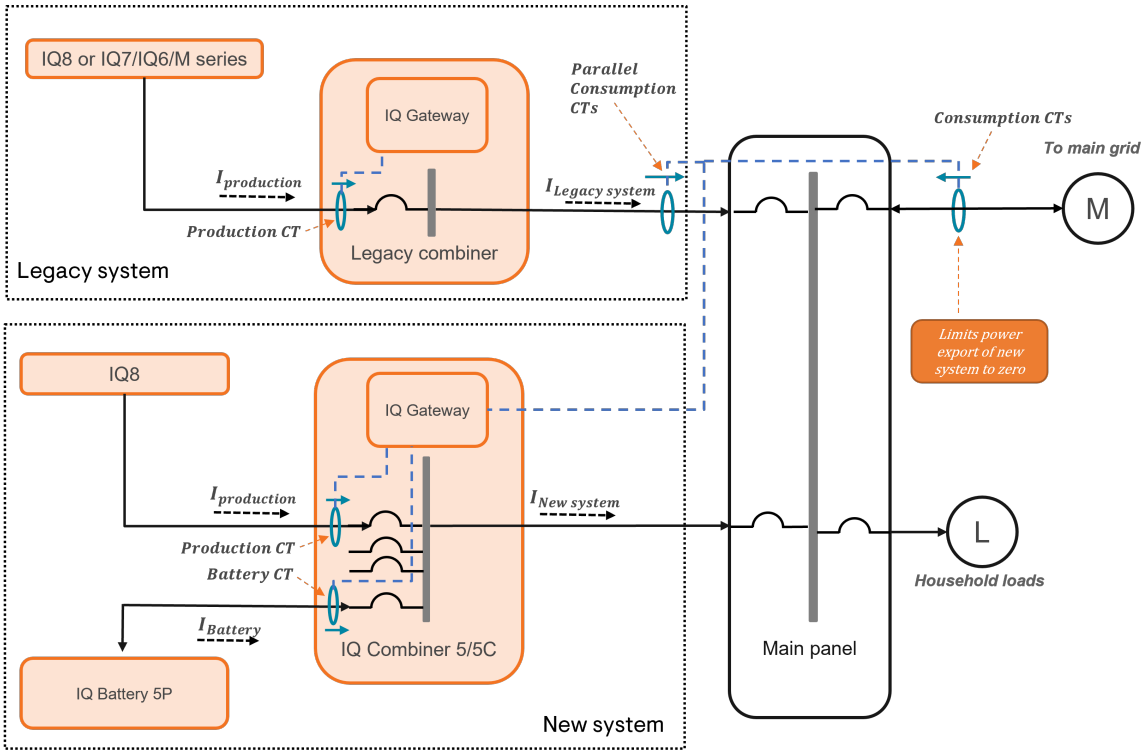


Figure 37: Grid-tied system expansion of Legacy Solar-only systems with added parallel Consumption CTs

