Connecting Multiple Sunny Boy Inverters to a Three Phase Utility

Technical Note

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Abstract

Sunny Boy string inverters are used throughout the world for all sizes of grid tied photovoltaic (PV) installations. Large installations within the United States have historically used central inverters. The interconnection difference between these two approaches is a trade-off between AC or DC circuit collection.

This document has been updated to include new inverters that have been introduced in the US market. These new inverters have different requirements and special considerations when installed into a three phase electrical service.

Introduction

This document does not attempt to detail all the National Electrical Code (NEC) or local codes applicable to photovoltaic installations. All of the requirements of the NEC, including those found in Article 690-Solar Photovoltaic Systems, should be followed. These guidelines will include some of those requirements, but by no means all of them. Local electrical and building codes should also be followed and they may dictate additional requirements not found in these guidelines or the NEC.

Connecting a large number of string inverter AC outputs to a utility system is much simpler than combining a similar number of PV DC circuits for connection to a central inverter. Interfacing a central inverter with a large PV array requires a specially designed DC collection center. It must be rated for 600Vdc (in the US), contain over-current protection for each individual PV string circuit, and bus work for the single output circuit to the central inverter. The PV disconnect device required by NEC Article 690 must be load-break rated for 156% of the combined PV array short-circuit current. These large collection centers are typically custom built, very expensive and will not be listed to UL1741. The components necessary for connecting multiple AC inverter outputs to a utility system are readily available, less expensive than similar DC rated components, simple to install, comply with UL and NEC requirements, and are familiar to electricians and inspectors.

Three-phase utility systems are discussed through this document. Typically, PV installations involving more than 10kW will be connected to a three-phase distribution system. However, this document may also be applied to single or split-phase distribution systems as needed.

Dedicated Inverter AC Sub-Panel

The simplest solution to connecting multiple inverter AC outputs to a single point of utility connection is frequently an AC sub-panel dedicated to the PV power system (refer to the single line drawing at end of this document). This sub-panel may be installed near the PV inverters to minimize the distance of the multiple AC wire runs. All components are readily available and simple to install.

Care should be taken to balance the inverters around the three phases of the distribution system. Loading individual inverter output breakers from the top of the panel will minimize the current path through the panel bus bars, while insuring the inverter outputs are balanced around the three phase system. If inverters with various AC output current ratings are combined, install the inverters with the greatest output currents above inverters with lesser output currents. This will minimize the high current path to the main conductors. If any load breakers are installed in the dedicated sub-panel, position them below the inverter breakers.

Connect the output of the sub-panel to the main utility distribution panel with the proper type and size wire for the installation. There may be site specific conditions which require the AC conductor sizes changed from their standard diameter. This document will cover the specific requirements for these changes, and their implications throughout the AC connection system.

NEC Requirement Overview

Distribution Panel Sizing

The main utility distribution panel requires a main circuit breaker properly sized for the combined maximum output current of all the string inverters. NEC Section 690.64(B)(2) dictates: "The sum of the ampere ratings of overcurrent devices in circuits supplying power to a busbar or conductor shall not exceed the rating of the busbar or conductor." Therefore the sub-panel busbars must be rated to carry the combined currents of the main panel breaker as well as the sum of all the individual breakers within the panel.

DC Conductor and Over-Current Protection Sizing

On the DC side the NEC requires that the PV output source circuit conductors and over current devices be sized for 156% of the short-circuit current rating of the PV array. This 156% multiplier comes from two 125% multipliers. The first multiplier is found in Article 690.8(A)(1) for high irradiance level safety, and the second from Article 690.8(B)(1) as a general safety factor for sizing conductors and over current devices. For one or two PV strings per inverter, the PV conductors will be large enough not to require any DC protection between the PV array strings and the inverter. In the event of a ground fault at any point in the PV wiring, the string conductors are large enough to handle the full current capacity of the PV array. Fuse protection may be required for more than two PV source circuits per inverter if the modules and module conductors are not rated to carry 156% the short-circuit rating of the entire PV array. In this case a fuse rated for 156% of the string short-circuit current rating or the PV module manufacturer's series fuse rating as provided on the PV module data sheet is required between each PV string circuit and the inverter.

