ENPHASE.

TECHNICAL BRIEF

# Concept of operations: Fourth generation Enphase Energy System with IQ Meter Collar

**Applicable regions: North America**

# Contents

# 1. Overview

This document describes the concept of operations of the Enphase Energy System (EES) 4.0 and related equipment during grid transitions.

Enphase Energy Systems using IQ Meter Collar (MC-200-011-V01), IQ Battery 10C (IQBATTERY-10C-1P-NA), IQ Battery 10CS (IQBATTERY-10CS-1PNA), IQ Combiner 6C (X-IQ-AM1-240-6C), IQ Series Microinverters are certified under UL 1741 SA/SB [IEEE 1547:2018 and IEEE 1547.1:2020].

The following table lists the terminology used in this document.

| Term | Definition |
|---|---|
| Interactive mode (or on-grid) | Inverter intended for use in parallel with power sources such as an electric utility to supply common loads and capable of delivering power to the utility. – NFPA 70 (NEC 2020).<br>Also referred to as grid-following, grid-tied, grid-interactive, or utility-interactive. |
| Island mode (or off-grid) | The operational mode for stand-alone power production equipment or an isolated microgrid, or for a multimode inverter or an interconnected microgrid that is disconnected from an electric power production and distribution network or other primary power source. – NFPA 70 (NEC 2020). |
| Intentional island | A planned electrical island that is capable of being energized by one or more Local EPSs. These (1) have DER(s) and load, (2) have the ability to disconnect from and to parallel with the Area EPS, (3) include one or more Local EPS(s), and (4) are intentionally planned. – IEEE 1547-2018. |
| Multimode | The ability of an inverter to switch between interactive and island mode. |
| Multimode on-grid mode | The interactive mode of operation of Enphase microinverters is that once they sense a loss of grid or grid out of bounds, they start operating in island mode (or off-grid). |
| Interactive only mode | The interactive mode of operation of Enphase microinverters, in which even if they sense a loss of grid or grid out of bounds, they remain in interactive mode. |
| IQ Meter Collar | Refers to any IQ Meter Collar. |
| IQ Combiner | Refers to IQ Combiner 6C. |
| IQ8 Microinverter | Refers to any IQ8 Microinverter unit. |
| IQ Battery | Refers to IQ Battery 10C/10CS. |
| DERs | Refers to distributed energy resources, that is, PV microinverters or batteries. |

# 2. Transition from multimode on-grid to island/off-grid mode

1. The IQ Meter Collar, IQ8 Microinverters, and the microinverters inside the IQ Batteries simultaneously detect a loss of grid or grid out of bounds by sensing

   - Voltage
   - Frequency
   - Under frequency
   - Anti-islanding (SANDIA frequency shift in microinverters)

   **NOTE:** Undervoltage, underfrequency, and anti-islanding trips are observed for grid outages. Overvoltage and over-frequency trips occur at voltages/frequencies specified by grid interconnection requirements. The system is also island-based on voltage and frequency ride-through limits as per the grid code.
2. Upon detecting a loss of grid or a grid out-of-bounds condition, the IQ Meter Collar opens its internal MID to disconnect the home and the DERs from the utility grid. The behavior of the PV and battery microinverters after detecting a grid loss is determined by the presence or absence of the IQ Meter Collar.

