Solar (PV) Systems Interconnect

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S-Max 250 kW Solar Grid-Tied Inverter

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Power Xpert Solar 250 kW Inverter

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Power Xpert Solar 250 kW Inverter Open

General Description

The Power Xpert Solar™ 250 kW inverters are designed for commercial and utility-scale photo-voltaic (PV) systems. Engineered for ease-of-installation, operation and maintenance, the Power Xpert Solar inverters contain the intelligence to automate the commissioning, operation and shutdown procedures with minimal physical action. These robust, utility-interactive, three-phase inverters are based on Eaton's mature motor-drive assembly featuring Eaton's Active Front End© (AFE) control technology.

The Power Xpert Solar 250 kW inverter is designed specifically for 480 Vac three-phase utility (grid) applications and 600 Vdc (open circuit) PV systems. It is an excellent choice for either indoor or outdoor installations from a company known for its state-of-the-art electrical products and industry support.

Features and Benefits

Table 39.1-1. Power Xpert Solar 250 kW Inverter Features and Customer Benefits

Feature	Customer Benefit
Dual-Stage 250 kW inverter with hysteresis ■ 2 x 125 kW design	■ Provides optimum efficiency in lower irradiance conditions, solar mornings and evenings ■ Offers less stressful power-stage operation for improved inverter longevity ■ Seamless dual-inverter operation
Grid-sensor based vector control	■ Precise synchronism and fast response to grid dynamics, ensuring a stable operation and an improved solar energy harvesting
Advanced proportional-integral-derivative (PID) control ■ Control loop feedback mechanism/algorithm	■ Precise synchronization to the grid ■ Finer current and power limits ■ Improved temperature limits ■ Better reactive power or power factor control
DC excitation algorithm and system control	■ Smart PV energy utilization over wasteful utility-based methods of energizing the transformer ■ Faster morning "wake-up" and power export ■ Faster mid-day re-connect improves energy harvesting during utility anomalies and outages ■ Minimal-stress "zero-crossing" grid connection process ■ Less part-count for improved solar-system reliability ■ Smart-control algorithm ensures lower stress on isolation transformer over adverse environmental conditions ■ Seamless grid connection and utility interface
Large DC bus capacitors	■ Extremely low ripple-current on the PV array makes for a better, trouble-free solar-module operation ■ Reduced stress on solar modules and wiring
Inverter re-combiner box with DC circuit breaker option available	■ Optional inverter re-combiner box with DC breakers to meet NEC 2011 requirements for safe DC disconnect, eliminating the need for external DC disconnects ■ DC breaker option eliminates the need to replace DC fuses, allowing cost and time savings (lowering O&M costs) ■ Current sensing of each DC input is available for array zone monitoring; DC input current is reported to inverter controller, which makes it available via Modbus ■ DC breakers can be individually turned off, allowing isolation of a defective sub-array while allowing other sub-arrays to operate. This feature enhances de-bugging procedures and maximizes fault-tolerance ■ DC breakers are available on different configurations and ampacity (90A DC, 100A DC, 125A DC, 150A DC, 175A DC, 200A DC and 225A DC)
AC overcurrent protection and safety	■ Inverter is equipped with a 200 kAIC AC breaker that is operable from the outside of the unit via lockout/tagout–capable handle ■ No need for AC fuse replacements, minimizing O&M costs ■ Inverter doors are fitted with mechanical interlocks that will safely shut down the inverter if doors are opened
Maximum power point	■ Fast (mSec based) response time with variable step-size control reacts to sudden changes ■ Improved current response for low-irradiance periods, sudden-onset shading and grid outages ■ Superior solar-energy harvesting

Table 39.1-1. Power Xpert Solar 250 kW Inverter Features and Customer Benefits (Continued)

Feature	Customer Benefit
Isolation-transformer-based solar inverter ■ Operates with all photovoltaic modules (technologies) ■ Negative and positive grounded PV systems	■ Monocrystalline silicon ■ Ploycrystalline silicon ■ Copper Indium Selenium (CIS) ■ Copper Indium Gallium (di) selenide (CIGS) ■ Cadmium Telluride (CdTe) ■ Amorphous Silicon (a-Si)
Eaton logic controller (ELC) watch-dog system	■ Ensures greater system integration and information response for display and stored performance data ■ Isolates controls from external interference (anti-hacking)
Rich standard features and options list ■ For National Electrical Code®, OSHA and NFPA® 70E compliance ■ Manufacturing plant and facility process adherence	Standard (default examples) ■ Full-load DC switch disconnect and AC breaker ❑ Lockout/tagout compatible ■ Lockable display and controls door with window ❑ Sealed against the elements ■ Configurable utility connection ❑ Three-wire delta (A/B/C), no neutral required ❑ Four-wire wye (A/B/C/N), N-sensing only ■ 100 kA surge protection ■ 200 kAIC AC breaker ■ Large DC and AC conductor gland plates ❑ Bottom and immediate sides ■ Color, menu-driven display ■ Indicator lights (LEDs) and selection switch ❑ Remote, field-duplicable up-fits – Remote indicators (LEDs) – Remote OFF (shutdown) Options: ■ AC view-window for visible blade disconnect ■ Infrared inspection ports for DC and AC cabinets ■ CEC approved 2% PBI power meter ■ Internal heater for humidity and cold temperature control ■ Multiple DC input (combiner) fuse and breaker options ■ SunSpec Alliance compatible monitoring (gateway)
Two-cabinet design ■ Inverter and isolation transformer	■ Enables integration into electrical rooms ■ Better package for roof-top installations ■ Easier to receive, lift, transport and secure ■ Design category(s) seismic complaint ■ Terminated transformer cables included
Easy maintenance ■ Eaton's Electrical Services & Systems (EESS)	■ No ladder required to service cooling-system air filters; ground-level access ■ Three-door design ensures wide opening for limited-access locations ■ Country and worldwide local services
Commissioning	■ Country and worldwide local services
Human machine interface (HMI)	■ Inverter is equipped with a color touch screen LCD display that reports inverter status and allows operator to safely control and troubleshoot the inverter without opening doors

Standards and Certifications

- UL® 1741 2nd Edition January 2010, IEEE® 1547
- NFPA 70, National Electrical Code (NEC)
- CEC Listed (California Energy Commission)
- Seismic qualified to IBC/CBC

Product Selection

The catalog number is what determines the exact product feature set. The base configuration and subsequent catalog number of the Power Xpert Solar™ 250 kW inverter is **SOX23111B1092M0011**.

Table 39.1-2. Catalog Numbering System

SOX 2 3 1 1 1 B 1 0 9 2 M 0 0 1 1

Part String
SOX = Power Xpert Solar inverters

Power Range
2 = 250 kW

Reserved
3 = None

Utility Connection Configuration
1 = Delta
2 = Wye

AC Output Voltage
1 = 480 Vac

Ground Scheme
1 = Negative ground
2 = Positive ground

Reserved
B = None

Viewing Windows
1 = None
2 = DC section
3 = AC section
4 = AC and DC section

Recombiner OCPD—Fusing
0 = No OCPD
2 = 4 x 300A
3 = 8 x 150A
4 = 6 x 225A
5 = 6 x 200A
6 = 8 x 175A
7 = 8 x 125A
9 = Breaker option

Recombiner OCPD—DC Breaker
1 = 16 x 90A
2 = 14 x 100A
3 = 12 x 125A
4 = 8 x 150A
5 = 8 x 175A
6 = 7 x 200A
7 = 6 x 225A
9 = Fuse option

Recombiner OCPD—DC Breaker with Shunt Trip and Current Sensors
0 = OCPD circuit breaker without shunt trip and current sensors
1 = OCPD circuit breaker with shunt trip and current sensors
2 = Not applicable (fuse option)

Inverter Communication
M = Modbus/TCP protocol (Ethernet-based)

Revenue-Grade Meter
0 = No meter
1 = Revenue-grade meter included

Reserved
0 = No options

IR Inspection Port
1 = None
6 = AC and DC cabinets

Destination Market—Language
1 = USA/English

Technical Data and Specifications

Table 39.1-3. Basic Parameters

Description	Power Xpert Solar 250 kW	Transformer (Supplied with Inverter)
Nominal power output	250 kW	N/A
Dimensions in inches (mm) W x H x D	94.00 x 93.00 x 46.00 (2387.6 x 2362.2 x 1168.4)	64.00 x 50.00 x 40.00 (1625.6 x 1270.0 x 1016.0)
Gross weight in lbs (kg)	4000 (1814)	2850 (1293)

Table 39.1-4. Basic Parameters

Input from Photovoltaic Array	Transformer Connections	Output to Utility (Grid)
600 Vdc (maximum)	Supplied, terminated cables	480 Vac
300–600 MPPT	Equipment grounding conductor	Delta (three-wire) or wye (four-wire)

Front ISO View of Inverter with Transformer

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Table 39.1-5. Electrical, Mechanical and Equipment Specifications

