

TECHNICAL BRIEF

IQ8D Rapid Shutdown Compliance

1. Introduction

The use of rooftop photovoltaic (PV) arrays on the customer or consumer side of distribution systems has created new safety concerns for first responders, in particular firefighters who respond to fires or calls where PV has been installed. There is a risk of shock to firefighters when responding to calls where PV arrays are present and may have been damaged. A means of PV hazard control or hazard reduction for the systems are required to provide assurance and protection to firefighters who may not be aware that the PV is generating energy.

The IQ8D micro inverter-based Commercial PV system is compliant with the Rapid Shut Down by creating a UL 3741 Listed array regardless of the modules used. UL 3741 is a binational US/Canadian Standard that offers greater consistency in the safety of photovoltaic hazard control across many countries and jurisdictions.

Each IQ8D microinverter supports two series-connected PV modules and integrates with the Enphase IQ8D Commercial Gateway and Enphase Enlighten monitoring and analysis software.

2. Rapid Shutdown Requirements

Commercial PV systems designed with IQ8D are compliant with the Rapid Shutdown requirements as long as:

1. The individual system components (Enphase and non-Enphase) are UL listed and are installed as per respective manufacturer instructions.
2. The IQ8D microinverter, when installed with two PV modules in series, has been evaluated under UL 3741, and can be installed to meet the requirements from 2014, 2017 and 2020 NEC Article 690.12(B)(2)(1). Under the coldest environmental conditions, the total Voc of both modules connected in series must be less than 160.44 V dc. This ensures compliance with UL 3741 and therefore can be installed according to the NEC
3. The IQ8D microinverter, as evaluated under UL 3741, meets requirements from 2017 and 2020 NEC Article 690.12(B)(2)(1). Under the coldest environmental conditions, the total Voc of both modules connected in series must be less than 160.44 V dc. This ensures compliance with UL 3741 and the NEC.
4. The Rapid Shutdown initiator is used to trigger the hazard reduction function of the rooftop PV array.
5. The AC voltage after initiating the hazard reduction function will be less than the 30 V limit within 30 seconds per the requirements of 690.12 (B) (1) outside the array boundary.

This technical brief elaborates on the Rapid Shutdown compliance with IQ8D based commercial PV System and how Enphase meets the above requirements.

Note: Except for IQ8D microinverter, all other Enphase microinverters are complied with Rapid shutdown using 690.12 (B) (2) (2). i.e; the 80Vdc limit.

3. IQ8D System Level Compliance

3.1 Enphase IQ8D System – UL Listing

Enphase System components are UL listed as per below table:

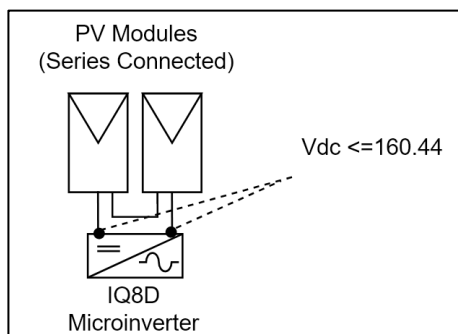
Enphase BoM	UL Standard
IQ8D Microinverter	UL 3741 UL Standard for Safety, Photovoltaic Hazard Control, UL listed as PV Rapid Shutdown Equipment (PVRSE) CA Rule 21 (UL 1741-SA) UL 62109-1, UL1741/IEEE1547, FCC Part 15 Class B, ICES-0003 Class B, UL 1699B UL Standard for Safety, Photovoltaic (PV) Arc-Fault Circuit Protection, CAN/CSA-C22.2 NO. 107.1-01
IQ8D DC adapter cables	UL 9703
QD Cables	UL 3003 (raw cable), UL 9703 (DG cable, cable assemblies)
IQ8D Commercial Gateway	UL 916, CAN/CSA C22.2 No. 61010-1
PLC Filter	RoHS / cURus

The installer needs to ensure that the non-Enphase System BoM components are UL listed as well and installed as per the respective manufacturer installation instructions.