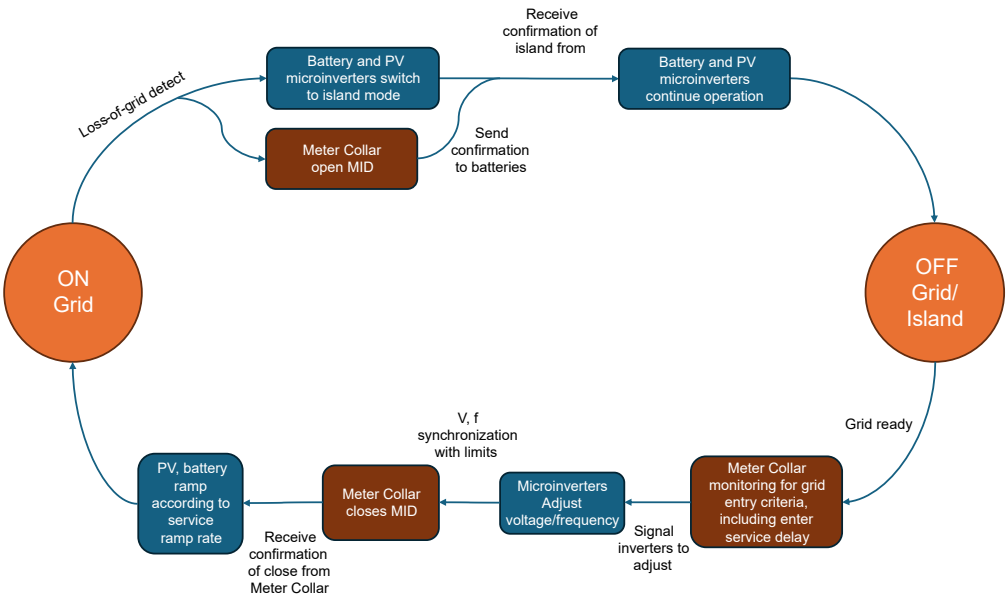
   - If an IQ Meter Collar is present, the inverters in the battery seamlessly switch to the island mode.
   - If the system does not have an IQ Meter Collar, the battery microinverters trip and cease to energize the premise's wiring.
3. The IQ Meter Collar contains the MID relay, and the IQ Combiner contains the DER relay for PV and battery inputs. The IQ Meter Collar will not attempt to close the MID to go on-grid mode unless communication is established with the microinverters.
4. When disconnecting from the utility grid, if the IQ Meter Collar is unable to open the MID or if the IQ Combiner is unable to detect the state of the MID (that is, due to loss of communication with the IQ Meter Collar), the IQ Combiner opens the DER relays that disconnect the PV and battery from the home and the utility grid. This occurs within 2 seconds.
5. In addition, after transitioning to island mode, the IQ Combiner waits for the IQ Meter Collar to confirm the disconnection from the utility grid. In case of any failures, the DER relay in the IQ Combiner isolates the PV and battery from the grid within 2 seconds. Additionally, within a predetermined time period (see System operation during a loss of communications on page 6), the microinverters will automatically reboot into the default grid-following mode.
6. While operating in island mode, the PV and battery microinverters require constant communication with the IQ Meter Collar. If communication fails, the IQ Meter Collar will continue to monitor the microgrid voltage and will not close the MID relay even if the grid is restored, until the batteries discharge and the microgrid collapses.

# 3. Transition from island/off-grid to multimode on-grid mode

1. The IQ Meter Collar continuously samples the voltage and frequency on the grid side of the MID. It detects the presence of the grid when the grid returns.
2. After the grid is back, the IQ Meter Collar monitors the grid voltage and frequency to ensure it is within the entry service criteria as dictated by the grid interconnection parameters (Rule 21 in CA, Rule 14H in HI, or IEEE 1547 in other states, and so on). For example, see Grid re-entry rule examples on page 8.
3. When the grid voltage and frequency are within the entry service criteria, the IQ Meter Collar waits for the required entry service delay as required by the local grid code. This entry service delay is 15 seconds for Rule 21 as outlined in the Grid re-entry rule examples on page 8.
4. After the enter service delay has elapsed, the IQ Meter Collar sends the grid voltage and frequency to the PV and battery microinverters.
5. The PV and battery microinverters receive the grid voltage and frequency. The microinverters then adjust the microgrid voltage and frequency to synchronize with the grid.
6. The IQ Meter Collar detects that the microgrid is synchronized with the grid voltage and frequency. It then closes the MID to connect the home and DERs to the grid. It then signals the PV and battery microinverters to go into Multimode on-grid mode.
7. The microinverters revert to multimode on-grid mode within one second.