Description	Specification
AC Output Specifications—Factory Default	
Maximum continuous output power	250 kW
Weighted efficiency (CEC)	96%
Maximum continuous output current	312A
Maximum branch overcurrent protection	400A ①
Nominal operating voltage	Three–phase 480 Vac
Operating voltage range	423–528 Vac
Nominal operating frequency	60 Hz
Operating frequency range	57.0–60.5 Hz
Tare loss	70W
Total Harmonic Distortion	< 3% THD
Power factor	> 0.99
Utility connection	Delta three-wire (A, B, C); wye four-wire (A, B, C, N) ②
Line synchronization characteristics	Method 1, variation 1
Limits of voltage accuracy measurement	(±1%)
Rated output power at 25C, 40C and 50C	250 kW
Fault Current Specifications	
Maximum fault current	365A for 8 ms
Integral AC breaker OCPD rating	200 kAIC ①
Maximum utility back feed into PV array	0A
Interconnection Integrity Test Categories	
C62.41.2 Ring wave surge category	B
C62.41.2 Combination wave surge category	B
C37.90.1 RF immunity—compliance	Yes
C37.90.2 Communication circuit—compliance	Yes
DC Input Specifications	
DC maximum input voltage	600 Vdc
DC maximum power point tracking range (MPPT)	300–500 Vdc ③
DC operating range	300–600 Vdc
DC Input start (wake-up)	400 Vdc ④
DC operating current nominal	860A
Maximum DC ISC input	1340A
Factory configured PV array grounding	Positive (option)/negative (default)
Mechanical Specifications and Features	
Operating temperature range without power fold back	–20° to 50°C
Storage temperature range	–30° to 70°C
Enclosure rating	UL Type 3R
Enclosure(s) construction	Polyester powder coated
Relative humidity	0 to 95% noncondensing
Inverter weight	4000 lbs (1814 kg)
Transformer weight	2850 lbs (1293 kg)
Inverter envelope dimensions in inches (mm) H x W x D	94.00 x 93.00 x 46.00 (2387.6 x 2362.2 x 1168.4)
Transformer dimensions in inches (mm) H x W x D	64.00 x 50.00 x 40.00 (1625.6 x 1270.0 x 1016.0)
Inverter and transformer mounting	Padmount—not freestanding
Isolation transformer—external	Delta/Wye
Cooling	Forced-air, convection
Maximum altitude	3300 ft (1000m) ⑤
Air flow/inverter	48m^3/min. / 1700 cfm
Seismic rating successfully evaluated	Seismic qualified to IBC/CBC

① 400A (per phase) AC breaker.

② Factory default is delta three-wire; wye four-wire is field selectable (qualified personnel). The neutral is not a current carrying conductor in the wye four-wire configuration size per NEC Table 250.122. The inverter can operate in the delta configuration into a wye connection, without the neutral. Consult factory.

③ To ensure the full MPPT range without power-clipping (reduced power output), prudent PV system designs shall consider the PV array's Vmp voltage drop to the point of the inverter connection, ambient temperatures and the PV system installation type's effects on Vmp, solar module miss-match and tolerance variations, degradation of solar modules over time (solar system life), etc. Typical Vmp design values, based upon known and expected conditions are 5–10% over the minimum MPPT tracking voltage. Reference NEC® 2011 Section 690, Solar Photovoltaic Systems.

④ Factory default is 400 Vdc. Field selectable to 300 Vdc by qualified personnel.

⑤ Maximum output power may de-rate above 3281 ft (1000m) due to environmental conditions (effective cooling). The maximum rated altitude is 9842 ft (3000m).

Table 39.1-6. Commissioning and Operating—Inverter Settings

Description	Default	Adj. Values ①
AC negative sequence current threshold	50A	N/A
AC negative sequence voltage threshold	260 Vac	N/A
Inverter DC start voltage	400 Vdc	300–400 Vdc
Condensation management	On	On/off

① Stated limits of accuracy for voltage ±1%.

Table 39.1-7. Commissioning and Operating—IEEE Settings

Description	Voltage and Frequency ②③		Trip Times	
	Default	Adj.	Default	Adj.
Fast overvoltage	120% (576) Vac	130–120% (624–576) Vac	0.16	N/A
Slow overvoltage	110% (528) Vac	120–110% (576–528) Vac	1	N/A
Fast undervoltage	50% (240) Vac	50–30% (240–144) Vac	0.16	N/A
Slow undervoltage	88% (423) Vac	88–50% (423–240) Vac	2	N/A
Overfrequency	60.5 Hz	60.5–60.4 Hz	0.16	N/A
Slow underfrequency	59.8 Hz	59.8–57 Hz	1.7	0.16–300
Fast underfrequency	57 Hz	57.0–57.1 Hz	0.16	N/A

② Stated limits of accuracy for voltage ±1%.
③ Stated limits of accuracy for frequency two cycles.

DC Section Options—Combiner Option

The Power Xpert Solar 250 kW inverter offers two over-current device options for the inverter input circuit—fusing options and DC breaker options. It is also available without input protection as the default. Regardless of the option selected, the inverter shall be installed in accordance with the latest edition of the National Electrical Code, ANSI/NFPA 70. All option fuses are rated for 600 Vdc.

Table 39.1-8. DC Input Fusing Options

Input Option Name	Conductor Size (Terminal Range)	Terminal Temperature Rating
No DC fuse input. Prepared busbars for landing the non-grounded PV conductors. Lugs not included	Per NEC (For UL approved crimp-on type 3/8-inch ring terminals)	N/A
Four DC fuse inputs Two 300A fuses per bus	(2) 2/0 (1000–250 kcmil)	75°C
Six DC fuse inputs Three 225A fuses per bus	(1) 250 kcmil (1000–250 kcmil)	75°C
Eight DC fuse inputs Four 125A fuses per bus	(1) 1/0 (350 kcmil–6 AWG)	75°C
Eight DC fuse inputs Four 150A fuses per bus	(1) 2/0 (350 kcmil–6 AWG)	75°C
Eight DC fuse inputs Four 175A fuses per bus	(1) 3/0 (350 kcmil–6 AWG)	75°C
Eight DC fuse inputs Four 200A fuses per bus	(1) 4/0 (350 kcmil–6 AWG)	75°C

Table 39.1-9. DC Input Breaker Options

Input Option Name	Conductor Size (Terminal Range)	Terminal Temperature Rating
Breaker options	Per NEC (For UL approved crimp-on type 3/8-inch ring terminals)	N/A
Six DC breaker inputs Six 225A DC breakers per panel	(2) 2/0 (4 AWG–4/0)	75°C
Seven DC breaker inputs Seven 200A DC breakers per panel	(2) 1 AWG (4 AWG–4/0)	75°C
Eight DC breaker inputs Eight 175/150A DC breakers per panel	(1) 4/0 (4 AWG–4/0)	75°C
Twelve DC breaker inputs Six 125A DC breakers per panel	(1) 1/0 (4 AWG–4/0)	75°C
Fourteen DC breaker inputs Seven 100A DC breakers per panel	(1) 1 AWG (16 AWG–1/0)	75°C
Sixteen DC breaker inputs Eight 90A DC breakers per panel	(1) 2 AWG (16 AWG–1/0)	75°C

Ventilation Requirements

The required volume of air at the intake is 1700 cfm (48m^3/min). No additional planning is required for the inverter to achieve this air-flow, based upon the clearances listed in **Figure 39.1-1**.

When installed inside a structure or located indoors, the cooling required for the Power Xpert Solar 250 kW inverter is 570 BTU/min and Eaton encourages coordination with our engineering team.

Dimensions in Inches (mm)

