Technical Brief

Calculating AC line voltage rise for IQ8D Microinverter with QD Cable

IQ8D-VRISE-MKT-00408-01-EN-US

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Overview

This technical brief presents voltage rise guidelines for IQ8D Microinverter branch circuits and methods for calculating the AC line voltage rise when using the Enphase IQ8D Microinverters™ and the Enphase QD Cable™.

Applying proper voltage rise calculations during your system design helps prevent nuisance voltage out-of-range trip issues due to high line voltage conditions. Less resistance in conductors also results in less power loss, less heat at the terminals, and improves performance of the PV system.

When designing circuits for electrical loads, these calculations are commonly called voltage drop (VDrop). Since PV systems with inverters generate electricity instead of consuming it, voltage rises at the AC terminals of each inverter. Therefore, this brief refers to these calculations as voltage rise (VRise).

Recommendations

To minimize voltage rise, Enphase recommends that you apply these guidelines when planning your system:

- Enphase recommends that the total percentage of voltage rise in the AC wiring be a maximum of 2%, with (an inclusive) less than 1% voltage rise in the QD Cable. Although the QD Cable is optimized for minimal VRise, it is still important to calculate total VRise for the entire system for the farthest microinverter in the branch circuits from point of common coupling (as described in “Voltage Rise by Wire Section”).

- Although the National Electric Code recommends that branch circuit conductors be sized for a maximum of 3% VRise (Article 210.19, FPN 4.), this value in practice is generally not low enough for a utility-interactive inverter. Additional losses exist at the terminals, connectors, and in circuit breakers; however, if you design for a 2% total voltage rise, these other factors may be ignored. A 2% VRise limit in the IQ8D Microinverter system design shall ensure high quality installations with lower energy losses and higher system reliability.

- It is recommended to Center-feed the branch circuit to minimize voltage rise in a fully populated branch circuit. Since the VRise is nonlinear, reducing the number of Microinverters on a QD Cable from the field wireables/ junction box to the farthest microinverter by center feeding and creating sub-branch circuits greatly reduces the voltage measured at the farthest microinverter in each sub-branch. To center-feed a branch, divide the circuit into two sub-branch circuits protected by a single overcurrent protection device (OCPD). Find out more in “Advantages of Center-Feeding the AC Branch Circuits”.

- Use the correct wire size for the AC extension cables and home-run cables during the system design. Using undersized conductors can result in nuisance tripping of the microinverter when an AC voltage out-of-range condition occurs. “What Contributes to Voltage Rise?” provides more information.

- Use the calculation methods in “Calculating Total Voltage Rise” to determine voltage rise values for your project.

Background

The IEEE 1547 standard requires grid-tied or utility-interactive inverters to cease power production if the measured AC grid voltage or frequency is too high or too low. Enphase IQ8D microinverter, like all utility-interactive inverters, will cease to export power based on the grid profile or compliance to local AHJ. For e.g. when measured voltage exceeding +5% or +15% over the nominal 120V over a prescribed duration.
If the voltage measured is outside of the limit, the Enphase IQ8D microinverter enters an AC Voltage Out-Of- Range (ACVOOR) condition and ceases to export power until this condition clears. Besides voltage variations from the AC grid, voltage changes within the system wiring can also contribute to VRise and could cause Microinverters to sense an over-voltage condition and cease operation.
The Enphase IQ8D microinverter reference point for voltage measurement is at the microinverter AC output. Since the microinverter is located in the array, and the point of common coupling (PCC) is generally at the site main panel, the distance from the microinverter AC output to the PCC could be substantial.
All components within system wiring contribute to resistance and must be considered when calculating the total VRise. The main factors that determine voltage rise in an Enphase Microinverter system are:

- distance from the Microinverters to the PCC, and
- conductor size.

“What Contributes to Voltage Rise?” provides details on factors contributing to the voltage rise in the IQ8D PV system. Typically, you can quantify the voltage rise of three distinct wire sections as described in “Voltage Rise by Wire Section”. There is also some resistance associated with each OCPD (Over Current Protection Device) but this is generally not considered.

What contributes to voltage rise?

Enphase Microinverter systems are installed as dedicated branch circuits of 9 IQ8D Microinverters with each branch circuit protected by a 20A OCPD. The following points must be considered for each branch circuit when calculating VRise.

- Wire size: Improper wire size can result in nuisance tripping of the utility-protective functions in the microinverter. Undersized conductors can cause the voltage measured at the microinverter to fall outside of the IEEE limits, triggering an ACVOOR condition. This results in loss of energy harvest. Although the National Electric Code recommends that branch circuit conductors be sized for a maximum of 3% VRise (Article 210.19, FPN 4.), this value in practice is generally not low enough for a utility-interactive inverters. Enphase recommends that the total percentage of voltage rise in the AC wiring to be a maximum of 2%, with (an inclusive) less than 1% voltage rise in the QD Cable.
- There is a tradeoff made between increased wire size and increased cost. You can often increase wire size by one AWG trade size with minimal cost impact. At some point, increasing the wire size necessitates increases in the conduit and/or terminal size, thus further increasing costs. However, the increased wiring and conduit costs can be offset by the increase in energy production over the lifetime of the system. These are important to invest in, especially for long wire runs.
- Circuit current: Circuit current varies depending on which "wire section" is being considered in the installation. "Voltage Rise by Wire Section" describes a typical installation containing three wire sections where current is considered. With QD Cable, current increases with each microinverter added to the circuit.
- Circuit length: There is often little control over circuit length, but center-feeding the dedicated branch circuit significantly reduces voltage rise within the branch, as described in "Advantages of Center-Feeding the AC Branch Circuits".
- Voltage Safety margin: If service voltage is chronically high, the utility will sometimes perform a tap change on the distribution transformer. This can provide a percent or two of additional voltage margin.
- Utility voltage: The utility typically is required to maintain voltage at the PCC within +/- 5% of nominal and in some states within +/- 3% of nominal. The protective functions of the Microinverters are set to +10% / -12% in the grid profile. The high voltage end of the tolerance is of most concern because the inverters are a source and not a load. If the utility is consistently 5% high, that leaves less than 5% for all wiring and interconnection losses as well as inverter measurement accuracy. If you are concerned about the utility voltage, you may request that your utility place a data logger at the PCC and make a record of the voltages available to you at the site.