3.2 IQ8D microinverter Rapid Shutdown compliance:

The IQ8D microinverter has a DC operating voltage range of 30 Vdc to 119 Vdc; and operating temperature range of -40°C to +60°C. The IQ8D microinverter can be connected with two 60- or 72-cell PV modules which when connected series do not exceed the maximum DC input voltage limit (119 Vdc).

To qualify as Listed Rapid Shutdown Array under UL 3741, the IQ8D is UL listed as **PV Rapid Shutdown Equipment (PVRSE)** and the array's Voc voltage at the minimum operating temperature of -40°C must be less than or equal to 160.44 Vdc.



According to UL 3741, the value 160.44 Vdc has been arrived at by multiplying the human body resistance (Human body + Glove + Turnout gear resistance) with the maximum safe current (0.04A) passing through the body which does not cause involuntary contraction or ventricular fibrillation from electrical shocks to emergency responders. The UL 3741 Standard considers the resistances of the Personal Protective Equipment, i.e. gloves and turnout gear. UL 3741 also analysed the body model impedances for various possible current paths which change depending on the body contact points, e.g. Hand to hand, hand to foot, hand to butt, etc. The result of this UL 3741 analysis was used to determine the worst-case conduction path which resulted in the lowest body resistance. This resistance can then be used to calculate the highest allowable voltage between any two conductors or any single conductor and ground.

	Imax	0.04	A		
	Glove	Human Body	Turnout gear	Total	
Resistance	2083	1612	316	4011	Ohms
Voltage	83.32	64.48	12.64	160.44	Vdc

The UL 3741 committee did extensive testing of firefighter PPE to determine the impedance of gloves and turnout gear when saturated with sweat and water of varying conductivity based on concentrations of suppression additives and arrived at the above resistances for different exposure voltages and the probability of occurrences.

The IQ8D itself has a maximum operating Voltage limit of 119 Vdc and after pairing with two series-connected modules the IQ8D array voltage will never exceeds 119 Vdc (which is less than 160.44 Vdc limit in the UL 3741 Standard) and hence this meets the requirement of a "Listed Rapid Shutdown Array".

Module Make	Model	Power (W)	Voc @25C (V)	Voc @ -40C (V)	Voltage (V) at the DC input port of IQ8D when two modules are connected in series
Hanwha Q CELLS	Q. PEAK DUO ML-G9 400	400	45.1	53	106
SunPower	SPR-A405	400	47.7	56.1	112.1
JA Solar	JAM72S10-400/PR	400	49.5	58.2	116.4
LG	LG400N2K-A5	400	49.4	58.1	116.1
Canadian	CS3W-400P	430	47.2	55.5	111
Boviet Solar Technology Co. Ltd.	BVM6612M-400L-H	400	49.2	57.8	115.7
Trina Solar	TSM-400DE15H.T0(II)	400	50.4	59.2	118.5
Jinko Solar Co Ltd	JKMS400M-72L-V-TI	400	49.8	58.5	117.1
REC Solar	REC400NP 72 XV	400	49.4	58.1	116.1
LONGi Green Energy Technology Co. Ltd.	LR4-72HBD-430M	430	48.9	57.5	115

A UL 3741 Listed IQ8D array complies with RSD in accordance with 2017 and 2020 NEC 690.12 (B)(2)(1) inside the array boundary. The array shall be field labelled to meet the rapid shut down requirements in accordance with 2017 and 2020 NEC section 690.12 (B) (2) (1). Enphase's single module PV microinverters automatically qualified under the 80 Volt limit which is the second option in 2017 and 2020 NEC section 690.12 (B) (2) (2)

3.3 Rapid Shutdown Initiation Device

The installer needs to ensure that the IQ8D based commercial PV rooftop system has a Rapid Shutdown initiation device(s) that triggers the hazard reduction function of the PV system. Such as a disconnect switch or circuit breaker.

The device shall clearly indicate the "on" and "off" position. shall indicate that when in the "off" position, the rapid shutdown function has been initiated for all PV systems connected to that device. For multiple rooftop installations, an initiation device(s) shall be installed for each system and located at in a readily accessible location outside the building. The rapid shutdown initiation device(s) shall consist of at least one of the following:

- (1) Service disconnecting means
- (2) PV system disconnecting means
- (3) Readily accessible switch that indicates whether it is in the "off" or "on" position
- (4) An approved circuit breaker

3.4 AC Voltage in a Deenergized System

The opening of the main system disconnect (Rapid Shutdown initiator) will remove AC voltage to the IQ8D microinverter and therefore the microinverter will cease to energize the conductors.