DC Disconnect

NEC Section 690.15 requires a means to disable all ungrounded conductors of all sources. Local utilities and inspectors generally require a PV disconnect switch between the inverter and the PV array. The switch must be DC load-break rated for the maximum voltage of the PV array (600Vdc maximum for most Sunny Boy installations), as well as 156% of the short-circuit current rating of the entire PV array. Many disconnect switches require the DC conductor be series through 2 or more poles of the switch for DC applications. However there are some disconnect switches that have been evaluated by UL® for 600Vdc using only a single pole. NEC Section 690.13 does not allow the grounded conductor to be disconnected unless there is a fault condition. Most PV arrays installed in the United States ground the negative conductor. To satisfy NEC Section 690.13, the negative conductor will pass through the DC disconnect enclosure without being switched, therefore only the positive conductor will pass through the switch poles.

AC Over-Current Protection

NEC Section 690.9(A) requires each inverter to have individual AC over-current protection. Each inverter type has its own circuit breaker size requirement. Please consult the following table for the proper circuit breaker size for each inverter.

Inverter Model	Max AC Current	Breaker Size	# of poles
SB 700U	6.6 A	10 A	1
SB 1100U	5.2 A	10 A	2
SWR 1800U	15.0 A	20 A	1
SWR 2500U	10.4 A	15 A	2
SB 3800U	16 A	20 A	2
SB 6000U (240 and 208V_{AC})	25.0 A	40 A	2
SB 6000U (277V_{AC})	21.7 A	30 A	1

Circuit breakers should be rated for bi-directional operation. Fuses are typically Class R dual element type, but other types may be used if rated for the application. NEC Section 690.8(B) specifies the over-current protection should be rated at not less than 125% the rated current of the inverter calculated in NEC Section 690.8(B)(3) in accordance with NEC Section 240.3(B) & (C). All Sunny Boy inverters are AC current limited, so it is not necessary to consider the short circuit current PV array when sizing the AC over-current protection.

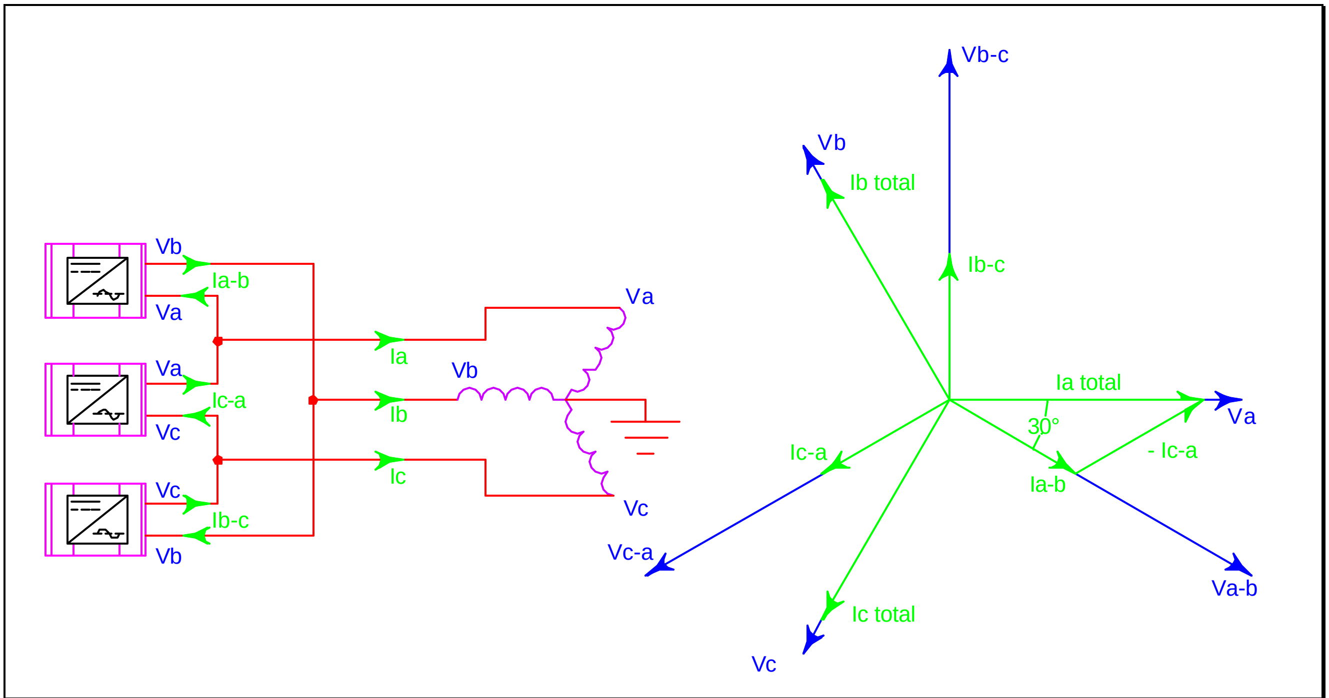
Below is an example for sizing the AC protection for one SWR2500:

$$\text{Calculate Protection for One Sunny Boy 2500 Inverter}$$
$$10.4 * 125\% = 13\,A \text{ Use a two} - \text{pole } 15\,\text{A breaker for each SB2500 Inverter}$$