Option 2: Grid-tied system expansion with added subpanel

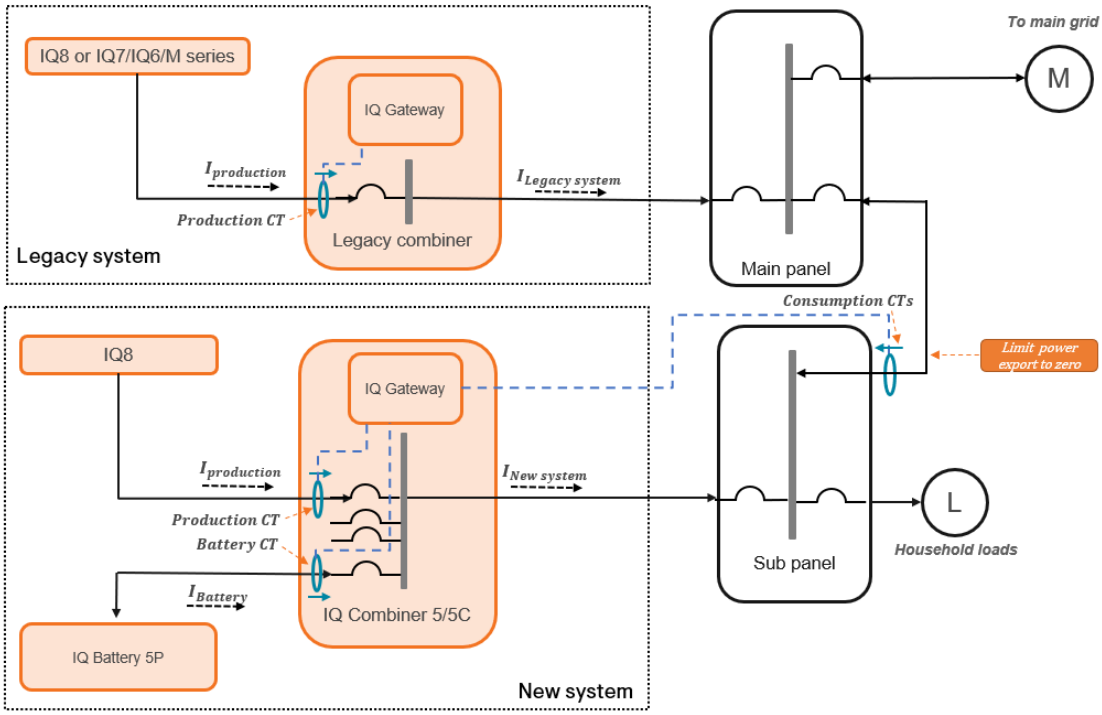


Figure 38: Grid-tied system expansion of Legacy Solar-only systems with an added subpanel

Grid-forming expansion for legacy NEM 2.0 PV Only system

Option 1: Grid-forming system expansion with added parallel Consumption CTs on legacy system

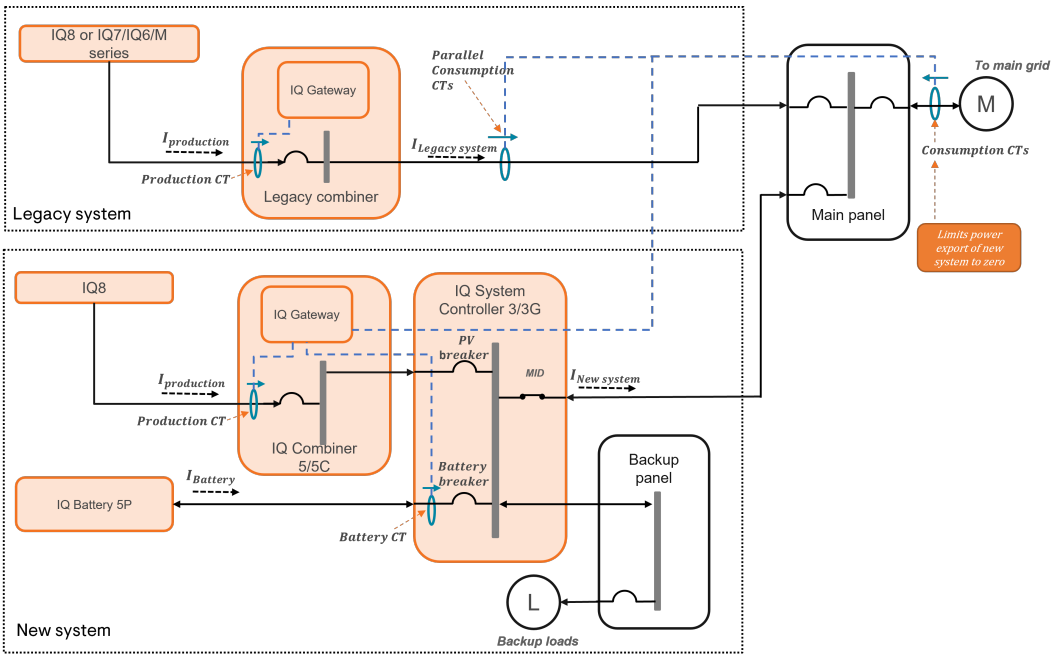


Figure 39: Grid-forming system expansion of Legacy Solar-only systems with added parallel Consumption CTs