Voltage rise by wire section

In this section, we are considering system configuration where each AC branch circuit are connected to PV sub panel and sub panel is connected to main panel. Following is the different wire sections contributing to voltage rise in the circuit.

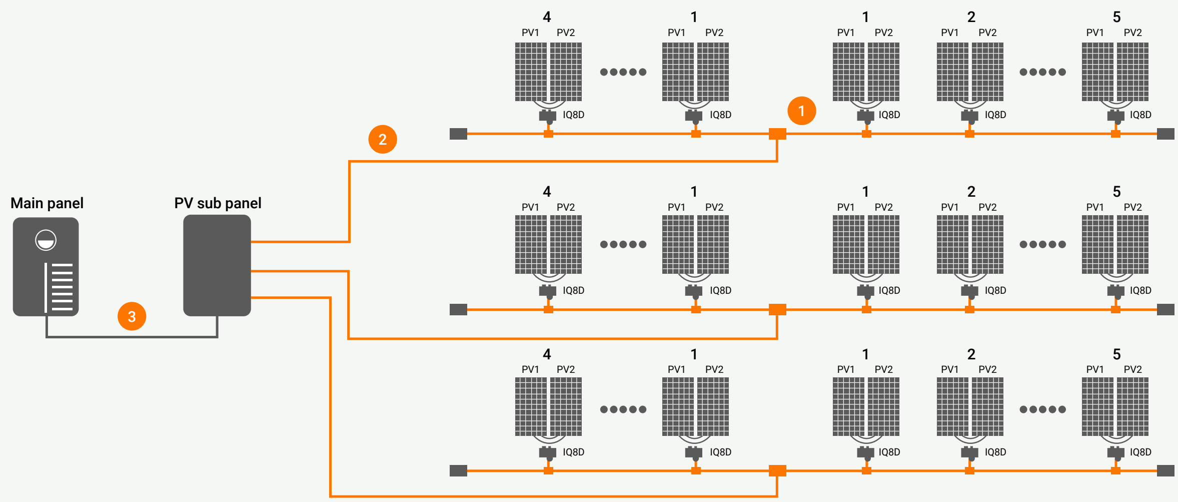


Figure 1

IQ8D Microinverter system using an Enphase IQ Combiner or PV sub panel

VRise section	Description
1	Internal voltage rise within the QD Cables. See internal VRise values for IQ Microinverters in Tables 1.1 through Table 1.3. Only the QD Cable with microinverter connectors is addressed in this section
2	Voltage rise from the array-mounted AC junction box / field wireables, along the AC branch circuits, to the PV sub panel containing the dedicated microinverter OCPDs (circuit breakers). See tables 2.1 through tables 2.2 for voltage rise in section 2
3	Enphase PV sub panel to the PCC. Voltage rise from the PV sub panel to the PCC. The table 3.1 in “Conductor Lengths by Wire Section” list maximum distances that maintain a 1% voltage rise for this wire section

Table 1

Calculate each component individually and verify that the total voltage rise is less than 2%. “Calculating Total Voltage Rise” lists formulas to determine voltage rise. Additional losses exist at the terminals, connectors, and in circuit breakers; however, if you design for a 2% total voltage rise, these other factors may be ignored.

Calculating total voltage rise

Voltage rise formulas

Enphase IQ8D microinverter is a single phase microinverter which is designed for three phase 208V small commercial applications. The IQ8D microinverter with QD Cables will meet the three phase requirements. The three phase QD Cable provides auto phase balancing through phase rotation across the QD Cable connectors. All resistances of the system components are part of this complex three-phase circuit. This technical paper simplifies the VRise calculations for the three phase voltages considering the current, resistance across each phase for VRise calculations

The VRise percentage for an Enphase Microinverter system is:

% of Total VRise = % VRise Section 1 + % VRise Section 2 + % VRise Section 3

Where,

% VRise Section 1 = % by number of Microinverters in Internal VRise of QD Cable with IQ8D Series Microinverters
% VRise Section 2 = VRise Section 2 ÷ System Voltage 208V
% VRise Section 3 = VRise Section 3 ÷ System Voltage 208V

Voltage rise in QD Cable

QD Cable is a 4 core 12 AWG cable with 4 conductors for L1, L2, L3 and neutral sense. QD Cable has power on two phases, sensing on the remaining phase and neutral for phase loss detection. This arrangement alternates between phases for each drop to achieve self-phase balancing. The QD Cable 4 pin male connectors plug directly into the IQ8D Microinverters. The following table lists the QD Cable types for Three phase systems.