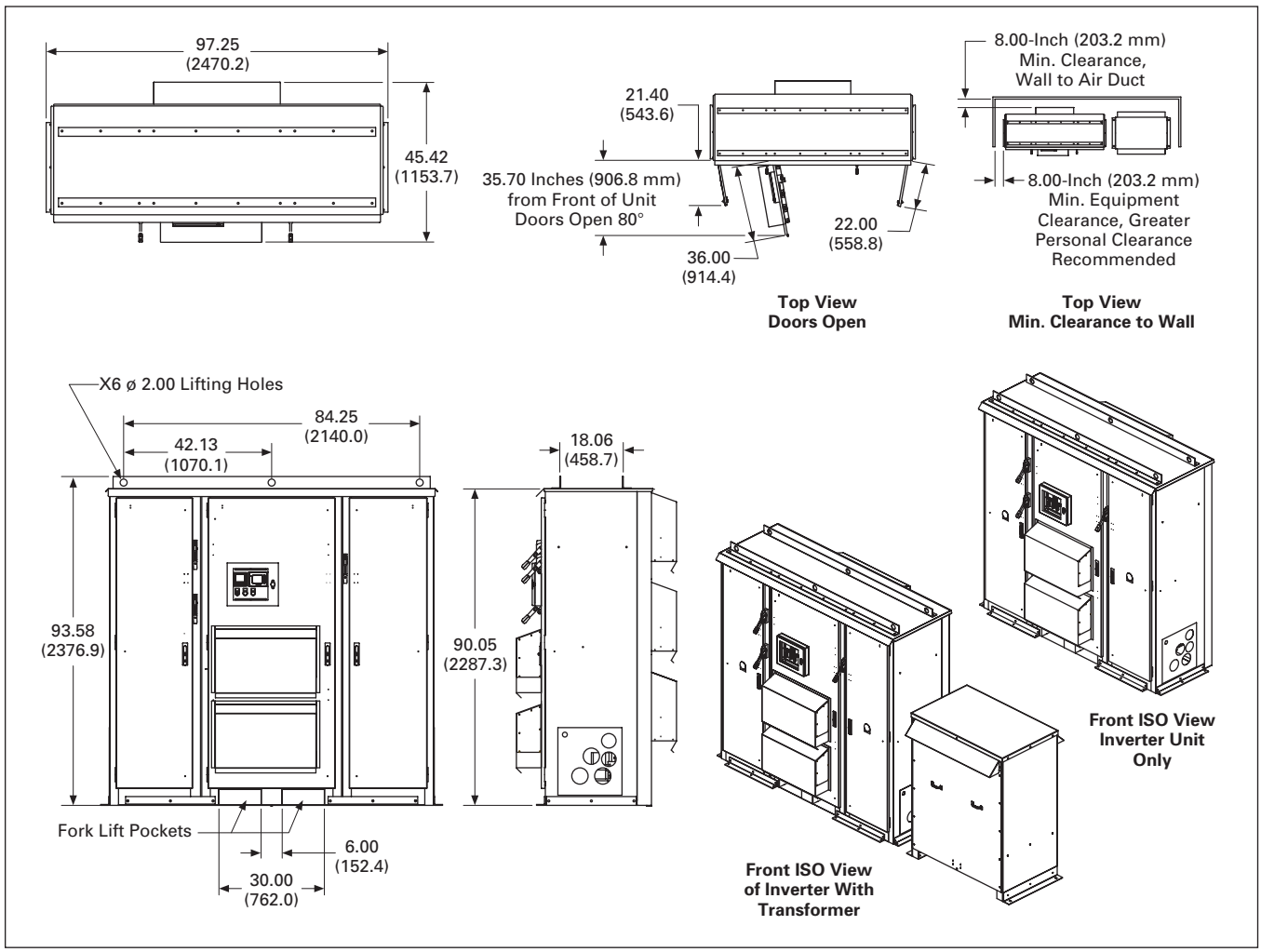

Figure 39.1-1. Power Xpert Solar 250 kW Dimensions and Connection Diagrams

3.8–7 kW Grid-Tied Solar Inverter

3.8–7 kW Grid-Tied Solar Inverter

General Description

The Eaton Grid-Tied Solar Inverters offer market-leading efficiency and voltage operating range, which maximizes energy yield and return on investment for consumers. Installation time and costs are greatly reduced through integrating the combiner box, AC/DC disconnects and wire raceway. The design also simplifies service on the unit through a two-piece modular configuration that allows the wiring box to remain connected and mounted if in the event you need to replace the power module.

Features and Benefits

Ratings and Warranty

- 3800W, 4000W, 5000W, 6000W, 7000W
- 10-year warranty

Maximum Energy Harvest

- 97% CEC efficiency
- Broad voltage operating range (105–500 Vdc) for superior performance in low light and high temperature environments
- Transformerless design

Saves Installation Time and Cost

- Integrated PV system AC/DC disconnect switch
- Four branch circuit–rated negative and positive fused inputs
- Integrated NEC compliant wire raceway

Versatility in Installation

- Field-selectable voltage output: 208/240/277 Vac
- LCD display with nighttime monitoring capabilities.
- NEMA 3R enclosure
- Two-piece modular design

Eaton Value

- A global leader in inverter technology
- Complete balance of system provider
- Eaton reputation for quality, support and service
- Installation certification via Eaton Certified Contractor Network (ECCN)

Features

Standards and Certifications

- ETL listed (in compliance with UL 1741 standards)
- CSA
- CEC listed (California Energy Commission)

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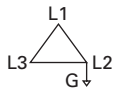
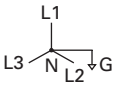
Technical Data and Specifications

Table 39.1-10. Input/Output Specifications

Description			PV240		PV250	PV260	PV270
Nominal power output			3800W	4000W	5000W	6000W	7000W
Dimensions W x H x D in inches (mm)			17.10 x 33.30 x 8.30 (434.3 x 845.8 x 210.8)		17.10 x 33.30 x 8.30 (434.3 x 845.8 x 210.8)	17.10 x 33.30 x 8.30 (434.3 x 845.8 x 210.8)	17.10 x 33.30 x 8.30 (434.3 x 845.8 x 210.8)
Gross weight in lbs (kg)			86 (39)	86 (39)	90 (41)	101 (46)	101 (46)
Input (DC side)	Internal combiner/ multi-string	Maximum number of strings	4		4	4	4
		Terminal block	(+) x 4, (–) x 4, (G) x 1		(+) x 4, (–) x 4, (G) x 1	(+) x 4, (–) x 4, (G) x 1	(+) x 4, (–) x 4, (G) x 1
		Admissible conductor size	14–6 AWG		14–6 AWG	14–6 AWG	14–6 AWG
	External combiner/ single string	Bypass fuse terminal block	(+) x 1, (–) x 1, (G) x 1		(+) x 1, (–) x 1, (G) x 1	(+) x 1, (–) x 1, (G) x 1	(+) x 1, (–) x 1, (G) x 1
		Maximum admissible conductor size	4 AWG		4 AWG	4 AWG	4 AWG
Output (AC side)	Terminal block		Terminal block labeled with 1, 2, 3 and G		Terminal block labeled with 1, 2, 3 and G	Terminal block labeled with 1, 2, 3 and G	Terminal block labeled with 1, 2, 3 and G
	Admissible conductor size		10–6 AWG		10–6 AWG	10–6 AWG	10–6 AWG

Grid Standard			
	208V/240 Three-Phase Delta	**250V Split Phase**	**277V Three-Phase Wye**

Terminal	1	2	3	⏚	1	2	3	⏚	1	2	3	⏚
Wire	L1	L2	—	L3	L1	L2	N	G	L1	N	—	G

Table 39.1-11. Technical Data

Description	PV240		PV250	PV260	PV270
Input (DC)					
Nominal DC voltage	360V	360V	360V	360V	360V
Maximum DC voltage	600V	600V	600V	600V	600V
System startup voltage	150V	150V	150V	150V	150V
Shutdown voltage	Typical 80V	Typical 80V	Typical 80V	Typical 80V	Typical 80V
MPPT voltage range	105–500V	200–500V	105–500V	105–500V	105–500V
Full rating voltage range	225–500V	225–500V	225–500V	225–500V	225–500V
Maximum DC current	19A	19A	26A	32A	37A
Number of DC input terminals	4	4	4	4	4
Output (AC)					
Nominal AC power at 240 Vac and 277 Vac	3800W	4000W	5000W	6000W	7000W
Nominal AC power at 208 Vac	3800W	3800W	4600W	6000W	7000W
Max. AC power at 240 Vac at 277 Vac	3800W	4000W	5000W	6000W	7000W
Maximum AC power at 208 Vac	3800W	3800W	4600W	6000W	7000W
Nominal AC voltage	208V, 240V or 277V	208V, 240V or 277V	208V, 240V or 277V	208V, 240V or 277V	208V, 240V or 277V
Nominal frequency	60 Hz	60 Hz	60 Hz	60 Hz	60 Hz
Disconnection time of excess operational frequency range	≤0.16 sec	≤0.16 sec	≤0.16 sec	≤0.16 sec	≤0.16 sec
Nominal AC current at 208 Vac	18.3A	18.3A	22.1A	28.9A	33.7A
Nominal AC current at 240 Vac	15.8A	16.7A	20.8A	25.0A	29.2A
Nominal AC current at 277 Vac	13.7A	14.4A	18.1A	21.7A	25.3A
Maximum AC current at 208 Vac	18.3A	18.5A	22.5A	30.0A	35.0A
Maximum AC current at 240 Vac	15.8A	18.5A	22.5A	28.5A	33.2A
Maximum AC current at 277 Vac	13.7A	16.4A	20.5A	24.6A	28.7A
Power factor	>0.99	>0.99	>0.99	>0.99	>0.99
Efficiency					
Peak efficiency	97.5%	97.5%	97.5%	97.5%	97.5%
CEC efficiency	97.0%	97.0%	97.0%	97.0%	97.0%
General Data					
Topology	Transformerless	Transformerless	Transformerless	Transformerless	Transformerless
Dimensions in inches (mm) W x H x D	17.10 x 33.30 x 8.30 (434.3 x 845.8 x 210.8)	17.10 x 33.30 x 8.30 (434.3 x 845.8 x 210.8)	17.10 x 33.30 x 8.30 (434.3 x 845.8 x 210.8)	17.10 x 33.30 x 8.30 (434.3 x 845.8 x 210.8)	17.10 x 33.30 x 8.30 (434.3 x 845.8 x 210.8)
Gross weight in lbs (kg)	86 (39)	86 (39)	90 (41)	101 (46)	101 (46)
Power consumption: standby/night	<7W / <0.2W	<7W / <0.2W	<7W / <0.2W	<7W / <0.2W	<7W / <0.2W
DC insulation resistance	>4 megohms	>4 megohms	>4 megohms	>4 megohms	>4 megohms
Enclosure	NEMA 3R	NEMA 3R	NEMA 3R	NEMA 3R	NEMA 3R
Heat dissipation	Force air cooling, variable fan speed according to temperature on heat sink				
Operating temperature range	–25 to +50°C	–25 to +50°C	–25 to +50°C	–25 to +50°C	–25 to +50°C
Humidity	0 to 95%, noncondensing	0 to 95%, noncondensing	0 to 95%, noncondensing	0 to 95%, noncondensing	0 to 95%, noncondensing
Communication	RS-232/Super-485	RS-232/Super-485	RS-232/Super-485	RS-232/Super-485	RS-232/Super-485
Ground fault protection	Internal GFCI and isolation detection function in accordance with UL 1741				
Disconnect	Integrated AC and DC switch	Integrated AC and DC switch	Integrated AC and DC switch	Integrated AC and DC switch	Integrated AC and DC switch
Certifications	ETL (in compliance with UL 1741), CSA, CEC	ETL (in compliance with UL 1741), CSA, CEC	ETL (in compliance with UL 1741), CSA, CEC	ETL (in compliance with UL 1741), CSA, CEC	ETL (in compliance with UL 1741), CSA, CEC
DC surge protection	4 kV	4 kV	4 kV	4 kV	4 kV
AC surge protection	6 kV	6 kV	6 kV	6 kV	6 kV
Warranty	10 years	10 years	10 years	10 years	10 years