To calculate the size of the three-phase dedicated panel breaker, the single-phase currents must be calculated. There are two general cases for this calculation. In the first case, each inverter is attached to a single line of the three phase system. Using SWR 1800U or SB 700U inverters in a 208 WYE system or using SB 6000U inverters in a 480 WYE system are examples of this. In the second case, each inverter is attached to two of the three phases in the system. Using SWR 2500U, SB 3800U or SB 6000U inverters in a 208 WYE or Delta system or using SB 1100, SWR 2500, SB 3800U, or SB 6000U inverters in a 240 Delta system are examples of this case.

To calculate the single phase currents in the first case is quite simple. All we need to do is add the maximum AC output current of all of the inverters attached to each phase. We should then compare the results to determine the maximum current supplied to a single busbar. Whichever phase has the largest single phase current will determine the size of the over current protection and conductors from that panel to the main service.

To calculate the total phase currents in the second case, where inverters are installed on each of two phases in the three phase system, consider the following diagram:



Calculate the A phase current

From the diagram

$Ia = Iab - Ica$

From the phasor diagram

$Ia_{total} = 2Iab\cos(30)$

or $Ia_{total} = \sqrt{3}Iab$

Assuming all inverters can generate equal current, the peak currents on each phase will be

$10.4 \times \sqrt{3} = 18$ Amps

To calculate phase currents for 9 inverters, 3 across each phase to phase connection

$3 \times 18 = 54$ Amps per phase

Per NEC 690.8(A)

$54 \times 1.25 = 67.5A$

NEC 240 - 3(b) states to use the next standard size protection device, which in this case is an 70A Circuit Breaker from NEC 240.6(A)

There is an exception to this rule stated above. If you have a single 2-leg inverter in a three phase system, for example a single SB 6000U in a 208 WYE system, or the 10th SWR 2500U on a 208 WYE system, then the √3 multiplier is not used for that single inverter's current contribution. So the maximum single phase current for ten (10) SWR 2500 inverters in a 208 WYE system would be:

$$\boxed{3*10.4\sqrt{3} + 10.4 = 64.4A*125\% = 80.5A}$$

AC Wire Sizing

The current rating of the AC wiring should be greater than the protection devices in the circuit to insure the over-current device clears before any of the current-carrying components fail during an over-current condition. Considerations should also be made for the wire insulation type, insulation temperature rating, conduit type, and ambient temperature that the wire will experience (within the conduit). This is dependent upon the conditions of the installation. Consider the following example continued from case 2 above:

Minimum ampacity requirement : 70 Amps (from breaker rating)

Direct burial or raceway installation, insulation type: THHW, 75° C

Calculate necessary current rating with 50° C temperature derating :

From NEC Table 310-16 correction factors :

$$\frac{54A}{0.75\,cf} = 72A$$

The wire current rating must be greater than calculated and greater than the current rating of the AC protection device (70A). From NEC Table 310-16, copper wire, 75° C, THHW insulation :

Use minimum 4 AWG, rated at 85 Amps. This will also satisfy the main breaker rating.

There are many situations where the AC conductors need to be larger than the sizes calculated above, for example when the AC voltage drop becomes excessive due to long AC wire runs. If it becomes necessary to increase the wire diameter of the ungrounded conductors then the NEC requires that the grounded and grounding conductors also be increased. An example and full explanation of this can be found in the Design Considerations section.

Main Breaker and AC Panel Sizing

Regardless of which method was used to determine the maximum single phase current, the main breaker size is determined by the multiplying the largest single phase current by the NEC required 125% safety factor.

To properly size the AC panel, we must keep in mind NEC Section 690.64(B)(2) which requires that the sum of all breakers supplying current to a busbar must not exceed the rating of the busbar. To determine how many breakers are feeding current to a busbar, we again have two cases. If we are using single line inverters, then the multiply the number of inverters per phase by their breaker rating and add the main breaker size. If we are using two line inverters, then we must be careful to include all of the breakers attached to each busbar. Because each inverter has two legs, we will have twice as many breakers attached to each busbar as you would think.