QD Cable TYPES / ORDERING OPTIONS

Model Number	Max Voltage	Size	Connector Spacing	PV Module Orientation	Connector Count per Box
Q-12-10-150	277 VAC	12 AWG	1.4 m (4.6 ft)	Portrait	150
Q-12-20-135	277 VAC	12 AWG	2.4 m (7.9 ft)	Landscape	135
Q-12-42-63	277 VAC	12 AWG	4.6 m (15.1 ft)	Landscape Ballast	63

Table 2

Refer to the following tables to find VRise in QD Cable for your project based on the number of IQ8D Microinverters in an AC Branch Circuit.

Table 1.1 through Table 1.3 below provide VRise values for the IQ8D Microinverters in an AC branch circuit (with maximum of 9 micros per branch circuit) for multiple QD Cable options. Use these values to help calculate total VRise for your project based on number of Microinverters in the branch circuit. As the number of Microinverters in a branch circuit increase, the voltage at each microinverter rises in an exponential manner.

Portrait PV module orientation – 1.4 m (4.6 ft) Pitch

Microinverters	IQ8D Microinverters per branch (208Vac 3 Phase System)								
	1	2	3	4	5	6	7	8	9
VRise (V)	0.05	0.1	0.2	0.3	0.4	0.6	0.7	0.9	1.1
VRise (%)	0.02%	0.05%	0.08%	0.14%	0.20%	0.27%	0.36%	0.46%	0.56%

Table 1.1: Internal QD Cable VRise (IQ8D – 208V / Portrait cable, QD-12-10-150)

Landscape PV module orientation – 2.4 m (7.9 ft) Pitch

#Microinverters	IQ8D Microinverters per branch (208Vac 3 Phase System)								
	1	2	3	4	5	6	7	8	9
VRise (V)	0.1	0.2	0.3	0.5	0.7	1.0	1.3	1.6	2.0
VRise (%)	0.04%	0.09%	0.15%	0.24%	0.35%	0.46%	0.62%	0.78%	0.95%

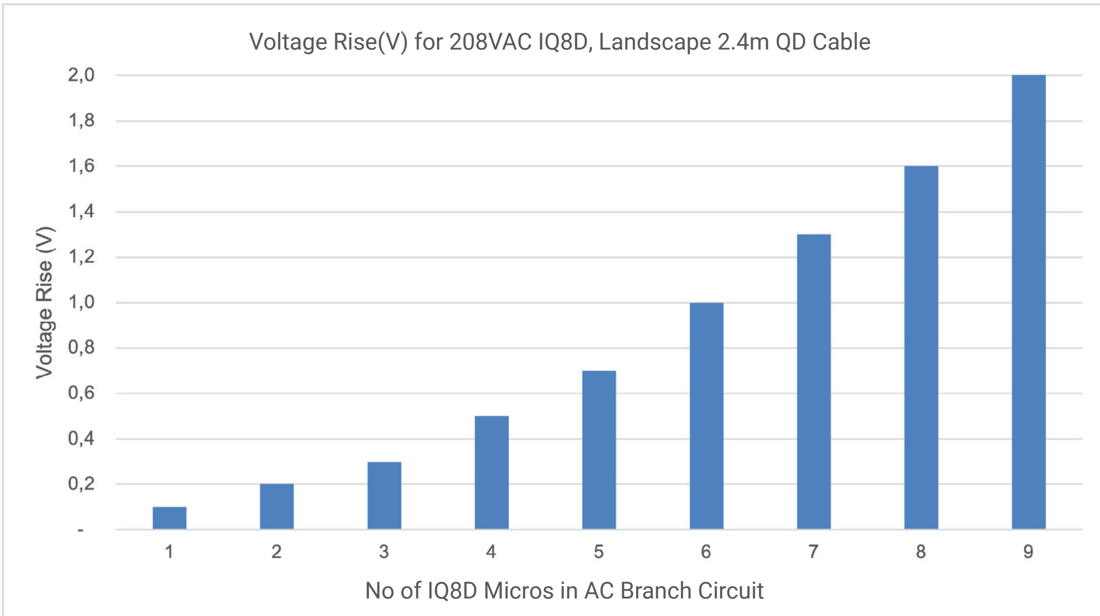
Table 1.2: Internal QD Cable VRise (IQ8D – 208V / Landscape cable, QD-12-20-135)

Landscape ballast PV module orientation – 4.6 m (15.1 ft) Pitch

#Microinverters	IQ8D Microinverters per branch (208Vac 3 Phase System)								
	1	2	3	4	5	6	7	8	9
VRise (V)	0.2	0.4	0.6	1.0	1.4	1.8	2.5	3.1	3.8
VRise (%)	0.07%	0.17%	0.28%	0.46%	0.67%	0.89%	1.18%	1.50%	1.83%

Table 1.3: Internal QD Cable VRise (IQ8D – 208V / Landscape ballast cable, QD-12-42-63)

The following graph illustrates how the number of Microinverters connected to a Landscape-oriented QD-12-10-135 (7.9 ft) QD Cable causes a non-linear voltage-rise when operating at 208 VAC.



Enphase recommends that the total percentage of voltage rise in the AC wiring be a maximum of 2%, with (an inclusive) less than 1% voltage rise in the QD Cable. Although the QD Cable is optimized for minimal VRise, it is still important to calculate total VRise for the entire system for the farthest microinverter in the branch circuits from point of common coupling.