Dimensions

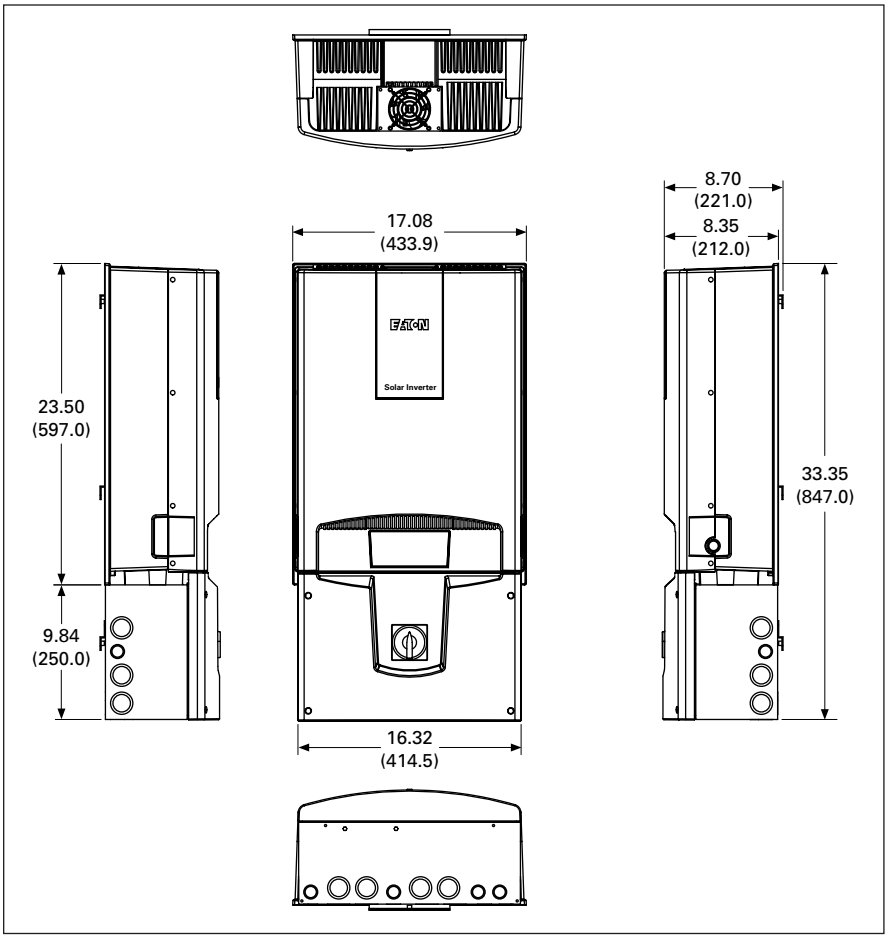


Figure 39.1-2. 3.8–7 kW Grid-Tied Solar Inverter Dimensions

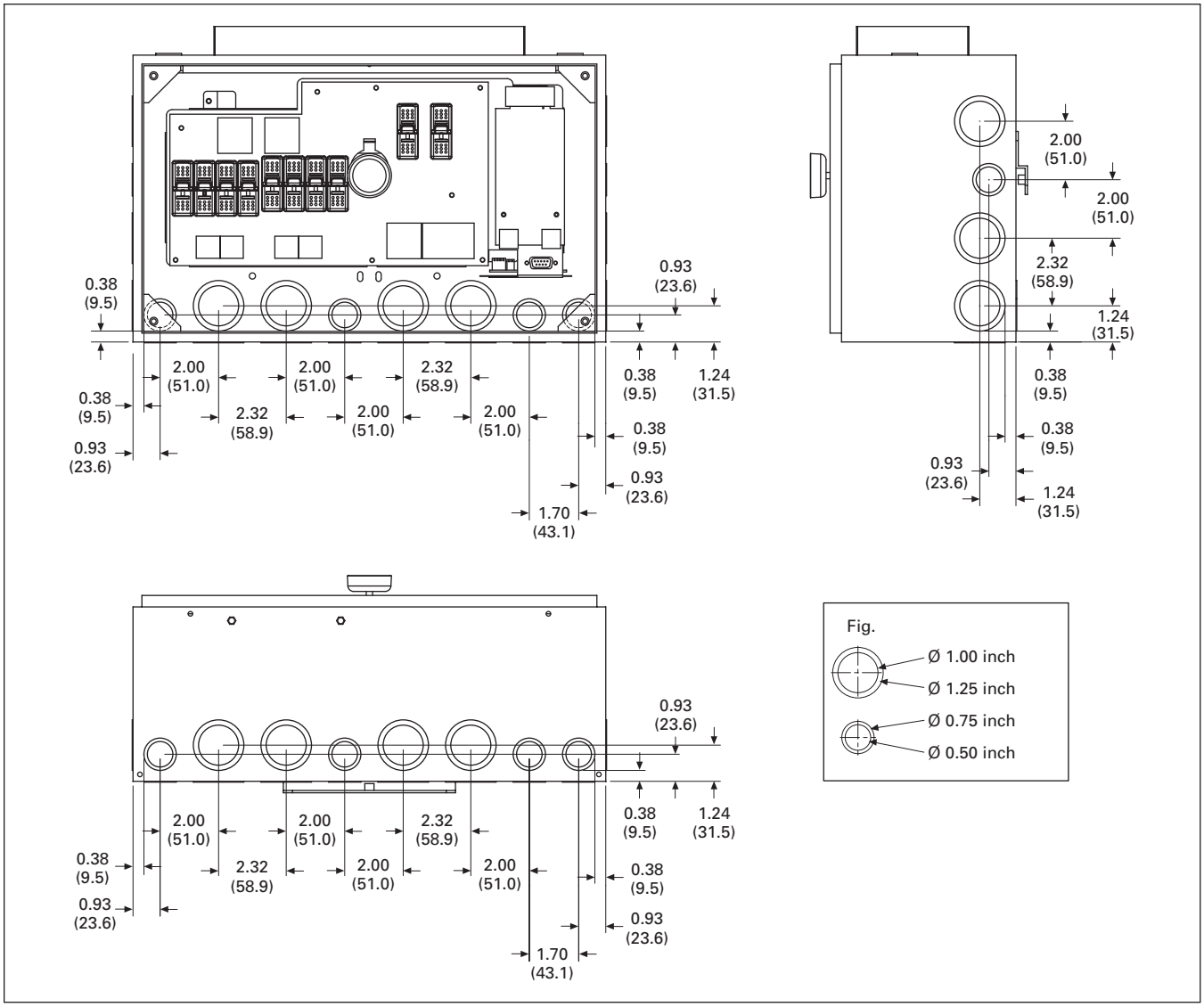


Figure 39.1-3. Knockouts on the Wiring Box

Table 39.1-12. Knockout Dimensions

Description	Diameter of Knockout	Quantity
Knockouts on the underside and backside	Combo 1.25 and 1.00 inches Combo 0.75 and 0.50 inches	4 4
Knockouts on the left-hand side and right-hand side	Combo 1.25 and 1.00 inches Combo 0.75 and 0.50 inches	3 1

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Solar Disconnect Switch

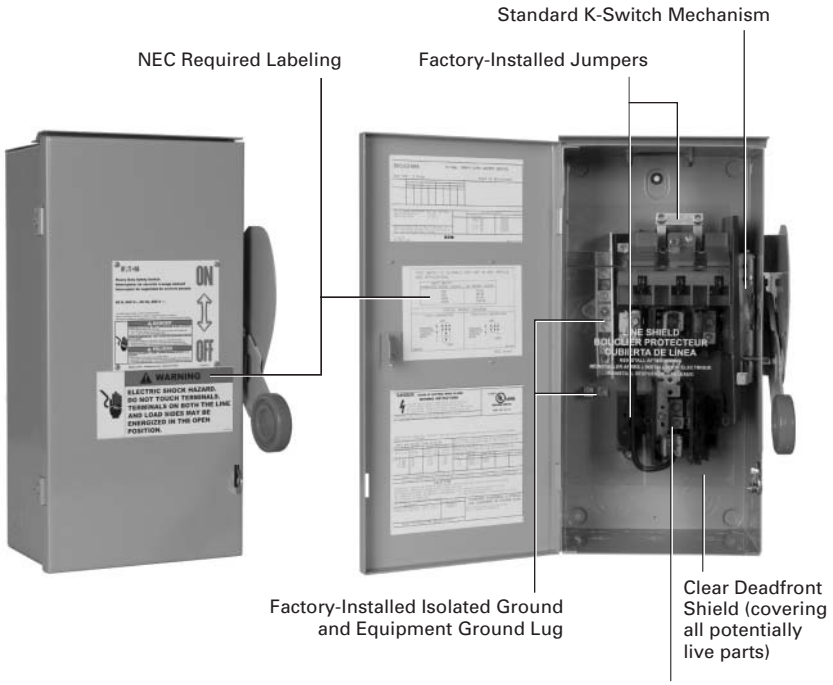
Solar Disconnect Switch

General Description

600 Vdc Heavy-Duty Fusible and Non-Fusible

- 30–600A
- Single-pole switch capable of switching 1–600 Vdc circuit

Features



600 Vdc Heavy-Duty Fusible and Non-Fusible

Switching 600 Vdc

When photovoltaic panels convert the sun's energy into electricity, the power generated is direct current (DC). Typically, the systems are designed with DC system voltages in the 400–600V range. This is much higher voltage than typically found in building systems. The higher voltage, when combined with the lack of a current sine wave with zero crossings, creates a number of challenges in wiring, particularly when switching circuits on and off.