Case 1:

Assume that we have six (6) SB 6000U inverters in a 480/277 three phase system. Each phase has two (2) 30 Amp breakers, and the main breaker should be a 60 Amp breaker. This means that we have a total of 120 Amps of breakers, [2 * 30 + 60], so the busbars must be rated for the next normal size over 120 Amps which will be 200 Amps.

Case 2:

Assume that we have ten (10) SWR 2500 inverters in a 208/120 three phase system. The maximum single phase current will be 64.4 Amps, as we calculated above, so the main breaker should be 100 Amps. To size the busbars, we will have a maximum of seven 15 Amp breakers on one phase, remember each inverter is attached to two phases, and the main 100 Amp breaker. So the total of all breakers supplying current to the busbars is [7 * 15 + 100] or 205 Amps. The means that the busbars must be rated at the next normal size over 205 Amps, or 300 Amps.

AC Disconnect

NEC Section 690-14 references Section 230.70 which requires all service entrance conductors be provided with a means to be disconnected from the building or structure. NEC Section 690.17 allows the AC circuit breaker to serve as the over-current protection device as well as the means of AC disconnect. However, many local utilities and electrical inspectors require a 'Heavy-Duty' lockable disconnect switch for isolation during system service or maintenance. For multiple inverter installations, only one AC disconnect switch is necessary for all of the inverters. Some utilities require only one AC disconnect for all generation equipment installed at the site. If there is a dedicated AC distribution panel, the disconnect switch may be placed between the dedicated AC sub-panel and the main building distribution panel. NEC Section 230.70 does not specify proximity of the disconnect switch to the PV system, but local inspectors generally require the switch to be placed near the inverters. The switch should have a current rating greater than or equal to the ratings of the over-current protection devices in the circuit. From the example above, a three-phase 100 Amp disconnect switch may be used. Individual inverter AC isolation may be achieved by the 15 Amp, 2-pole circuit breakers located in the dedicated AC distribution sub-panel.

Design Considerations

When planning a large PV installation using string inverters, consider the following:

Utility Interconnection Requirements

Consult with the local utility to understand any specific requirements for interconnecting a PV system to their distribution system. Large PV systems, usually defined as larger than 30 kW peak generating capacity, may have unique requirements depending on the existing distribution network. Most utility companies also have an application process that must be completed prior to interconnection.

Local Inspector Requirements

Consult with local building and electrical inspectors, as well as the local utility to understand requirements that may be unique to the installation or service area. For instance: NEC Section 690.17 allows the AC circuit breaker to serve as the over-current protection device as well as the means of AC disconnect. However, many local utilities and electrical inspectors require a 'Heavy-Duty' lockable disconnect switch.

Distance from Inverter to AC Sub-panel and PV Array

Long wire runs may require over-sizing of conductors to compensate for voltage drop. Voltage drop is caused by the resistance in the conductors; the smaller the conductor, the larger the resistance. Current passing through the conductor will create voltage per the simple V=IR relationship, Ohm's Law. As current increases, voltage linearly increases as the resistance is essentially fixed (resistance changes as a function of temperature, but consider it to be fixed at 75°C as assumed by NEC Table 9). The NEC allows for 3% drop on any conductor. Not only is this analogous to a 3% efficiency loss, but it also creates a 3% rise in voltage as the generation device delivers current to the utility. For equipment installed on utility systems with high line voltage, or widely varying voltage, generation equipment may frequently disconnect due to perceived utility over-voltage faults. For this reason it is critical to minimize the AC voltage drop more so than on the DC side. Voltage drop on the DC side will result in efficiency loss; however, this will not cause the inverter to function improperly. We recommend all conductors be sized for less than 1.5% voltage drop. Refer to NEC Chapter 9, Table 9 for information on conductor impedances.

Frequently, actual voltage rise in a distribution system will be greater than calculated due to poor or numerous wiring connections. Always use a minimum amount of quality fastening systems. SMA does not recommend using wire nuts for splicing wires. They are commonly installed improperly and are a notorious cause of high impedance connections.