Since voltage rise is exponential, reducing the number of Microinverters in the branch circuit greatly reduces the voltage measured at the farthest microinverter in the branch. One way to minimize this voltage rise is to center-feed the branch, that is, divide the circuit into two sub-branch circuits protected by a single OCPD.

Cable SKU (Pitch)	PV Module Orientation	VRise for last microinverter with end feeding	Recommended Vrise	Recommended AC Branch Connection: End / Center Feeding
QD-12-10-150 (4.6 ft)	Portrait	0.56%	<1% in QD Cable	End / Center Feeding*
QD-12-20-135 (7.9 ft)	Landscape	0.95%	<1% in QD Cable	End / Center Feeding*
QD-12-42-63 (15.1 ft)	Landscape Ballast	1.83%	<1% in QD Cable	Center Feeding**

** Center feeding possible only with junction box*
*** Center feeding with center tap connector in QD Cable or junction box*

Table 3

AC supply feeding recommendations for IQ8D Branch Circuits

QD-12-42-63 (15.1 ft) QD Cable Center Feeding Installation Recommendations :

A fully populated IQ8D branch circuit has 9 Microinverters and with QD Cable QD-12-42-63 (4.6m Landscape Ballast) the voltage rise for last microinverter becomes 1.83% which is more than recommended 1% voltage rise in QD Cable. Reducing the number of Microinverters on branch circuit to ≤ 6 Microinverters reduces voltage drop <1% (Refer Table 1.3). To maintain less than 1% of voltage rise in QD Cable for Landscape Ballast PV module orientation, Center-feeding is recommended for all installations with the QD-12-42-63 QD Cable.

Three Phase QD Cable provides Auto Phase balancing by rotating the connection in the QD connector with 3 different configurations (Refer Figure 2 for connections). In case of center feeding of AC branch circuit, it is important to maintain connections: Black-L1; Red-L2; Blue-L3 and Grey – Neutral Sense. In case of connection mismatch, phase balancing of the IQ8D System gets affected.

To avoid any mismatch, QD-12-42-63 cable includes a center-tapping connector with required connection configuration (Black-Pin 1; Red-Pin 2; Blue-Pin 3 and Grey – Pin 4) in an alternating pattern after sequences four and five connectors as shown in Figure 2

QD Cable being modular, can be easily cut to meet different AC branch circuit sizes. But to maintain VRise in QD Cable <1%; plan and install the system such that a maximum of 6 IQ8D Microinverters are installed on one side of center tapping connector so that the voltage rise to the farthest microinverter is maintained <1%.

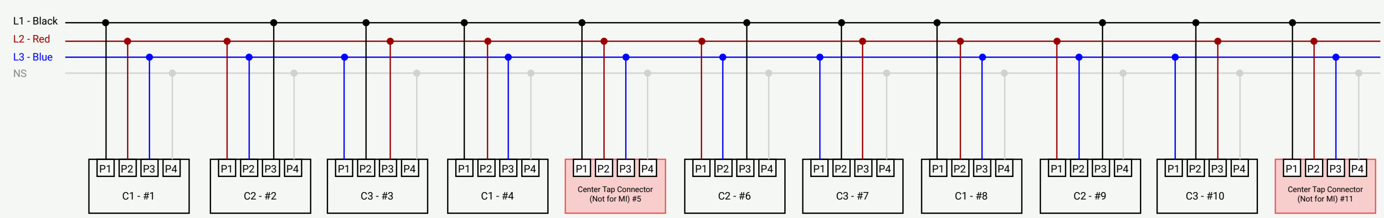


Figure 2

QD-12-10-150 (4.6 ft) and QD-12-20-135 (7.9 ft) QD Cable End Feeding Installation Recommendations :

A For QD Cable SKUs QD-12-10-150 and QD-12-20-135, the voltage rise in the QD Cable is <1% (Refer Table 1.1, 1.2) and hence End Feeding or Center feeding methodology can be used for the three phase AC Supply.

B Use the Enphase 3 Phase Field Wireable Connectors (QD-CONN-10M and QD-CONN-10F) for end feeding the AC supply to IQ8D Microinverter branch circuits.OR installers can use off-the shelf junction boxes for end feeding or center feeding the three phase AC supply to IQ8D Microinverter branch circuit.

NOTE: IQD Cable SKUS QD-12-10-150 and QD-12-10-135 does not include separate center tapping connector within the cable (Refer Figure 3). Hence it is recommended to use off-the shelf junction box for center feeding the three phase AC supply.

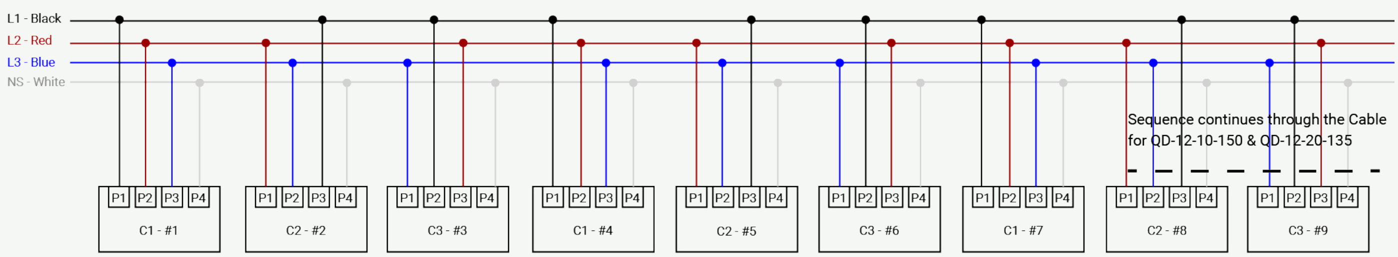


Figure 3

Installation guidelines for center feeding (QD-12-42-63 landscape ballast PV orientation)

The QD-12-42-63 cable includes a center-tapping connector in an alternating pattern after sequences four and five connectors as shown in Figure 2. So there are two center tap connectors available for branch of 9.