DC circuits consist of two wires—a positive and a negative. In most PV systems, one of these wires is grounded (like a neutral in an AC system). Which of the two wires is grounded is specified by the solar panel manufacturer. The more common application is a negative ground, and the location of this bond is usually found at the inverter. Per the National Electrical Code (NEC®) Section 690.5(A), only the current-carrying ungrounded conductor should be switched. Thus, in a negative-grounded system, only the positive wire is switched.

Unlike AC systems that possess a current sine wave with zero crossings, the interruption of higher voltage DC circuits requires an increased air gap to safely and quickly interrupt and break the arc. The increased gap is accomplished by wiring multiple poles of a single switch in series for safe arc interruption. All switch manufacturers require the use of multiple poles at 600 Vdc to maintain the UL listing. For this reason, a switch should only be used to switch one circuit. The UL listing of these products does not permit multiple circuits to be switched by one switch. Eaton's new offering of PV switches have multiple poles factory-wired, and they are approved for NEC Article 690 applications right from the box. Other manufacturers require the contractor to add jumpers to a two- or three-pole switch, add a neutral, and add labels to meet this requirement. For fusible switches, the new Eaton PV switch requires only one fuse per switch—saving the customer at least one fuse on each switch.

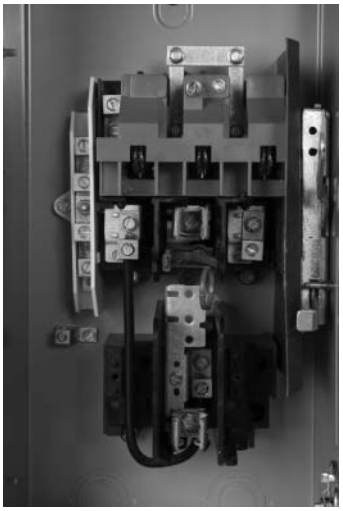
Eaton's Solar Disconnect

Eaton Corporation is proud to offer a new line of solar disconnects that provide the best solution for switching solar PV circuits. This exciting new offering is the first UL 98 listed switch that is labeled as "suitable for NEC Article 690 photovoltaic applications per UL 1741 requirements."

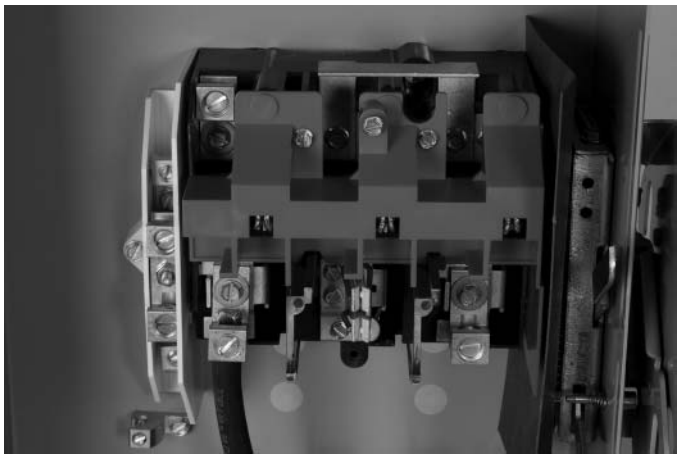
Features include:

- Marked as suitable for NEC 690 PV applications up to 600 Vdc
- UL 98 listed
- All switches are single-pole and suitable for switching one circuit
- Clear polycarbonate deadfront to guard against accidental contact with live parts
- NEC 690.17—compliant labeling warning that the switch terminals may be energized in the open position
- NEC 690.14.(C) 2 required "PV System Disconnect" label included
- Isolated ground terminals (neutral) for grounded conductors
- Ground lug for equipment grounding conductor
- NEMA® 3R, 12 and 4X stainless enclosures
- Fusible and non-fusible configurations—Class R fuse clips standard
- Fuse clips are located on the center pole to ensure that both fuse clips are de-energized—meets NEC Article 690.16, which requires isolation of the fuse from all potential supply sources
- Available for Flex Center modifications (windows, pilot lights, 316 grade stainless, and so on)

Solar Disconnect Switch



Solar Disconnect Switch (Interior View)



Solar Disconnect Switch (Close-Up Interior View)

Standards and Certifications

- UL 98 listed, File No. E5239 and marked suitable for NEC Article 690 applications to UL 1741

Product Selection

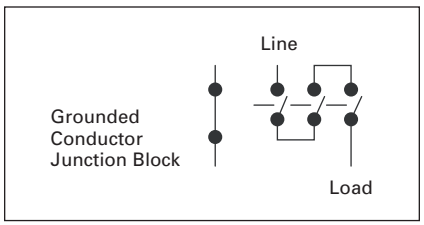


Figure 39.2-1. Non-Fused Construction

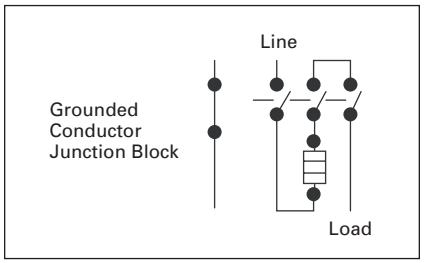


Figure 39.2-2. Fused Construction

Table 39.2-1. NEMA 3R

Ampere Rating	Fuse Class	Catalog Number
30	R	**DH161NRK**
30	R	**DH161URKN**
60	R	**DH162NRK**
60	R	**DH162URKN**
100	R	**DH163NRK**
100	R	**DH163URKN**
200	R	**DH164NRK**
200	R	**DH164URKN**
400	R	**DH165NRK**
400	R	**DH165URKN**
600	R	**DH166NRK**
600	R	**DH166URKN**
800	R	**DH167NRK**
800	R	**DH167URKN**
1200	R	**DH168NRK**
1200	R	**DH168URKN**

Table 39.2-2. NEMA 12

Ampere Rating	Fuse Class	Catalog Number
30	R	**DH161NDK**
30	R	**DH161UDKN**
60	R	**DH162NDK**
60	R	**DH162UDKN**
100	R	**DH163NDK**
100	R	**DH163UDKN**
200	R	**DH164NDK**
200	R	**DH164UDKN**
400	R	**DH165NDK**
400	R	**DH165UDKN**
600	R	**DH166NDK**
600	R	**DH166UDKN**
800	R	**DH167NDK**
800	R	**DH167UDKN**
1200	R	**DH168NDK**
1200	R	**DH168UDKN**

Table 39.2-3. NEMA 4X

Ampere Rating	Fuse Class	Catalog Number
30	R	**DH161NWK**
30	R	**DH161UWKN**
60	R	**DH162NWK**
60	R	**DH162UWKN**
100	R	**DH163NWK**
100	R	**DH163UWKN**
200	R	**DH164NWK**
200	R	**DH164UWKN**
400	R	**DH165NWK**
400	R	**DH165UWKN**
600	R	**DH166NWK**
600	R	**DH166UWKN**
800	R	**DH167FWK**
800	R	**DH167NWK**
1200	R	**DH167UWKN**
1200	R	**DH168NWK**
1200	R	**DH168UWKN**

Photovoltaic String Disconnect Switch Application

Introduction and Statement of Problem

New installations of solar photovoltaic (PV) generation systems have increased the need for disconnect switches and overcurrent protective devices capable of interrupting currents at voltages up to 600 Vdc. This application is covered by NEC Article 690, Solar Photovoltaic (PV) Systems. Products applied as overcurrent protection must meet the design and testing requirements of the individual standards for each product:

- Safety switches—UL 98
- Fuses—UL 248
- Circuit breakers—UL 489

PV system arrays generate DC current. The solar modules are wired in series, and the system voltage is the sum of the maximum output voltage of all of the modules in a string. 600 Vdc maximum was chosen as an optimal system voltage to reduce installation costs by reducing conductor size and to stay below the 600V threshold in NEC Article 490.

Prior to the growth in the number of installed PV systems, 600 Vdc was not a common system voltage. Thus, there was a limited availability of protection and switching devices that meet North American standards at this voltage. In addition, the grounding and ground fault requirements of these PV systems vary from that of other DC systems resulting in different switching and bonding schemes.

As the PV industry grows, overcurrent and switch products are intentionally or accidentally being applied in ways that are in conflict with the products' listings. Added to this, some manufacturers have "self-certified" products for use in ways that are outside of the products' listing.

These situations make it difficult for installers and Authorities Having Jurisdiction (AHJs) to understand how to properly apply or inspect these products. Using or approving a product outside of its listed rating is a violation of NEC Article 210.3, and could open the installer or the AHJ to liability for misapplication of the product.

Solar Disconnect Switch Typical Applications

Figure 39.2-3 shows a common one-line diagram of PV systems in use today. There are no standard installations due to the large variation in solar module capabilities and the large range of power capabilities. The DC system is 450–600V. There are a few problems associated with this configuration.