Consider the following example:

10AWG copper conductor in steel conduit, 750' wire run from inverter to service panel (from NEC Chapter 9 - Table 9)

$$Z_e = R \times PF + X_L \sin[\cos^{-1}(PF)]$$

$$Z_e = R, \text{ since PF}=1$$

$$Z_e = 1.21\Omega \text{ per } 1000' \text{, or } 1.82\Omega \text{ for } 1500' \text{ total circular distance}$$

assume : $V_{\text{nominal}} = 252\text{Vac}$ (high line voltage)

Maximum AC current for Sunny Boy 2500 = 10.4A

$$V_{drop} = IR$$

$$V_{drop} = 10.4 \times 1.82 = 18.93$$

Apparent voltage seen at inverter terminals :

$$V_{\text{terminal}} = V_{\text{drop}} + V_{\text{nominal}}$$

$$V_{\text{terminal}} = 18.93 + 252 = 270.93$$

Even though 10AWG wire is capable of carrying the 10.4 amps of current from the inverter, the wire impedance and run distance will cause significant voltage increase during full inverter output current. The upper voltage limit of the Sunny Boy 2500 is 264V in a 240Vac nominal system. To ensure that the inverter never exceeds this limit, they usually disconnect from the AC grid if the voltage approaches 262Vac. This inverter will most likely experience frequent utility voltage faults. In order to reduce the voltage drop from 7.8% with 10AWG to our recommended 1.5% we will need to increase the diameter of the wire to 3AWG.

Wire Size for Equipment Grounding Conductor

If it becomes necessary to increase the diameter of the ungrounded conductors, then NEC 250.122 states that we must increase the diameter of the equipment grounding conductor by a proportional amount. Table 250.122 lists the equipment grounding conductor size to use based on the size of the overcurrent protection for the branch circuit. Use this table to determine the base size for the equipment grounding conductor then use Chapter 9 Table 8 to determine the diameter increase ratio used to increase the diameter of this conductor.

Continuing the example above, for a Sunny Boy 2500 we should use a 15A 2-pole breaker. From Table 250.122 the proper equipment grounding conductor size is 14 AWG copper. When we increase the diameter of the ungrounded conductor from 10 AWG to 3 AWG we have to increase the diameter of the equipment grounding conductor a proportional amount. As you can see from the equations below, the proper grounding electrode conductor size for this 750' run is 6 AWG.

From Chapter 9 Table 8:

$10\,AWG = 10380\,cmils \qquad 3\,AWG = 52620\,cmils \qquad 14\,AWG = 4110\,cmils$

$$\frac{52620\,cmils}{10380\,cmils} = 5.07$$

$4110\,cmils * 5.07 = 20838\,cmils$

The next normal size greater than or equal to 20838 cmils is 6 AWG

$6\,AWG = 26240\,cmils$

Wire Size for grounded or neutral conductor

There are three different cases for neutral conductor sizing. Examples of these cases can be seen in the figures attached to the end of this document. In the first case, there are no neutral connections to the Sunny Boy Inverters, so the only sizing requirement is from the distribution panel to main panel wiring, if any. In the second case, the neutral conductor is considered a current carrying conductor by the NEC code and must therefore meet the requirements of NEC 200 and NEC 210. In the third case, the neutral conductor is for reference only and will not be a current carrying conductor. The NEC does not cover this type of case explicitly. Unless you can convince them otherwise, most inspectors will require that the grounded conductor be the same size as the ungrounded conductors even though it will not carry any current. This is usually based on rationales derived from case 2 like situations.

Power loss considerations

Another thing to consider is power loss caused by conductor impedance. Continuing with the example from above:

$$W = I^2 R$$
$$W = 10.4^2 \times 1.17$$
$$W = 126$$

This loss equates to about 0.5% of total power output of the system. Similar calculations should be done for the DC conductors. SMA recommends the inverter be located near the PV panels, but some installations may require long DC wire runs. If that is the case then we will have to strike a balance between voltage drop, power loss, and economic cost associated with larger wires.

As a last note on cable size, the Sunny Boy 6000U will take up to 6AWG cable on the AC and DC inputs, and the others will take up to 10AWG. If the cables used in the AC and DC wire runs are larger than the maximum input size, you will need to use some device to reduce the wire size just before it enters the inverter.

Termination Techniques

Each inverter should have a dedicated AC wire run to a dedicated circuit breaker. Do not parallel inverters prior to main feed to the utility sub-panel. All connections should be high quality bonds from mechanical devices or crimp devices such as mechanical compression fittings found in circuit breakers or compression lugs for connection to solid bus bar. Do not place multiple wires into any single connection device. Poor quality or improperly installed conductor splicing devices (wire nuts, split nuts, butt connectors, etc.) may create a high impedance bond. This can lead to excessive heating, causing voltage drop and system losses. Extended operation could lead to arcing and fire. Be sure all termination devices are properly installed and meet the environmental requirements for the device.