- When installing IQ8D Microinverter system using QD-12-42-63 cable; select the center tap connector such that a maximum of 6 IQ8D Microinverters are installed on one side of center tapping connector so that the voltage rise to the farthest microinverter is maintained <1%.
  NOTE : When using QD-12-42-63 for installations ; few of the center tap connectors shall remain unused based on system configuration. Do not remove pre-installed sealing caps on the center center tap connector, if the connector is not used for center feeding using Center Tap Adapter Cable (QD-LINKFW-10).
- Use a center tapping adapter cable (QD-LINKFW-10) to connect the center-tapping connector to the extension cable to PV sub panel using a male three phase field wireable connector (QD-CONN-10M).
- Provide an AC connection from the three-phase field wireable connectors to the three phase 208V grid supply using equipment and practices as required by local jurisdictions.

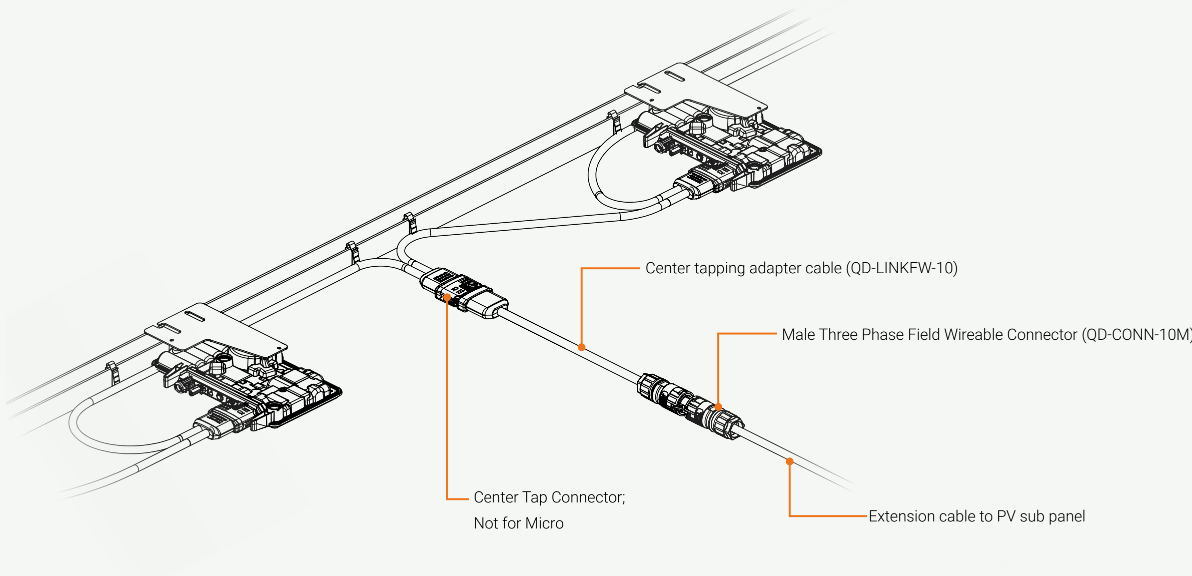


Figure 4

Center Tapping Adapter Cable

The Center Tapping Adapter Cable with 300 mm (11.8 inches) length has 4 pole Link connector on one side which should be connected to center tap connector in QD Cable and 3 phase field wireables on other side which should be used to make connections with extension cable to PV subpanel.
The 3 phase Field wireables allows connection for cable with wire gauge from 12AWG to 10AWG with outer diameter from 8 mm (0.3 inches) to 21 mm (0.8 inches).

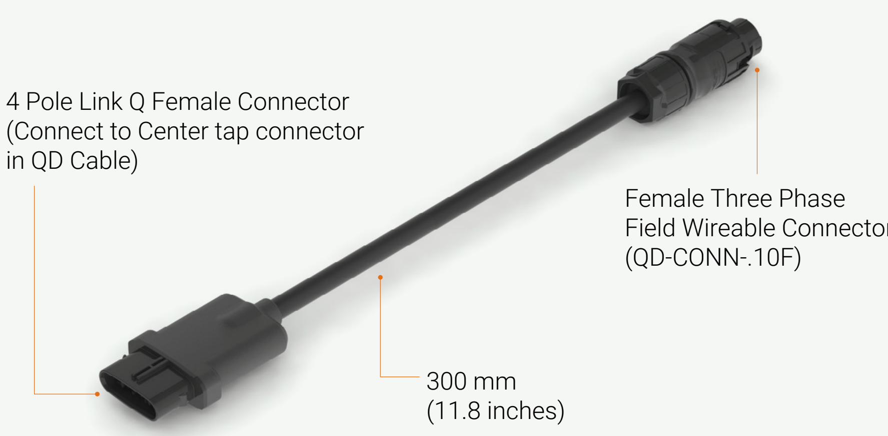


Figure 5

Figure 6 and Figure 7 show Voltage Rise for last microinverter when AC branch circuit connection is done with end feeding and center feeding respectively with Q-12-42-63 landscape ballast cable.
The cumulative Vrise for last microinverter in End feeding connection is 3.8V (1.83%) vs Vrise of 1.39V (0.67%) for center feeding connection.