Option 2: Grid-forming system expansion with added subpanel

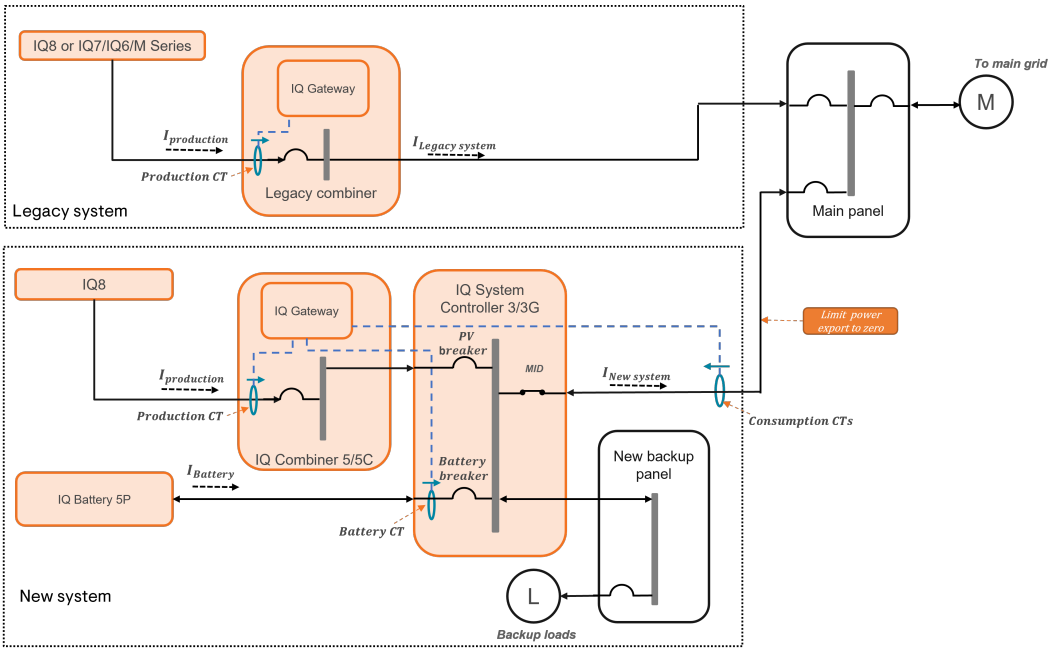


Figure 40: Grid-forming system expansion of Legacy Solar-only systems with an added subpanel