Some breakers and terminal blocks are listed for use with more than one conductor per contact. These devices will be clearly marked for this application.

AC Point of Interconnection

Photovoltaic inverters may be connected to the AC distribution system on either the load or supply side of the service disconnecting means. NEC Section 230.82 exception 6 specifically allows PV systems to be tied to the supply side; however, protection and disconnecting equipment must be suitable for use as service equipment. In this case you are creating a second service entrance, and all of the requirements for a service entrance now apply. NEC Section 690.64(B) explains the requirements for interconnection on the load side of the service disconnecting means. Each inverter must have a dedicated circuit breaker of fusible disconnecting means. Also, the sum of all overcurrent devices is not allowed to exceed the rating of the service busbar or conductor (load center).

Installing One Inverter on a Three Phase System

Installing one inverter on a three-phase system is quite simple. If you have a single leg inverter, the SWR 1800U at 120V or SB 6000U at 277V for example, then simply choose the phase you will attach to, install a properly sized AC breaker, and ensure that your service panel is adequately sized for the added supply of current. Any two leg inverter, the SWR 2500, SB 1100, SB 3800U, or SB 6000U (240 or 208) for example, may be installed across any two phases that supply the appropriate voltage for that inverter. The same requirements for breaker and distribution panel size apply here as well. Sunny Boy inverters are equipped with an internal isolation transformer, which allows connection with any configuration of grounded or floated utility distribution system.

Balancing Inverters on a Three Phase System

Some Sunny Boy inverters generate line-to-line current, while others generate line-to-neutral currents, but they all may be connected to three-phase WYE or delta utility services. Line-to-line connected inverters eliminate imbalanced neutral currents caused by single-phase inverters connected to the AC neutral. However the single leg inverters can cause neutral current imbalances if they are not balanced across the three phases. In any case, the Sunny Boy utility voltage protection will shut down the inverter in the event a significant phase imbalance occurs.

Care should be taken to evenly balance the total number of inverters around the distribution system. This will insure that all system distribution conductors carry an equivalent amount of current. It is not necessary to install multiples of three inverters on three phase systems. Sunny Boy installations should never create more than a single inverter's maximum output power of imbalance on properly designed systems, but this will vary based on the type of inverter used in the system. Using a dedicated AC distribution panel described above will simplify balancing multiple inverter installations.

Delta or WYE Utility Interconnection

Sunny Boy inverters may be connected to a grounded or ungrounded delta or WYE utility distribution system. The output of the Sunny Boy inverters can be single-phase 120, 208, 240, or 277Vac depending on which inverter is used in the system. There should be both a DC and AC system grounding point in the inverter at or near the PE connection within the inverter. The SWR 2500 has no AC center ground from the inverter to create a 120Vac single-phase reference. Therefore, multiple inverter installations with the SWR 2500 are connected to the utility system phase-to-phase, in a delta manner, regardless of the existing utility configuration. Multiple inverters may be connected to either a grounded or floating WYE system in a phase-to-phase manner. There will be no connection between the inverters and the neutral ground of a WYE or grounded delta system.

For the single leg inverters, the SWR 1800 and SB 6000U (277), there is a connection to the AC center ground reference. These inverters can only be attached to a grounded neutral WYE transformer in a phase to neutral manner.

Finally the SB 6000U (208 or 240) and SB 3800U must have a neutral reference connection if one is present in the three phase power system according to the new IEEE 1547 standard. If the inverter is connected to a 208 or 240 ungrounded DELTA transformer then no neutral connection is required. If the inverter is connected to a 120/208 WYE or the across the two legs of a 240 DELTA with Stinger transformer that are grounded then the neutral connection must be made in addition to the connection to the two hot legs. For more information about these connections please see the SB 6000U or SB 3800U installation and operation manual, whichever is appropriate.

Isolation Transformers

Each Sunny Boy inverter is equipped with an internal isolation transformer. This isolates the AC utility system from the inverter and the PV system. This also allows a grounded PV array to be used with a ground referenced AC distribution system. This means that additional isolation transformers external to the Sunny Boys should not be used. With all of the Sunny Boy models now available, there should be a Sunny Boy inverter to match every AC distribution transformer in common usage. If you find that the voltage must be stepped up or down for a specific installation, using an auto-former transformer is all that is required.