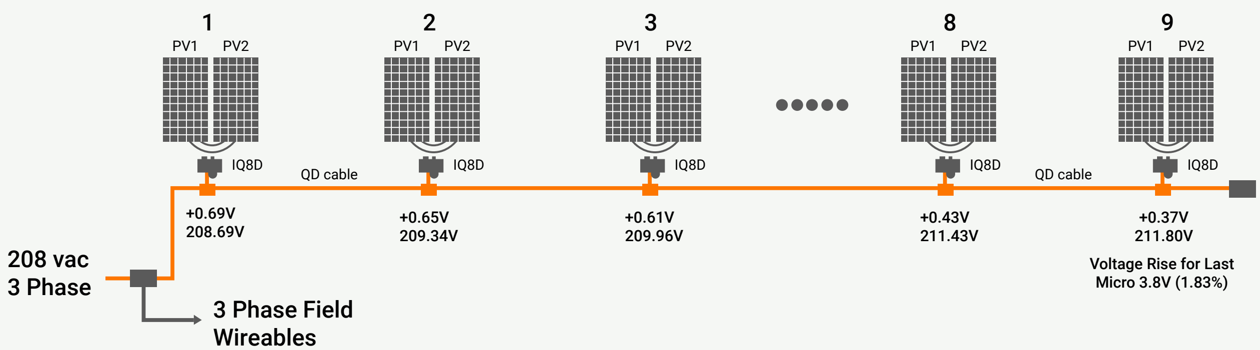


Figure 6

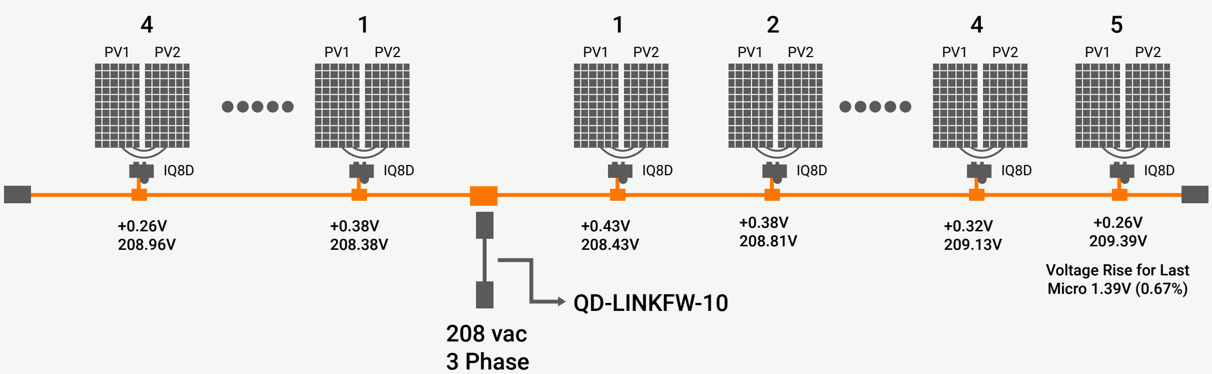


Figure 7

Voltage rise in extension cable from field wireables / junction box to PV sub panel

Refer table 2.1 and table 2.2 below to determine % voltage rise in extension cable from field wireables / junction box to PV subpanel. Table 2.1 and Table 2.2 shows voltage rise for 12 AWG and 10AWG cable respectively based on number of Microinverters and length of the cable
3 Phase field wireables accept cable up to 10AWG with maximum outer diameter of 21mm.

If the number of Microinverters per AC branch circuit are not in multiple of 3; then line current for the IQ8D PV system shall not be balanced. But for Vrise calculations, table 4 considers the line current with maximum value to calculate VRise in worst case scenario possible.

12 AWG length QD Raw Cable	IQ8D Microinverters per branch (208Vac 3 Phase System)								
	1	2	3	4	5	6	7	8	9
3.05 m (10 ft)	0.05%	0.06%	0.07%	0.12%	0.14%	0.15%	0.20%	0.21	0.22
6.10 m (20 ft)	0.10%	0.13%	0.15%	0.24%	0.27%	0.29%	0.39%	0.42%	0.44%
9.14 m (30 ft)	0.15%	0.19%	0.22%	0.37%	0.41%	0.44%	0.59%	0.63%	0.66%
12.19 m (40 ft)	0.20%	0.26%	0.29%	0.49%	0.55%	0.59%	0.78%	0.84%	0.88%
15.24 m (50 ft)	0.24%	0.32%	0.37%	0.61%	0.68%	0.73%	0.98%	1.05%	1.10%
18.29 m (60 ft)	0.29%	0.39%	0.44%	0.73%	0.82%	0.88%	1.18%	1.26%	1.32%
21.34 m (70 ft)	0.34%	0.45%	0.51%	0.86%	0.95%	1.03%	1.37%	1.46%	1.54%
24.38 m (80 ft)	0.39%	0.52%	0.59%	0.98%	1.09%	1.18%	1.57%	1.67%	1.76%
27.43 m (90 ft)	0.44%	0.58%	0.66%	1.10%	1.23%	1.32%	1.76%	1.88%	1.98%
30.48 m (100 ft)	0.49%	0.65%	0.73%	1.22%	1.36%	1.47%	1.96%	2.09%	2.20%