   **NOTE:** If the grid fails again before the inverters go to multimode on-grid mode, the IQ Meter Collar will isolate the home from the grid using the MID to ensure safety.
8. The PV and battery microinverter follow the enter service ramp rate to increase the power produced or discharged, thereby ensuring that grid interconnection parameters for DERs are met.
9. During a single fault scenario where the IQ Meter Collar MID fails to operate correctly, the DER relay in the IQ Combiner will disconnect the PV and batteries from both the home and grid.

The following figure shows the fourth-generation Enphase Energy System concept of operations during transitions.



# 4. System operation during a loss of communications

Loss of communications between IQ Meter Collar and distributed energy resources (DERs) such as microinverters and IQ Batteries do not impact the safety or isolation provided.

## 4.1 Safety and isolation in an Enphase system

- The IQ Meter Collar is a UL 414 safety-certified and UL 1741-compliant (including SA, SB, and multimode) isolation device.
- The isolation device, that is, the IQ Meter Collar, does not depend on loss of communication with DERs to ensure safety.
- A MID relay inside the IQ Meter Collar ensures isolation from the grid on voltage and frequency trips and ride-throughs, as well as anti-islanding trips.
- IQ Meter Collar is UL 1998 certified and uses a UL Listed relay for MID operation.
- The IQ Combiner will independently open the DER relay and isolate the microinverters from the utility grid within 2 seconds if there is a MID failure or communication failure with the IQ Meter Collar.

## 4.2 On-grid to off-grid transition: Loss of communication

- On a grid outage, the MID relay isolates the system from the utility grid.
- Microinverters (in the IQ Battery and PV) switch to Island (off-grid mode). This switch can happen slightly ahead of the MID opening, causing a closed transition transfer or a make-before-break. The time of the closed transition is approximately 100 ms. The redundancy of relays (that is, MID and DER relays inside the IQ Combiner) ensures safety in all such transfers. If there is any failure to isolate using the MID or there is a loss of communication with the MID (that is, the MID state cannot be detected), the DER relays open within 2 seconds.
- When isolated from the grid, microinverters transition to off-grid mode and are not required to conform to the applicable grid code.
- Microinverters rely on communication of the MID opening from the IQ Meter Collar to stay in off-grid mode.
- If the communication is lost within 20 seconds, all PV microinverters automatically reboot and revert to the default grid-following mode (and all grid code-driven parameters are restored to a grid-compliant value, for example, Rule 21).
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## 4.3 Off-grid to on-grid

- When switching from off-grid to on-grid, the IQ Meter Collar ensures that enter service times are followed and that the grid voltage and frequency are within the limits specified by the applicable grid codes.
- After the entry service timing is met, the IQ Meter Collar, through IQ Combiner commands the microinverters to match grid voltage and frequency.

- The IQ Meter Collar then monitors the microgrid and grid voltage and frequency to ensure that they are synchronous and closes the MID relay.
- The IQ Meter Collar then sends a message to the microinverters through IQ Combiner confirming MID closure. The microinverters revert to grid-following mode within one second with all grid code parameters restored to specified values, for example, Rule 21.
- The IQ Combiner sends the message multiple times until it confirms that every microinverter is in multimode on-grid mode. The exact timing depends on the number of microinverters in the system and the “noise level” of the local EPS in the PLC frequencies, for example, >100 kHz. Similar to the multimode on-grid to Island (off-grid) transition, microinverters have the same loss of communications behavior to fall back to grid-tied when there is no communication with the system confirming MID closure.
- Note that entry service and trip and ride-through requirements are always enforced by the IQ System Controller. Therefore, a loss of communication time only enables grid support functions such as AGF (VW, FW, VVAR) in the microinverters, not parameters such as grid entry criteria.