Check with the utility of jurisdiction regarding the transformer being considered. Some utility companies have specific requirements regarding the type and configuration of transformers installed on their distribution systems. When transformers are added, be sure to reference NEC Article 450 and Section 690.9(B) for appropriate code requirements.

PV Array Conductor Grounding

NEC Section 690.41 & 42 requires the PV array be electrically grounded at any single point on the PV output circuit. In the Sunny Boy inverter family, this is accomplished within the inverter enclosure. The PV array negative conductor is connected to the PE terminal on the AC interface terminal block. No other PV conductor ground may be made for the ground fault detection circuitry to function properly.

A ground bond is required between the PE terminal within the inverter enclosure and the system earth ground. This may be a conductor from PE to the building neutral bus. The grounded DC conductor may not be smaller than the largest PV circuit conductor (see NEC Section 250.166).

In the event of a PV array ground fault, current will flow through the PV negative ground connection within the inverter and clear a 1 Amp fuse (GFDI fuse) in series with the ground connection. The inverter will shut down and report the GFDI fuse is open. The inverter will not attempt to restart until the ground fault has been corrected and the GFDI fuse replaced.

Recent interpretations of the grounding requirements for PV systems can be found in other publications. For a good primer on appropriate grounding systems for use with in both single and multiple inverter installations please see the "Perspectives on PV" article published in the July-August 2005 edition of the IAEI News, p.83-87. (www.iaei.org)

Positive Ground PV Arrays

New modules are being created which require a positive ground system instead of the industry standard negative ground system. All Sunny Boy Inverters can be modified for use with a positive ground PV array. Please simply inform SMA when ordering inverters for use in a positive ground system so that we can make the appropriate modifications to the inverter.

Ungrounded PV Arrays

New in the NEC 2005 edition is a provision for ungrounded PV arrays. At this time of this revision, ungrounded arrays are not available in the US because the required double jacketed module interconnect wire has not been UL listed. Ungrounded PV arrays are the industry standard in Europe and SMA has several Sunny Boy Inverters available that can be used in ungrounded PV systems when they become available in the US.