Table 2.1. Raw QD Extension Cable (QD-RAW-300)

10 AWG cable	IQ8D Microinverters per branch (208Vac 3 Phase System)								
	1	2	3	4	5	6	7	8	9
3.05 m (10 ft)	0.04%	0.05%	0.06%	0.09%	0.10%	0.11%	0.15%	0.16%	0.17%
6.10 m (20 ft)	0.07%	0.10%	0.11%	0.18%	0.20%	0.22%	0.29%	0.31%	0.33%
9.14 m (30 ft)	0.11%	0.15%	0.17%	0.28%	0.31%	0.33%	0.44%	0.47%	0.50%
12.19 m (40 ft)	0.15%	0.19%	0.22%	0.37%	0.41%	0.44%	0.59%	0.63%	0.66%
15.24 m (50 ft)	0.18%	0.24%	0.28%	0.46%	0.51%	0.55%	0.73%	0.78%	0.83%
18.29 m (60 ft)	0.22%	0.29%	0.33%	0.55%	0.61%	0.66%	0.88%	0.94%	0.99%
21.34 m (70 ft)	0.26%	0.34%	0.39%	0.64%	0.72%	0.77%	1.03%	1.10%	1.16%
24.38 m (80 ft)	0.29%	0.39%	0.44%	0.73%	0.82%	0.88%	1.17%	1.25%	1.32%
27.43 m (90 ft)	0.33%	0.44%	0.50%	0.83%	0.92%	0.99%	1.32%	1.41%	1.49%
30.48 m (100 ft)	0.37%	0.49%	0.55%	0.92%	1.02%	1.10%	1.47%	1.57%	1.65%

Table 2.2: 10AWG Extension Cable

Conductor lengths for home-run wire section

Use the table 3.1 to help determine the proper wire size based on the number of Microinverters in the circuit and the length of the wire section. The table 3.1 list the maximum length in feet a particular conductor can be run to maintain 1% voltage rise for this section of wire. Keep in mind that if multiple sections are combined, then the conductor size should be increased appropriately to meet current rating.

Cable Gauge	IQ8D Microinverters per branch circuit to maintain <1% Vrise based on 208Vac 3 Phase System																	
	9	18	27	36	45	54	63	72	81	90	99	108	117	126	135	144	153	162
8 AWG	29 m (96 ft)	14 m (48 ft)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6 AWG	46 m (153 ft)	23 m (76 ft)	15 m (51 ft)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4 AWG	74 m (243 ft)	37 m (121 ft)	24 m (81 ft)	18 m (61 ft)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3 AWG	93 m (306 ft)	46 m (153 ft)	31 m (102 ft)	23 m (76 ft)	18 m (61 ft)	-	-	-	-	-	-	-	-	-	-	-	-	-
2 AWG	118 m (387 ft)	59 m (193 ft)	39 m (129 ft)	29 m (96 ft)	23 m (77 ft)	-	-	-	-	-	-	-	-	-	-	-	-	-
1 AWG	148 m (487 ft)	74 m (243 ft)	49 m (162 ft)	37 m (121 ft)	29 m (97 ft)	24 m (81 ft)	-	-	-	-	-	-	-	-	-	-	-	-
1/0 AWG	187 m (615 ft)	93 m (307 ft)	62 m (205 ft)	46 m (153 ft)	37 m (123 ft)	31 m (102 ft)	26 m (88 ft)	23 m (77 ft)	-	-	-	-	-	-	-	-	-	-
2/0 AWG	236 m (776 ft)	118 m (388 ft)	78 m (258 ft)	59 m (194 ft)	47 m (155 ft)	39 m (129 ft)	33 m (111 ft)	29 m (97 ft)	26 m (86 ft)	-	-	-	-	-	-	-	-	-
3/0 AWG	298 m (980 ft)	149 m (490 ft)	99 m (326 ft)	74 m (245 ft)	59 m (196 ft)	49 m (163 ft)	42 m (140 ft)	37 m (122 ft)	33 m (109 ft)	29 m (98 ft)	-	-	-	-	-	-	-	-
4/0 AWG	376 m (1235 ft)	188 m (617 ft)	125 m (411 ft)	94 m (308 ft)	75 m (247 ft)	62 m (205 ft)	53 m (176 ft)	47 m (154 ft)	41 m (137 ft)	37 m (123 ft)	34 m (112 ft)	31 m (102 ft)	-	-	-	-	-	-
250 kcmil	444 m (1458 ft)	222 m (729 ft)	148 m (486 ft)	111 m (364 ft)	88 m (291 ft)	74 m (243 ft)	63 m (208 ft)	55 m (182 ft)	49 m (162 ft)	44 m (145 ft)	40 m (132 ft)	37 m (121 ft)	34 m (112 ft)	-	-	-	-	-
300 kcmil	533 m (1750 ft)	266 m (875 ft)	177 m (583 ft)	133 m (437 ft)	106 m (350 ft)	88 m (291 ft)	76 m (250 ft)	66 m (218 ft)	59 m (194 ft)	53 m (175 ft)	48 m (159 ft)	44 m (145 ft)	41 m (134 ft)	38 m (125 ft)	35 m (116 ft)	-	-	-
350 kcmil	623 m (2046 ft)	311 m (1023 ft)	207 m (682 ft)	156 m (511 ft)	124 m (409 ft)	104 m (341 ft)	89 m (292 ft)	78 m (255 ft)	69 m (227 ft)	62 m (204 ft)	56 m (186 ft)	52 m (170 ft)	48 m (157 ft)	44 m (146 ft)	41 m (136 ft)	39 m (127 ft)	36 m (120 ft)	-
400 kcmil	713 m (2339 ft)	356 m (1170 ft)	237 m (780 ft)	178 m (585 ft)	142 m (468 ft)	118 m (390 ft)	101 m (334 ft)	89 m (292 ft)	79 m (260 ft)	71 m (234 ft)	64 m (212 ft)	59 m (195 ft)	54 m (180 ft)	50 m (167 ft)	47 m (156 ft)	44 m (146 ft)	41 m (137 ft)	39 m (130 ft)
500 kcmil	887 m (2911 ft)	443 m (1455 ft)	295 m (970 ft)	221 m (727 ft)	177 m (582 ft)	147 m (485 ft)	126 m (415 ft)	110 m (363 ft)	98 m (323 ft)	88 m (291 ft)	80 m (264 ft)	73 m (242 ft)	68 m (223 ft)	63 m (207 ft)	59 m (194 ft)	55 m (182 ft)	52 m (171 ft)	49 m (161 ft)