## 4.4 Abnormal operation behavior

If the MID does not open, the IQ Combiner receives communication of this failure once every 200 ms and opens the DER relay, which disconnects the PV and battery inverters. The DER relay provides hardware redundancy in case of MID failure or welded contacts.

## 4.5 MID contactor rating

The MID relay inside the IQ Meter Collar is capable of withstanding >220% of the interconnection facility-rated voltage as required in UL 1741SB, which reflects the requirement in IEEE 1547:2018 4.11.3. The IQ Meter Collar meets this as specified in the test report with Intertek 105894151CRT-001VOC.

# Appendix A

## Grid re-entry rule examples

### California Rule 21 example for grid re-entry

Under California Rule 21(PG&E is used as an example) under Section Hh, SMART INVERTER GENERATING FACILITY DESIGN AND OPERATING REQUIREMENTS FOR UL 1741SB INVERTERS, 2(k) Enter Service Ramp Rate Requirements, the delay to enter service is 15 seconds after a stable grid is detected. Other entry criteria, such as voltage and frequency limits, are covered in sections Hh, 2(c), and 2(f), referencing IEEE 1547-2018.

**ELECTRIC RULE NO. 21** Sheet 197
GENERATING FACILITY INTERCONNECTIONS

Hh. SMART INVERTER GENERATING FACILITY DESIGN AND OPERATING REQUIREMENTS FOR UL1741SB INVERTERS (Cont'd.) (T)

2. Prevention of Interference (Cont'd)

k. Enter Service Ramp Rate Requirements

The Smart Inverter is required to have the following ramp controls.

- Enter Service ramp control requirements as outlined in IEEE 1547-2018 section 4.10.3 with following default settings:
  - Delay enter service shall be 15 seconds per Hh.1.a.ii
  - Default Enter Service Duration shall be 50 seconds

The IQ System Controller additionally adheres to Section HHh, Microgrid operational requirements in Southern California Edison Rule 21, August 2023 revision. The specific requirements being called out are covered in Section 4.5, Section 3 (points 3, 7), and Section 2 (point 3).

h. Microgrid Operational Requirements

Generating Facilities that are operated as a Microgrid System and which isolate and island intentionally from the Distribution System to serve host load must adhere to all the following requirements:

(i) Shall not energize other SCE customers without SCE's prior approval; any such approval by SCE will be consistent with other applicable rules or tariffs.

(ii) Paralleling Device shall be capable of withstanding 220% of the rated voltage across the Paralleling Device.

(iii) Paralleling Device shall not be closed until synchronization with the grid has met the parameters in accordance with Table L.3

(iv) Paralleling Device shall not be closed into a de-energized grid when inverters are producing or absorbing active power and/or exchanging reactive power. Closing of the Paralleling Device into a de-energized grid when inverters are producing or absorbing active power and/or exchanging reactive power shall cause the inverter to cease to energize or trip automatically.

(v) Upon closing Paralleling Device, Smart Inverters must return to Grid Following Mode within 1 second.

(vi) When operating isolated from the grid (Microgrid operations), failure of communications between the Paralleling Device and microgrid control systems shall result in Generating Facility Smart Inverters to cease to energize or trip within 2 seconds of loss of communications.

(vii) Smart Inverters shall not change or modify the approved operating parameters from Grid Following Mode to Grid Forming Mode until such time the inverters have verified that the Paralleling Device has opened, via Paralleling Device mechanical provisions, to isolate the Generating Facility from the Distribution System.

## Hawaii Rule 14 example for grid re-entry

In Hawaii, under HECO Rule 14, Section 4 (e) covers the delay required for connection (5 minutes).