First, the switches shown are breaking 600 Vdc per pole. There are no UL 98 or 489 listed devices on the market today that are capable of passing the required short-circuit, overload and endurance tests associated with breaking a 600 Vdc circuit with one switching pole. When products from all manufacturers are tested to the standard in this configuration, the results are excessive heating caused by long arcing times and device failure within a very few test operation cycles.

Secondly, the fuses on the load side of the switch are not isolated from all potential sources as required by NEC Article 690.16. If "Sw. 2" is opened for maintenance, the load side fuse holders in the switch that are connected to the inverter will still be energized if "Sw. 1" is closed and the modules are exposed to solar irradiation.

Switch Selection for Operating Voltage

NEC 690.7 states that the maximum photovoltaic system source circuit voltage shall be calculated as the sum of the rated open circuit voltage of the series connected photovoltaic modules corrected for the lowest expected temperature. The correction factor can be as high as 1.25 per Table 690.7; this applies to crystalline and multicrystalline silicon modules. This theoretical voltage is the worst case (highest) possible voltage that the entire system could produce (based on temperature, irradiance and angle), but is not likely to occur. Devices must be selected based on this maximum voltage.

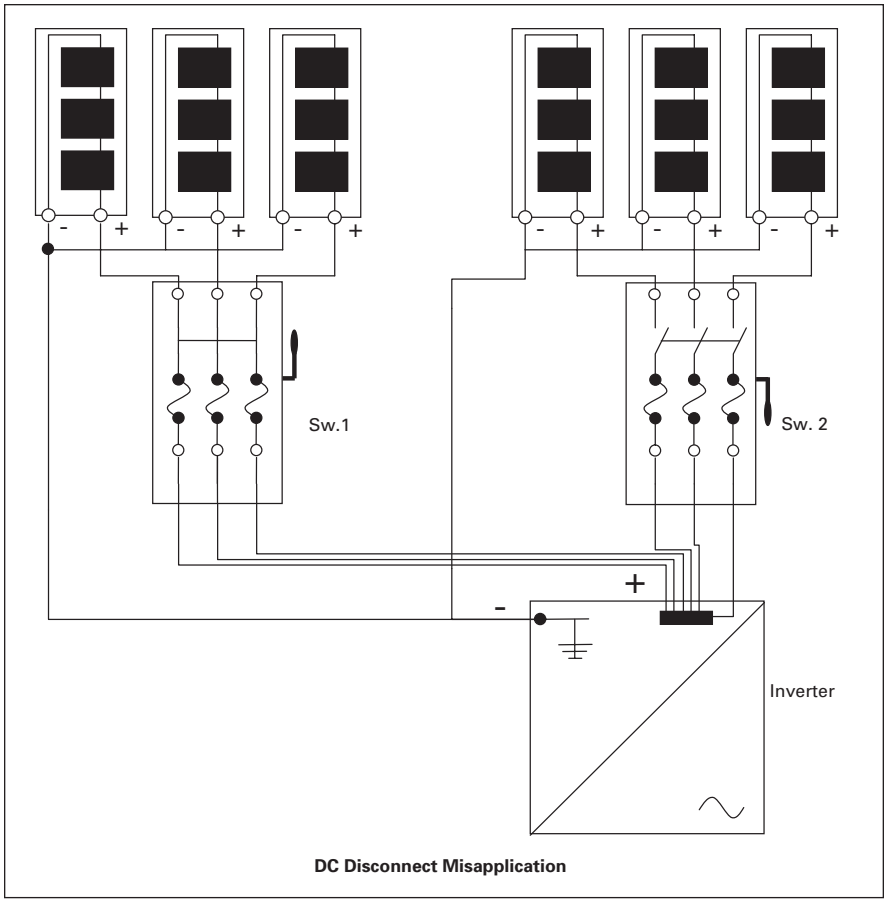


Figure 39.2-3. DC Disconnect Misapplication Example—Single-Pole Switching of 600 Vdc

DC Switch Design

Switching DC currents requires a higher arcing voltage to be developed in the switch to clear the current as compared to AC circuits. The reason for the higher voltage is that unlike AC, DC does not have zero voltage crossings to facilitate clearing the arc. Thus to break the current, the voltage drop required across the arc gap is very high.

Switching devices primarily designed for DC service require additional arc control structures or design features to increase the total arcing voltage, so that fewer switching poles are needed for each circuit. These higher arc voltages can be developed by increasing the arc length (either larger single opening air gaps, or multiple openings in series), by adding several arc splitter plates, or by both methods together.

An alternative method of stretching the arc uses a magnetic field induced by an electromagnet or a permanent magnet structure to force arc movement. The limitation of the magnetic field from a permanent magnet is that it is unidirectional. That is, the magnet only stretches the arc when current flow is in the "normal" direction. Thus this design is polarity sensitive, and will not operate properly if it is miswired or in a fault condition where current flow is reversed from normal. In these instances, the magnetic field would push the arc in the wrong direction away from the arc suppression structure, potentially causing switch failure, property damage or fire. Any switch that is suitable only for use with either a Negative Grounded or Positive Grounded systems is a unidirectional device, and is subject to the problem of insufficient arc suppression of reverse currents.

The risk of using polarity sensitive disconnects in a typical system with two or more disconnect switches is illustrated in **Figure 39.2-4** and explained here. If a ground fault were to occur in the cable from PV string number 1, with a solar condition such that the current from each panel were to be only 30% of the I_{SC}, the current flowing from SW2 into the faulted circuit would not open the fuse. Under this condition, the inverter would no longer produce power, and the system output shutdown would be noticed by the operator. However, fault current would still be flowing as shown.

If Sw. 1 was polarity sensitive and were to be opened first, the current from Sw. 2 would continue to flow from the load terminal toward the line terminal, because disconnect 1 could not clear the arc. In the case of this fault condition, with a polarity sensitive switch, the arc would not be cleared, potentially causing the switch to be damaged or to introduce a safety hazard to the operator; the ground fault would then continue. A non-polarity sensitive switch, on the other hand, would be able to interrupt the current and would not subject the operator to potential harm. The simplest disconnect switch design practice for supplying a UL-listed switch for the photovoltaic array is to apply a switch using multiple switching poles of an AC switch in series to increase the total arc gap, and thus to increase the total arcing voltage and to attain a significant DC rating. Switching devices and circuit breakers traditionally require multiple switching poles for DC systems above 250 Vdc. Eaton's Classic "K" series safety switch and DC rated Series C® circuit breakers require all three switching poles to be wired in series to clear 600 Vdc, which increases the arc voltage by way of forcing the arc through more air gaps. The UL standard for these products requires a minimum of two switching blades to attain a 600 Vdc rating. These requirements yield a general purpose DC switch capable of use for a wide range of applications. As these designs do not use induced magnetic fields, current flow can be in either direction through the switch, or in other words, the switch is non-polarity sensitive.

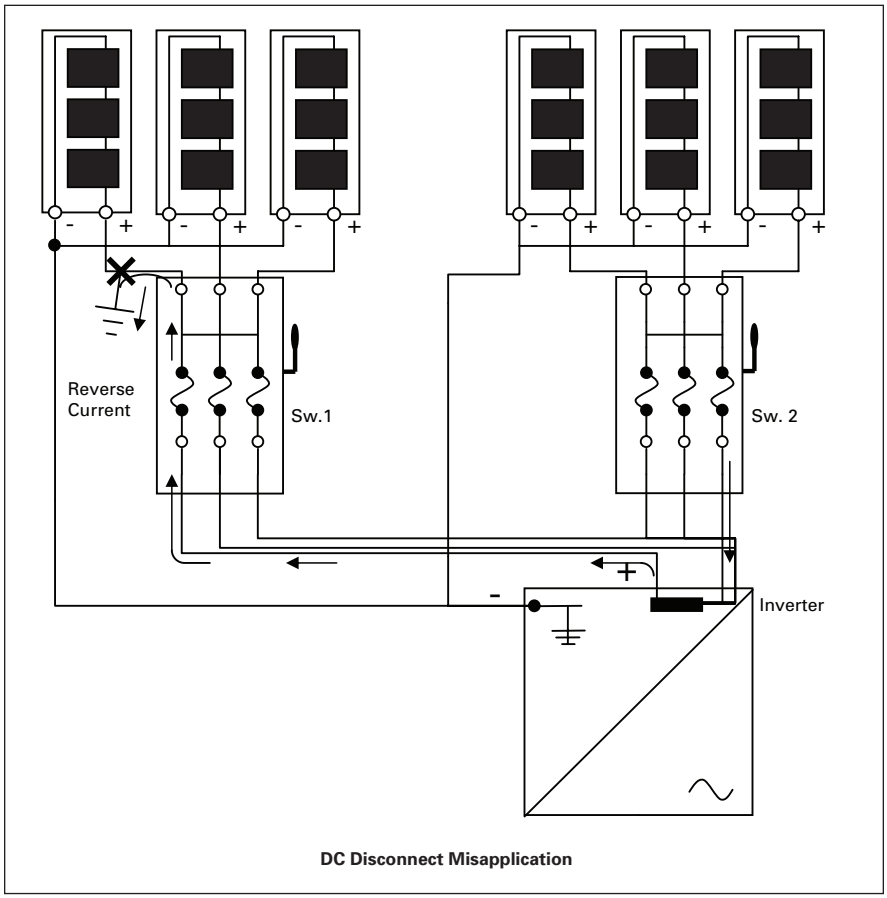


Figure 39.2-4. DC Disconnect Misapplication Example—Ground Fault and Overcurrent Protection Considerations With Polarity Sensitive Disconnects

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Fusing Options for DC Circuits

The 600V rated Class R fuse form is the standard configuration for the fused version Eaton PV disconnect switches. Fuses constructed with the time delay feature may be most appropriate for battery to inverter overcurrent protection to allow for temporary inrush requirements, but would be undesirable for a PV array protection. Other 600V Class R fuses are available for PV panel or semiconductor protection applications, may have a short melt time when overloaded. For PV array protection-specific applications, efforts should be made to specify a fast melt time fuse in all cases.