** Table considers cable rating and resistance for THWN-2 cables as per NEC 2017 guidelines

Table 3.1: Voltage rise in homerun cable from PV sub panel to main panel

Sample calculations for three-phase 208 VAC installations

As part of this analysis, we calculate VRise for a sample scenario of a fully populated IQ8D System with 162 IQ8D Microinverters. Each 20A circuit has 9 IQ8D Microinverters. Each branch circuit has been center-fed into two sub-branch circuits of 5 and 4 Microinverters each with landscape ballast mounting orientation using cable QD-12-42-63.

Section 1: Voltage rise in QD Cable
Refer to the following table to find the QD Cable VRise appropriate for your project.

Landscape ballast, east-west mount orientation – 4.6m Pitch

#Microinverters	IQ8D Microinverters per branch (208Vac 3 Phase System)								
	1	2	3	4	5	6	7	8	9
VRise (V)	0.2	0.4	0.6	1.0	1.4	1.8	2.5	3.1	3.8
VRise (%)	0.07%	0.17%	0.28%	0.46%	0.67%	0.89%	1.18%	1.50%	1.83%

Table 1.3: Internal QD Cable VRise (IQ8D –208V / Landscape ballast cable, QD-12-42-63)

For a sub-branch circuit of 5 IQ8D Microinverters when center feeding the AC branch circuit, the voltage rise on the 208 VAC QD Cable is 0.67%

Section 2: Voltage rise in extension cable from field wireables / junction box to PV sub panel
QD Cable is connected to PV sub panel using the extension cable using male and female field wireables or junction box. Use table 4, table 5 for calculating Voltage rise. To further reduce voltage rise, you may increase the conductor size and use the following calculation. Please note that field wireables accepts cables with gauge of 12AWG to 10AWG.
This run uses 40 feet of 10AWG extension cabling.

- VRise = (amps/inverter × number of inverters) × (resistance in Ω/ft) X (cable length in feet)
- The following example is for a fully populated circuit of 9 IQ8D Microinverters
- IQ8D full load AC current = 3.076A
- Wire gauge for Extension cable = #10 AWG THWN-2 CU
- #10 AWG THWN-2 CU resistance = 0.00124 /ft (from NEC 2017)
- Length of individual branch circuit = 40 feet
- VRise= (3.076A × 9) × (0. 00124 Ω/ft) × (40 ft) = 1.374 volts
- %VRise = 1.374 volts ÷ 208 volts = 0.66%

Section 3: Voltage rise in homerun cable from PV sub panel to main panel

To calculate the Voltage Rise in this portion of the circuit, multiply the combined current of the microinvers in the branch by the total resistance of the wire run
VRise = (amps/inverter × number of inverters) × (resistance in Ω/ft) X (cable length in feet)
The following example is for a fully populated IQ8D System of 162 Microinverters
This run uses 80 feet of 400kcmil extension cabling

- VRise = (amps/inverter × number of inverters) × (resistance in Ω/ft) X (cable length in feet)
- IQ8D full load AC current = 3.076A
- Wire gauge for Extension cable = 400kcmil THWN-2 CU
- 400kcmil THWN-2 CU resistance = 0.0000321 /ft (from NEC 2017)
- Length of individual branch circuit = 80 feet
- VRise= (3.076A × 162) × (0. 0000321 Ω/ft) × (80 ft) = 1.280 volts
- %VRise = 1.280 volts ÷ 208 volts = 0.62%

Summary of wire section calculations

For systems with very long branch circuit runs and/or very long runs from the PV load center to the PCC, it is best to make the VRise in the QD Cable as small as possible. After accounting for additional losses within connections, terminals, circuit breakers, and unexpected increases in wire length, we recommend implementation of a total system voltage rise of less than 2%

Section	Description	% VRise
Section 1	Voltage rise in QD Cable from the microinverter to the field wireables / junction box	0.67%
Section 2	Voltage rise from the field wireables / AC Junction box to the microinverter sub panel	0.66%
Section 3	Voltage rise from the microinverter sub panel to the main service panel (PCC)	0.62%
Total system voltage rise for all three wire sections		1.95%

Table 4

Conclusions

Center-feeding is a great way to decrease home run conductor costs, improve production, and increase system reliability. Follow the guidelines and calculations in this document to help minimize voltage rise issues with your installation and increase system production.

ENPHASE

Data subject to change.06-08-2022