The AC conductors within and outside the array boundary will meet the shutdown requirements of UL 3741 and the NEC.

Once deenergized, there will be an open circuit with very high load impedance and sensing this the IQ8D microinverters go into "safe mode".

The safe mode voltage of IQ8D based rooftop PV system after Rapid shutdown initiation, is approximately 12.5 Vac and is below the "30V limit within 30 seconds" requirement and therefore compliant with NEC section 690.12 (B) (1).

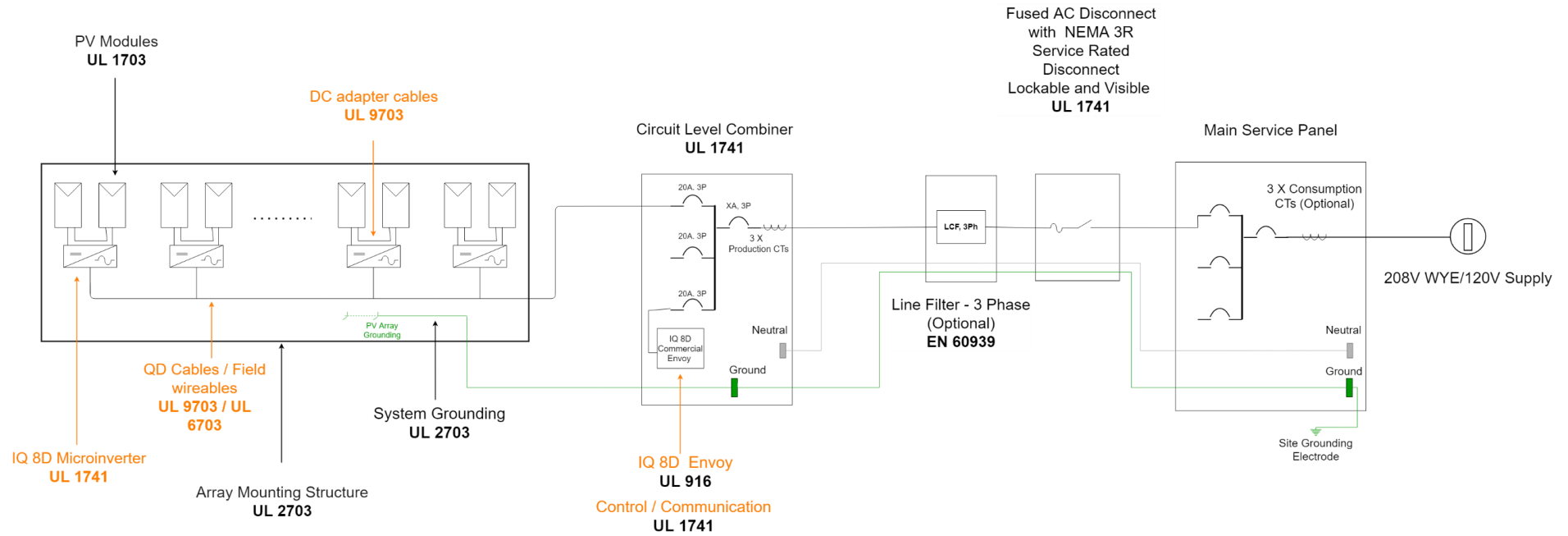
4. The RSD Compliant System

The IQ8D based commercial PV rooftop system comprising of multiple pieces of equipment coordinated to perform the functions as defined in the IQ8D system installation instructions will reduce the risk of electric shock hazard within a damaged PV array during firefighting procedures.

The IQ8D based RSD compliant system will reduce the likelihood of muscle tetanisation (involuntary contraction) and ventricular fibrillation from electrical shock by damaged or undamaged PV arrays during Firefighter operations.

The system layout on the next page shows an example of a Rapid Shutdown compliant rooftop PV system and components necessary to comply with the standard. Only one IQ8D circuit is shown as an example. The IQ8D based commercial PV systems will have many circuits based on system size.