Appendix B

Single-line diagrams

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

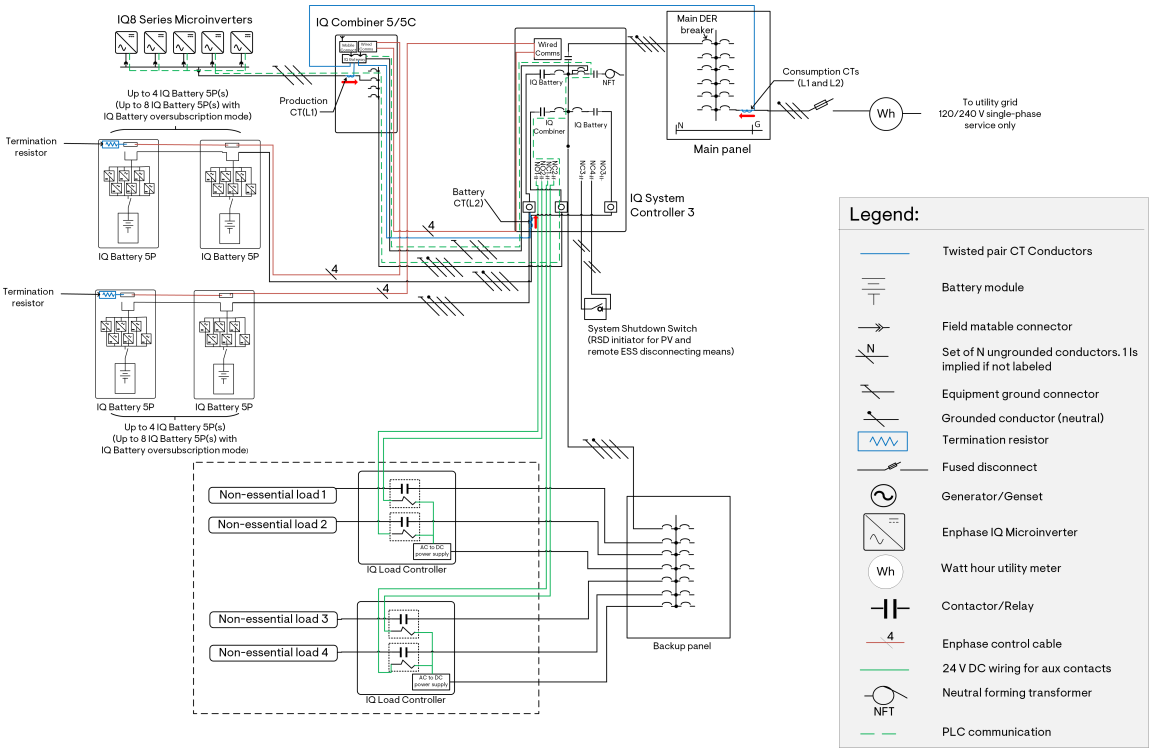


Figure 41: IQ Battery oversubscription, MPU avoidance, battery export/import only, and aggregate PEL with IQ System Controller 3

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

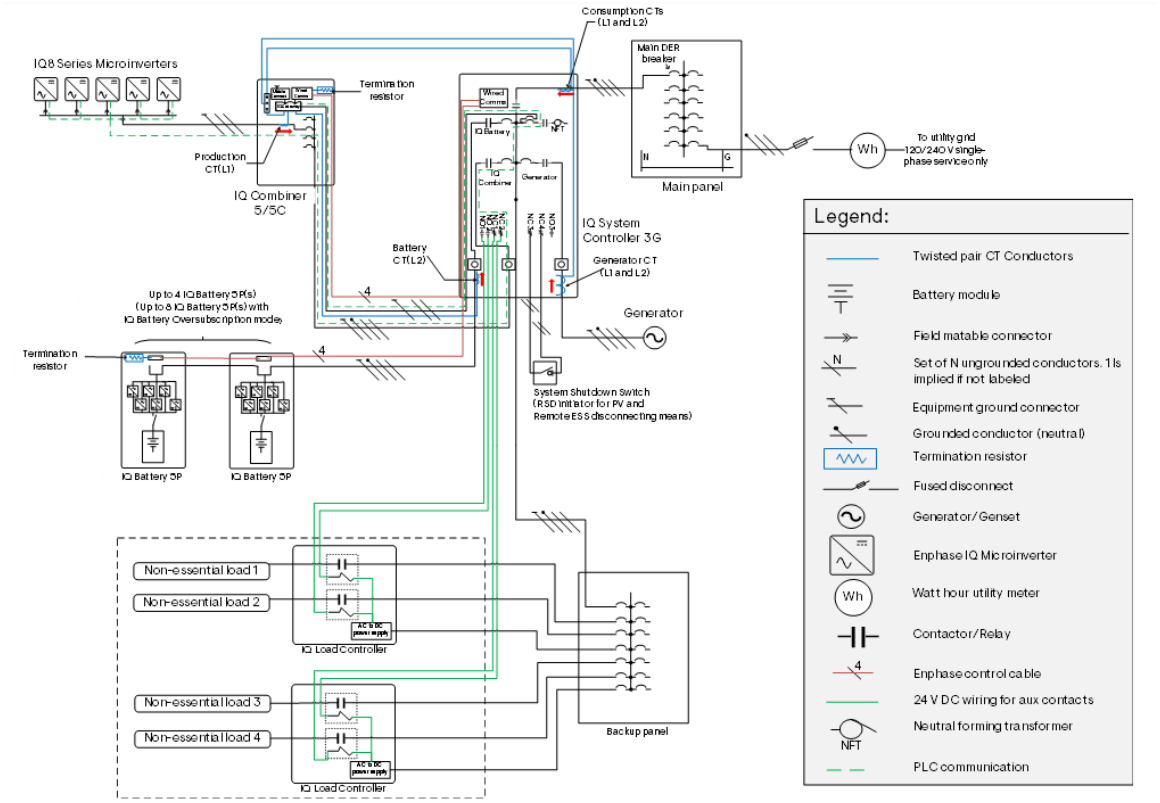


Figure 42: IQ Battery oversubscription, MPU avoidance, battery export/import only, and aggregate PEL with IQ System Controller 3G