Section 4(g) covers reclosing coordination, referencing IEEE 1547:2018.

e. Required Delay on Reconnection: The generating facility shall be equipped with automatic means to prevent reconnection of the generating facility with the utility distribution system until the utility service voltage and frequency are within the utility tariff normal operating ranges and stable for at least 5 minutes, unless earlier directed by the utility

g. Reclosing Coordination: The generating facility shall be coordinated with the utility system reclosing devices, by disconnecting from the utility distribution system within the first reclose interval and remaining disconnected until the voltage and frequency have stabilized, consistent with the enter service criteria specified in IEEE 1547-2018.

## PREPA/LUMA 2017 example for grid re-entry

In Puerto Rico, the entry condition is covered under Appendix F, Section G.3. Other requirements, such as voltage and frequency, are covered in Appendix F, point C, referencing IEEE 1547.

D. Confirmar que el inversor tenga programado el ajuste para mantener el factor de potencia unitario continuo en el punto de interconexión.
E. Si el inversor cuenta con la función de apagarse y desconectarse del sistema manualmente, verificar que opere adecuadamente.
F. El interruptor manual tiene que ser capaz de interrumpir la corriente máxima a la cual estará expuesto. Éste tiene que estar visible y accesible al personal de la AEE. Tiene que permitir la instalación de un candado de la AEE para asegurar la posición de abierto. Este interruptor manual puede utilizarse para realizar la prueba de desconexión del GD ante pérdida del servicio eléctrico de la AEE (anti-islas).
G. Para realizar la prueba de desconexión del GD ante pérdida de servicio eléctrico de la AEE, se deberán seguir los siguientes pasos de acuerdo con el tipo de sistema:
   - Para sistemas monofásicos:
     1. Durante operación normal del equipo, desconectar todas las fases simultáneamente, mediante un desconectivo apropiado que no sea parte del equipo bajo prueba.
     2. **Verificar que el equipo no energiza sus terminales de salida conectados con el sistema de la AEE.**
     3. Reconectar el equipo y verificar que el mismo no energiza sus terminales de salida hasta que transcurran 5 minutos.
   - Para sistemas trifásicos:
     1. Desconectar una sola fase y verificar que el equipo no energiza sus terminales de salida.
     2. Reconectar la fase y repetir este procedimiento para las demás fases.

## IEEE 1547:2018 enter service

IEEE 1547:2018 covers the enter service criteria under section 4.10, with the default voltage and frequency of re-entry captured in section 4.10.2.

### 4.10.2 Enter service criteria

When entering service, the DER shall not energize the Area EPS until the *applicable voltage* and system frequency are within the ranges specified in Table 4 and the permit service setting is set to "Enabled".[49]

**Table 4—Enter service criteria for DER of Category I, Category II, and Category III**

| Enter service criteria | | Default settings | Ranges of allowable settings |
|---|---|---|---|
| Permit service | | Enabled | Enabled/Disabled |
| Applicable voltage within range | Minimum value | ≥ 0.917 p.u.[a] | 0.88 p.u. to 0.95 p.u. |
| | Maximum value | ≤ 1.05 p.u. | 1.05 p.u. to 1.06 p.u. |
| Frequency within range | Minimum value | ≥ 59.5 Hz | 59.0 Hz to 59.9 Hz |
| | Maximum value | ≤ 60.1 Hz | 60.1 Hz to 61.0 Hz |

[a]This corresponds to the Range B of ANSI C84.1, Table 1, column for service voltage of 120–600 V.

The required delay before entering is defined in section 4.10.3 as programmable, with the default set to 300 s.

### 4.10.3 Performance during entering service

During entering service, the DER shall be capable of the following:

a) Prevent *enter service* when permit service setting is disabled.

b) DER shall be capable of delaying *enter service* by an intentional adjustable minimum delay when the Area EPS steady-state voltage and frequency are within the ranges specified in Table 4. The adjustable range of the minimum intentional delay shall be 0 s to 600 s with a default minimum delay of 300 s.

# 6. Revision history

| REVISION | DATE | DESCRIPTION |
|---|---|---|
| TEB-00294-1.0 | May 2025 | Initial release. |