UL 3741 compliant Rooftop Solar PV System



Enphase BOM
 Non Enphase BOM

Note:

1. The individual system components are UL listed and are installed and labeled as per respective manufacturer instructions.
2. The system shall have Rapid Shutdown initiator (s) which triggers the Rapid Shutdown functionality. The RSD initiators could be Circuit combiner output breakers, Main Service Panel breakers, or Added disconnect switch.

5. Conclusion

The IQ8D microinverter based rooftop PV system is Rapid Shutdown compliant.

The IQ8D microinverter is evaluated under UL 3741 and meets requirements from 2017 and 2020 NEC Article 690.12(B)(2)(1). Any compatible module combination that works with IQ8D microinverter, will result in a UL 3741 compliant array. This means any of the compatible 60 and 72 cell modules can be used with IQ8D microinverter and the resulting array will be a UL 3741 compliant as the maximum Voc at the minimum operating temperature is always below 160.44 Vdc.

The system shall have Rapid Shutdown initiator(s) on-site to trigger the RSD function.

The system shall have UL listed Enphase and non-Enphase System BoM components and installed as per the respective manufacturer installation instructions and field labelled.

A UL 3741 compliant array complies with Rapid Shutdown using NEC 690.12 (B)(2)(1) inside the array boundary and since the IQ8D output voltage will be ≤ 30 Vac it also complies with NEC 690.12 (B)(1) outside the array boundary.

The resulting IQ8D microinverter-based commercial PV system would be Rapid Shutdown compliant.

Annex 1: PVRSE Compliance

August 06, 2021



To whom it may concern:

The Enphase Energy microinverter model number IQ-8D has been evaluated by UL LLC and is certified for compliance to the requirements for PV Rapid Shut Down Equipment (PVRSE) as defined in UL 1741 and also the PV Hazard Control Equipment requirements defined in UL 3741.

The subject PV arrays consist of Enphase IQ8D microinverters, and Photovoltaic modules Listed to UL 1703 or UL 61730 (the UL 61730 Listed modules are classified as providing Class II or Class III protection from electric shock⁴). The completed PV Hazard Control arrays address the National Electrical Code article 690.12 (Rapid Shut Down) requirements for both outside and inside the array boundary when installed in accordance with the respective manufacturer's instructions

Specifically:

Controlled conductors outside the array boundary shall comply with NEC [690.12\(B\)\(1\)](#):

The Enphase IQ8D microinverter is Listed as PVRSE under UL 1741 and the ac output conductors will be reduced to 30Vdc in less than 30 seconds

Inside the array boundary, a PV array is required to comply with one of the three options in 2017 or 2020 NEC [690.12\(B\)\(2\)](#):

The Enphase IQ8D is Listed as PV Hazard Control Equipment under UL 3741. In accordance with the UL certification, when this inverter is combined with two of the previously noted PV modules Listed to UL 1703 or UL 61730, and installed according to the manufacturer's instructions, the resulting array constitutes a Listed PV hazard control system that complies with NEC 690.12 (B)(2)(1).

Notes:

- 1) The maximum dc input voltage rating, (119 Vdc) of the IQ8D is lower than the PV Hazard Control Limit established in UL 3741. The Enphase IQ8D has been evaluated and certified per UL1741 and UL3741 so when installed per the instructions to a pair of matching, Listed PV modules, connected in series, the resulting assembly constitutes a Listed PV Hazard Control System (Listed array). Additionally, the combined open circuit voltage, as calculated in accordance with NEC 690.7, is required to be less than or equal to the maximum dc input voltage rating of the IQ8D.
- 2) This letter only describes compliance with the Rapid Shut Down Requirements contained in NEC 690.12. Compliance with the requirements of NEC 690 Part V., Grounding and Bonding, must be determined separately. Common methods for compliance include use of a UL 2703 Listed grounding system or installation of a separate equipment ground installed in accordance with the manufacturer's instructions supplied with the PV modules and supporting structure.
- 3) This letter does not imply any determination by UL LLC, concerning the of the structural suitability of any PV array support structure used in the array.
- 4) For more information about Class II and Class III electric shock ratings see UL61730 and or IEC 61140.

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