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

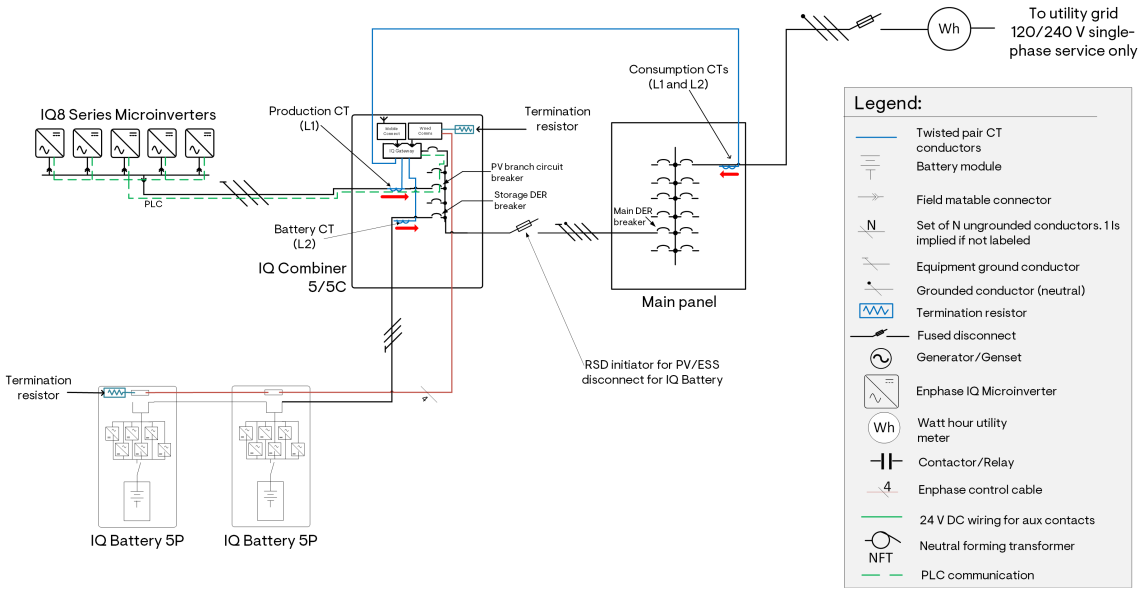


Figure 43: IQ Battery oversubscription, MPU avoidance, aggregate PEL, and battery export/import only with IQ Combiner 5/5C and IQ Battery 5P in the grid-tied configuration

MPU avoidance in grid-tied configuration with IQ Combiner 4/4C and IQ Battery 3T/10T