NEC Article 690 states that one PV panel string or two in parallel will not require fusing. Three strings or more in parallel may require fusing for each string, depending on the inter-panel wiring size (high series fuse ratings).

Eaton's fusible solar disconnects use the center pole as the location for the fuse holders. By placing the fuse clips between the two outer poles, the fuse clips are isolated from all potential power sources. Thus, in **Figure 39.2-5**, the fuse in the switch is isolated from any voltage that may be present from either the source or the inverter.

Summary

In summary, the growth of 600 Vdc power systems as a result of increased PV installations has brought about an increased understanding within the industry regarding the problems associated with breaking high voltage DC circuits. The energy that is required to be broken requires design elements that minimize the arcing time. When evaluating the suitability of switch products for solar applications, it is important to not only apply the product within its current and voltage rating, but to also understand the limitations of the product in regard to safe operation regardless of the direction of current flow.

Existing third-party standards that cover the electrical requirements of switching and overcurrent protection of PV systems are in place. Because well-established product standards exist that cover the design and testing of switches and circuit breakers, it is not desirable to permit the use of self-certification of products, or to expand switch product listing beyond the traditional and proven protocols.

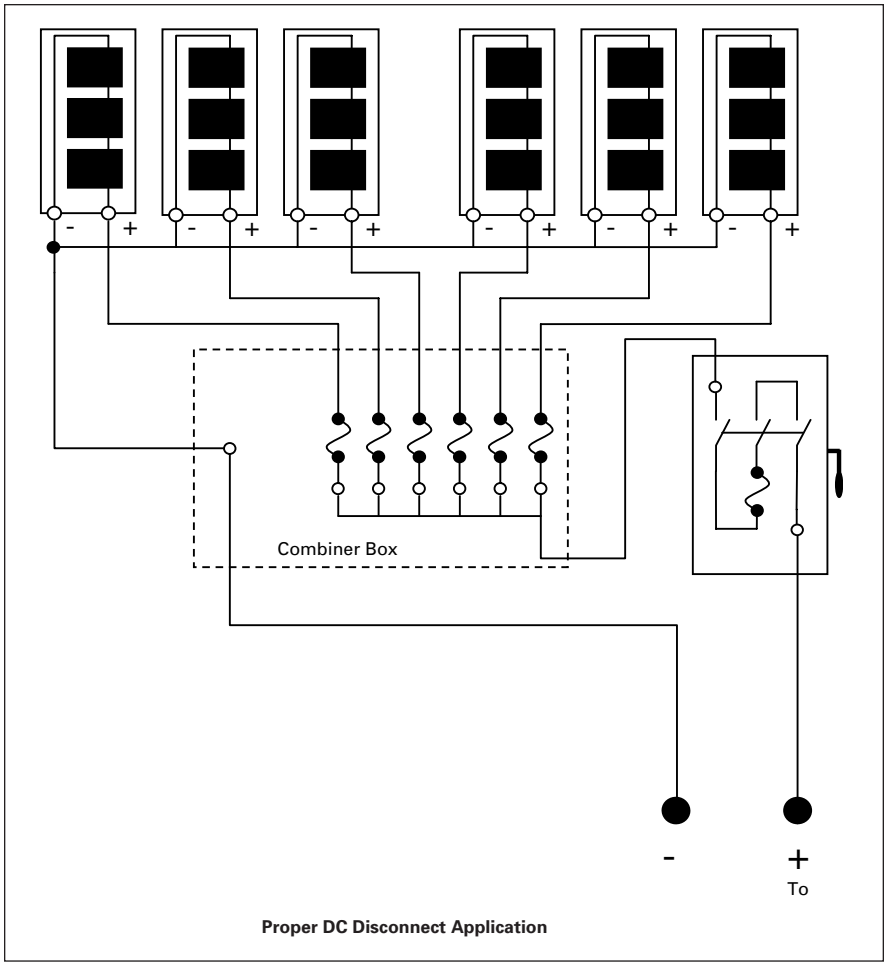

Figure 39.2-5. Proper DC Disconnect Application—PV System With String Combiner Box and Switch Wired in Accordance With Product's UL Listing

Dimensions

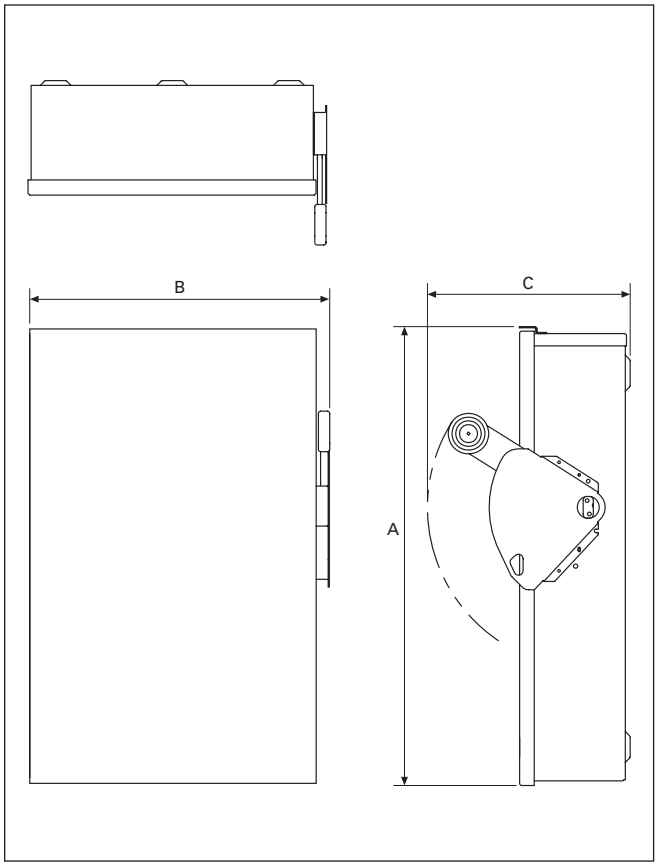

Figure 39.2-6. Type 3R Solar Switch Dimensions

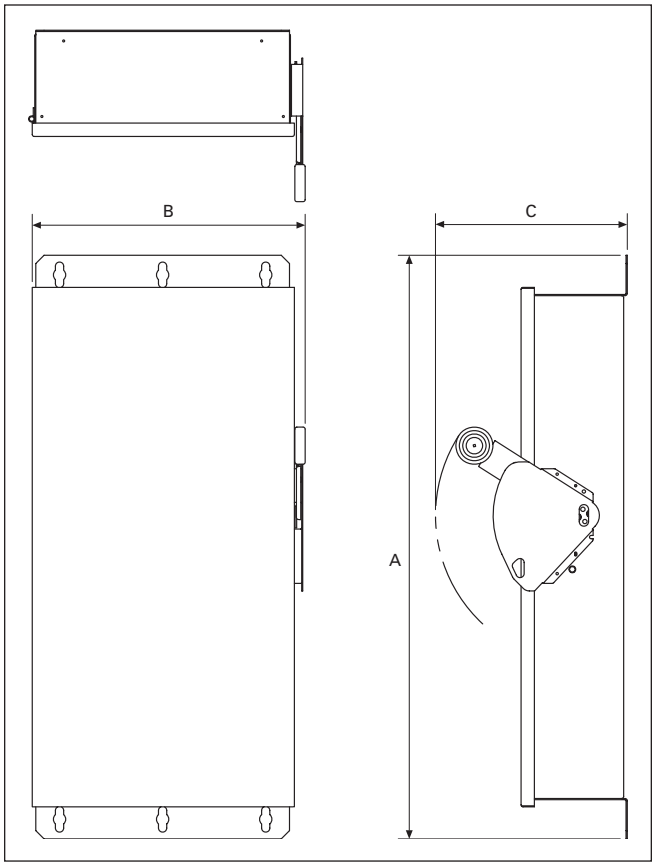

Figure 39.2-7. Type 12-3R and 4X Solar Switch Dimensions

Table 39.2-4. Type 3R Solar Switch Dimensions

Amperes	A	B	C	Main Lug Capacity ①	Ground Lug Capacity
30	16.35	8.87	9.89	#2 AWG–#14 AWG Cu/Al	#4 AWG–#14 AWG Cu/Al
60	16.35	8.87	9.89	#2 AWG–#14 AWG Cu/Al	#4 AWG–#14 AWG Cu/Al
100	22.15	11.84	9.89	1/0 AWG–#14 AWG Cu/Al	#4 AWG–#14 AWG Cu/Al
200	28.27	16.66	11.26	250 kcmil–#6 AWG Cu/Al	#2 AWG–#14 AWG Cu/Al
400	45.00	24.12	12.39	(1) 750 kcmil—1/0 or (2) 300 kcmil—1/0 Cu/Al	250 kcmil—#6 AWG Cu/Al
600	52.50	25.12	14.07	(1) 750 kcmil—1/0 and (1) 600 kcmil—#2 AWG Cu/Al	250 kcmil—#6 AWG Cu/Al

① A UL 98 limits the conductor current sizing to 75°C. 90°C wire may be terminated per Article 110.14(C); however, the maximum current capacity is limited to NEC Table 310.16, 75°C column.