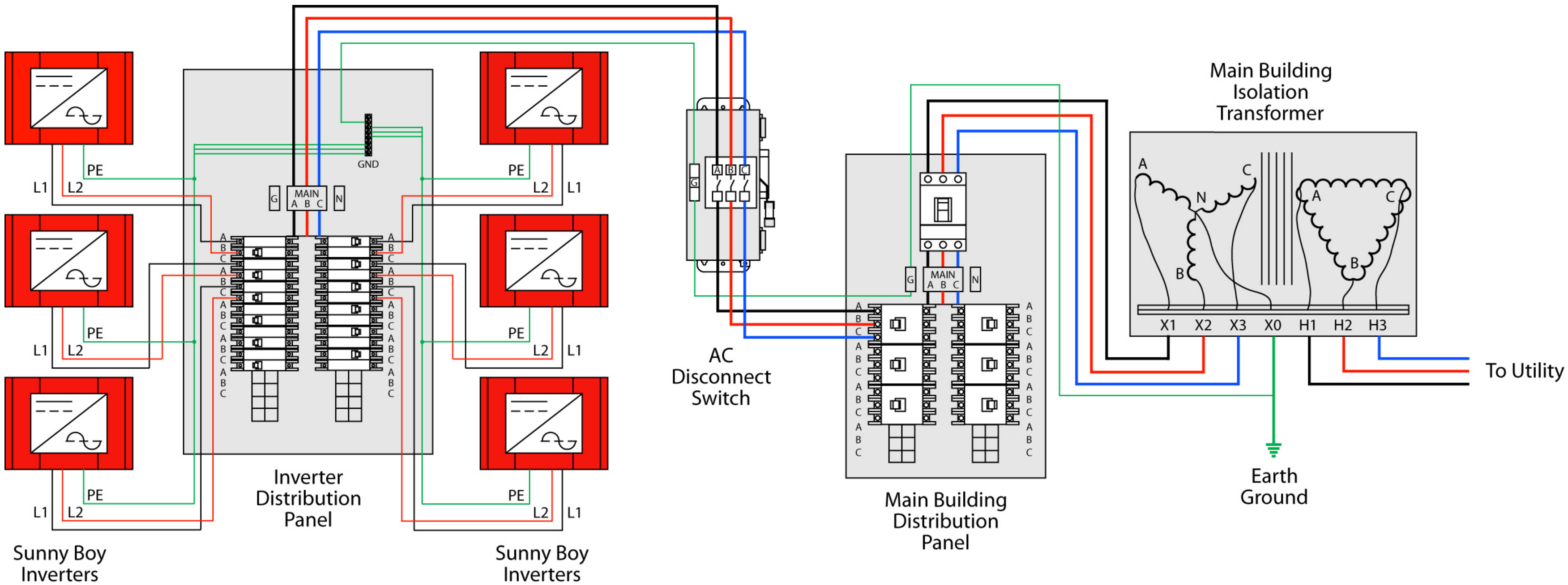
Equipment Grounding

All equipment ground conductors in the PV system should bond to a single point of earth ground for the entire electrical system. This point is typically the earth ground rod located near the isolation transformer (the same point the WYE neutral conductor is grounded). This includes all PV frame grounds, equipment chassis grounds, conduit, etc. PV frame grounds may be earth grounded at the array, and should also be bonded to the single point of earth ground. Equipment grounding conductors should be sized as required by NEC Section 250.122 (as required by NEC Section 650.45).

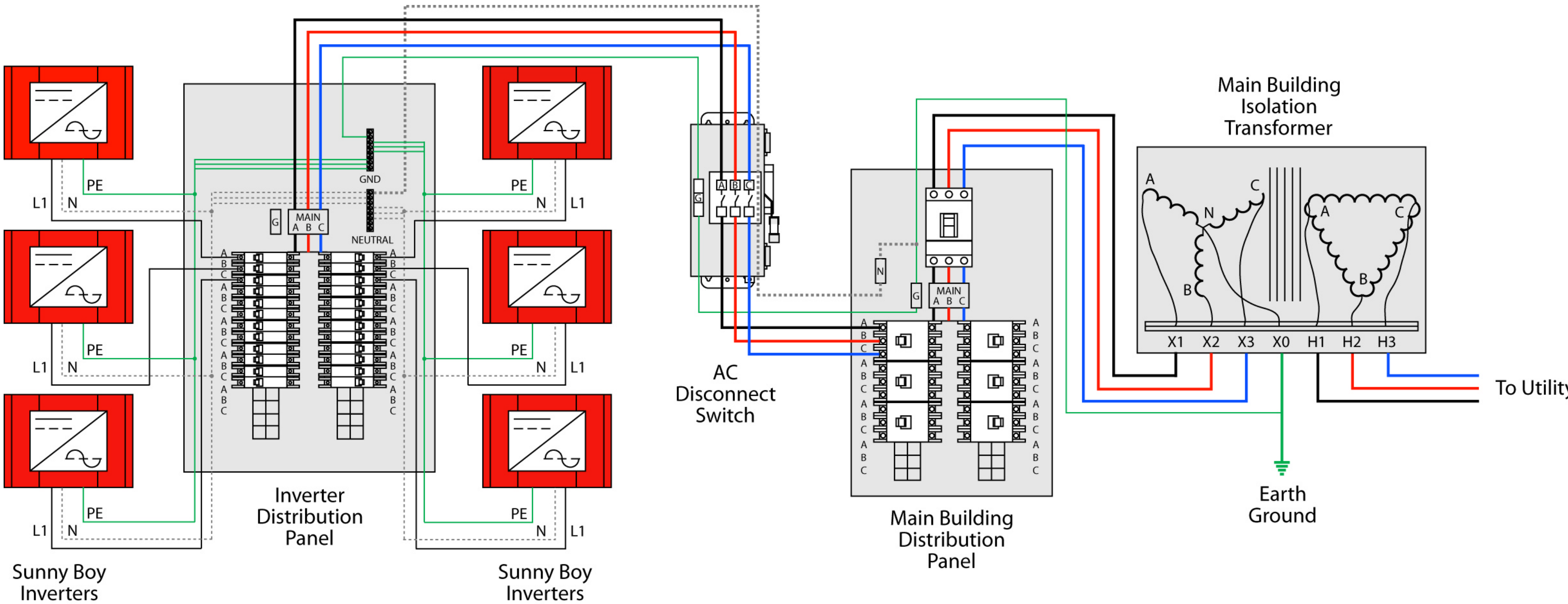
Appendix

Drawings:

Three phase distribution system using multiple two line single phase inverters (SWR 2500 [208 & 240])



Three phase distribution system using multiple single line single phase inverters (SWR 1800 & SB 6000 [277])



Three phase distribution system using multiple two line single phase inverters w/ neutral connection (SB 6000 [208 & 240])