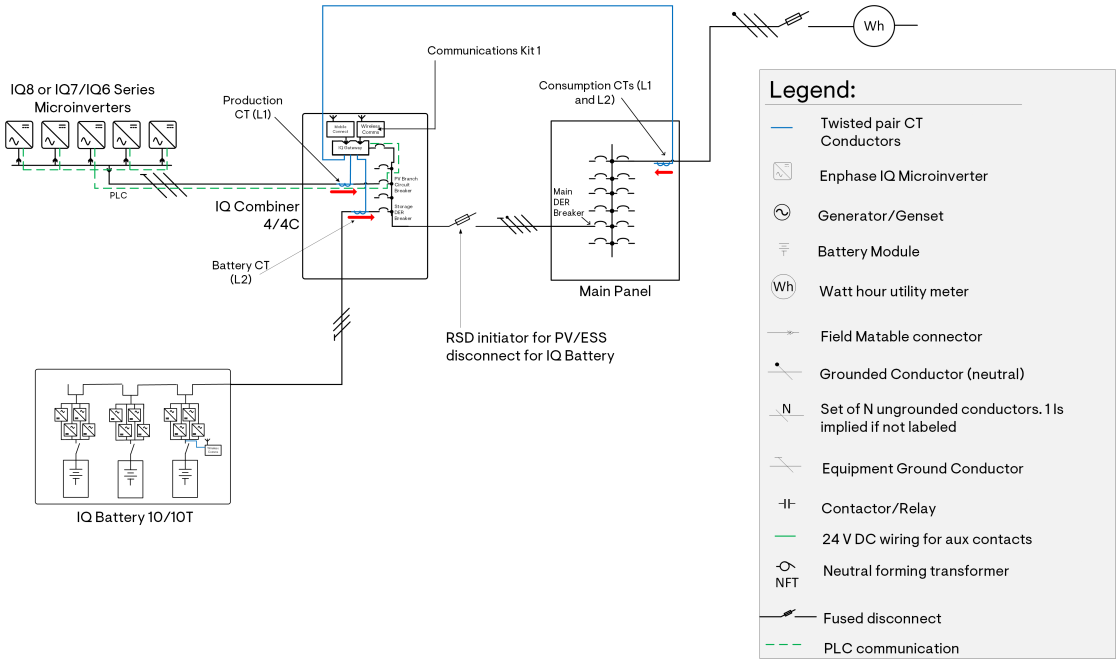


Figure 44: MPU avoidance in grid-tied configuration with IQ Combiner 4/4C

IQ Battery oversubscription, MPU avoidance, aggregate PEL, and battery export/ import only in grid-tied configuration with off-the-shelf subpanel

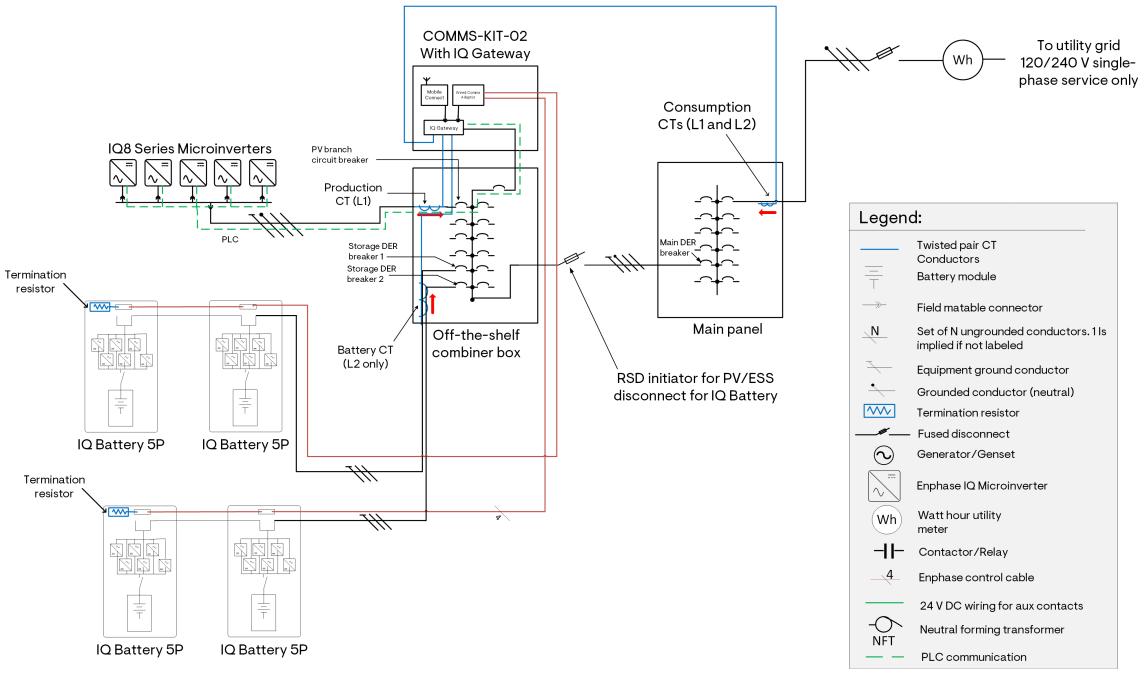


Figure 45: IQ Battery oversubscription, MPU avoidance, aggregate PEL, and battery export/import only in grid-tied configuration with off-the-shelf subpanel