Table 39.2-5. Type 12, 3R and 4X Solar Switch Dimensions

Amperes	A	B	C	Main Lug Capacity ②	Ground Lug Capacity
30 Non-fusible	14.14	8.76	10.22	#2 AWG–#14 AWG Cu/Al	#4 AWG–#14 AWG Cu/Al
30 Fusible	19.08	8.76	10.22	#2 AWG–#14 AWG Cu/Al	#4 AWG–#14 AWG Cu/Al
60 Non-fusible	14.14	8.76	10.22	#2 AWG–#14 AWG Cu/Al	#4 AWG–#14 AWG Cu/Al
60 Fusible	19.08	8.76	10.22	#2 AWG–#14 AWG Cu/Al	#4 AWG–#14 AWG Cu/Al
100	24.95	11.79	10.22	1/0 AWG–#14 AWG Cu/Al	#4 AWG–#14 AWG Cu/Al
200	35.38	16.95	11.63	300 kcmil–#6 AWG Cu/Al	#2 AWG–#14 AWG Cu/Al
400	57.47	24.12	12.43	(1) 750 kcmil—1/0 or (2) 300 kcmil—1/0 Cu/Al	250 kcmil—#6 AWG Cu/Al
600	63.00	26.34	14.25	(1) 750 kcmil—1/0 and (1) 600 kcmil—#2 AWG Cu/Al	250 kcmil—#6 AWG Cu/Al

② A UL 98 limits the conductor current sizing to 75°C. 90°C wire may be terminated per Article 110.14(C); however, the maximum current capacity is limited to NEC Table 310.16, 75°C column.

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Solar Combiner Box—Source Combiner and Array Combiner

Solar Combiner Boxes

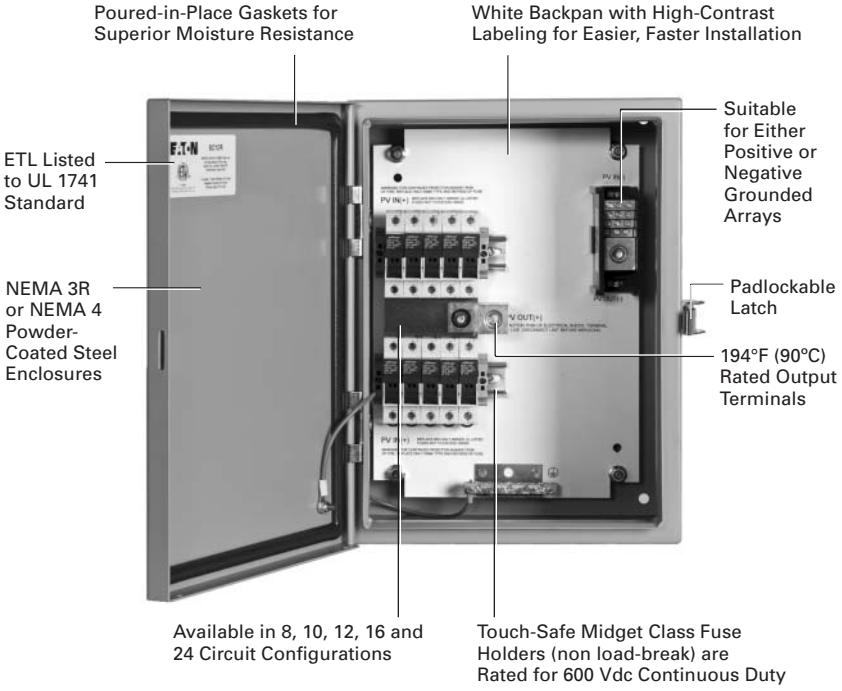
General Description

Photovoltaic (PV) systems contain many separate DC source circuits that must be combined into a single circuit prior to inversion into clean, usable AC power for the electric grid.

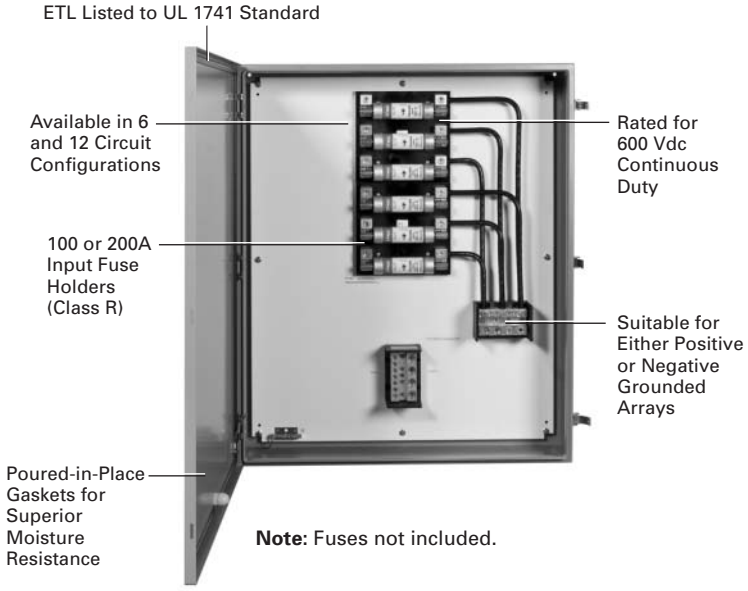
Solar combiner boxes aggregate the many DC source circuits present in a solar PV system, and provide the overcurrent protection requirements of the National Electrical Code. Containing input fuse holders for source protection, the load sides of the fuse holders are connected together on a common bus that contains the output lugs, allowing multiple circuits to be combined into one outgoing circuit.

Eaton's combiner boxes are available in two styles—source combiners and array combiners. Source combiners are located closer to the source, or the solar panels. They have smaller input fuse holders and lower output currents.

Features



Source Combiner Features



Array Combiner Features

Standards and Certifications

- ETL listed to UL 1741

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Product Selection

Note: Switched Combiners (for both Source and Array applications) that combine the below Combiners with DC disconnects in a single enclosure are also available. Contact Eaton for details.

Table 39.3-1. Source Combiners

Number of Circuits	Maximum Fuse Size ①	Incoming Wire Range	Output Conductors	Maximum Continuous DC Current	NEMA 3R Catalog Number	NEMA 4 Catalog Number
8	30	#16–#4	1–#6 to 350 kcmil	310	**SC8R**	**SC8P**
10	30	#16–#4	1–#6 to 350 kcmil	310	**SC10R**	**SC10P**
12	30	#16–#4	1–#6 to 350 kcmil	310	**SC12R**	**SC12P**
16	30	#16–#4	2–#6 to 350 kcmil	400	**SC16R**	**SC16P**
24	20 ②	#16–#4	2–#6 to 350 kcmil	400 ②	**SC24R**	**SC24P**

① Fuses not included.
② Total installed fuse capacity shall not exceed maximum continuous DC current rating.

Table 39.3-2. Array Combiners

Number of Circuits	Maximum Fuse Size ③	Incoming Wire Range	Output Conductors	Maximum Continuous DC Current	NEMA 3R Catalog Number	NEMA 4 Catalog Number
6	100	#6–2/0	2–#4 to 500 kcmil	720	**AC6100R**	**AC6100P**
12	100	#6–2/0	4–#4 to 500 kcmil	1520	**AC12100R**	**AC12100P**
6	200	#6–4/0	4–#4 to 500 kcmil	1520	**AC6200R**	**AC6200P**
12	200 ②	#6–4/0	4–#4 to 500 kcmil	1520 ④	**AC12200R**	**AC12200P**

③ Fuses not included.
④ Total installed fuse capacity shall not exceed maximum continuous DC current rating.

Dimensions

Approximate dimensions in inches (mm).

Table 39.3-3. Source Combiners

Height	Width	Depth	Weight in Lbs (kg)	NEMA 3R Catalog Number	NEMA 4 Catalog Number
16.00 (406.4)	12.00 (304.8)	6.00 (152.4)	30 (13.6)	**SC8R**	**SC8P**
16.00 (406.4)	12.00 (304.8)	6.00 (152.4)	30 (13.6)	**SC10R**	**SC10P**
16.00 (406.4)	12.00 (304.8)	6.00 (152.4)	30 (13.6)	**SC12R**	**SC12P**
16.00 (406.4)	12.00 (304.8)	6.00 (152.4)	36 (16.3)	**SC16R**	**SC16P**
20.00 (508.0)	20.00 (508.0)	6.00 (152.4)	45 (20.4)	**SC24R**	**SC24P**

Table 39.3-4. Array Combiners

Height	Width	Depth	Weight in Lbs (kg)	NEMA 3R Catalog Number	NEMA 4 Catalog Number
36.00 (914.4)	36.00 (914.4)	8.00 (203.2)	156 (70.8)	**AC6100R**	**AC6100P**
48.00 (1219.2)	36.00 (914.4)	8.00 (203.2)	227 (103.0)	**AC12100R**	**AC12100P**
42.00 (1066.8)	36.00 (914.4)	8.00 (203.2)	206 (93.5)	**AC6200R**	**AC6200P**
48.00 (1219.2)	36.00 (914.4)	8.00 (203.2)	278 (126.2)	**AC12200R**	**AC12200P**