IQ Battery oversubscription, MPU avoidance, aggregate PEL, and battery export/ import only in grid-tied configuration with IQ Combiner and off-the-shelf subpanel

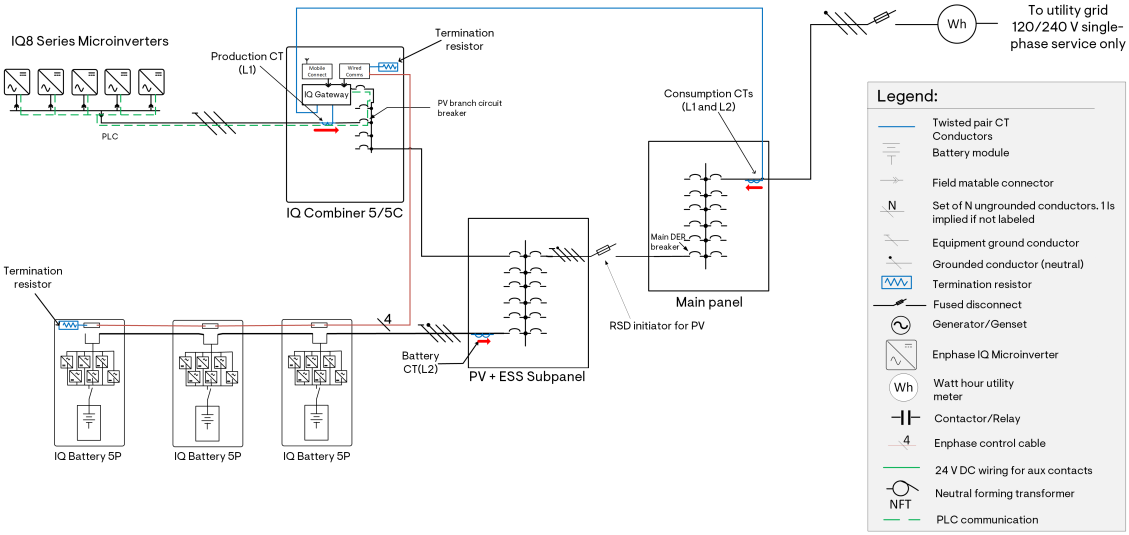


Figure 46: IQ Battery oversubscription, MPU avoidance, aggregate PEL, and battery export/import only in grid-tied configuration with IQ Combiner and off-the-shelf subpanel

8. Revision history

Revision	Date	Description
TEB-00049-6.0	May 2025	• Updated introduction section. • Updated the "Enphase Power Control in a grid-tied Enphase Energy System" section to include NEM integrity mode. • Added IQ Combiner 5/5C specifications to the "Benefit from longer backup time with high-power batteries" section. • Updated diagrams to include IQ Meter Collar.
TEB-00049-5.0	September 2024	• Updated introduction section to include the main panel upgrade with Busbar Overload Current (BBoC) feature and IQ EVSE MBTA. • Updated screens of the configuration of PCS features with the Enphase Installer App. • Added the appendix section Expansion of NEM 2.0 systems.
TEB-00049-4.0	February 2024	• Modified section “Battery import/export-only mode for Enphase Energy System”. • Updated “Current transformer placement for Enphase Power Control features” section. • Updated “Benefits of Enphase Power Control” section. • Added SLD for PCS in grid-tied configuration with IQ Combiner and off-the-shelf subpanel in Appendix.
TEB-00049-3.0	December 2023	• Updated Table 2 “Supported SKUs for added support on main panel upgrade avoidance for grid-tied PV and battery systems”. • Updated section “Main panel upgrade avoidance in grid-tied configuration”. • Updated diagrams to demonstrate MPU.
TEB-00049-2.0	September 2023	• 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 power export limit” section. • Updated the “Wiring diagrams” section.
TEB-00049-1.0	August 2023	• Updated “Enphase Storage System” to “Enphase Energy System”. • Updated “Introduction to Power Control System” section. • Added “Supported configurations for Enphase Power Control” section. • Added “Overview of Enphase Energy System” section.

Revision	Date	Description
		• 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. • 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.