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SOLECTRIA A YASKAWA COMPANY

Design Considerations

DC Considerations
AC Design Considerations
Solectria Commercial Solutions

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Solectria History

- Solectria Corporation was founded in 1989
- The EV division was sold in 2005 to Azure Dynamics
- Solectria Renewables was founded in 2005 focused on grid-tied PV inverter technologies
- Today, Solectria Renewables has a broad product line including:
  - Grid-tied PV inverters for residential, commercial & utility-scale applications
  - String combiners
  - Web-based monitoring solutions

SOLECTRIA
A YASKAWA COMPANY

Solectria Corporation Founded

Solectria Renewables Founded

Solectria divests vehicle products to Azure Dynamics

Original 10kW UL Listed

PVI 13-15KW UL Listed

PVI 60/77/90KW UL Listed

60/82/95KW UL Listed

PVI 3000-5300 Introduced

SolrenView Web Monitoring Introduced

Capacity Expansion to 200MW

SGI Series UL Listed

MSS Introduced

Capacity Expansion to 350MW

Capacity Expansion to 800MW

Disconnecting String Combiners Introduced

New SolrenView GUI Introduced

Introduced SGI 500 Premium Efficiency model with 97.5% CEC efficiency – highest in the industry

Introduced the SGI 500XTM & SGI 750XTM External Transformer

ARCCOM (AFDI String Combiner) Introduction

SGI 500XT transformerless 600V DC inverter introduced

PVI 14-28TL, 3-phase transformerless inverters

PVI 3800-7600TL, 1Ph transformerless inverters

Introduced PVI 50/60/75/85/100KW & Premium Efficiency Models

1989 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014

For those transitioning from Residential to Commercial…

- String Sizing
- Wire/OCPD Sizing
- Combiners & Subcombiners
- BOS Specification
- Inverter Specification
- Site Visits
- Incentives
- Equipment Layouts
- Engineering Drawings
- Performance Estimates
- Grounding
- Permitting/Inspection
- Interconnection Agreements
- Project Management
- Commissioning
- Interconnection Strategy
- Power Factor
- Three-Phase
- Utility Relaying

DEVELOP A STRONG PROJECT TEAM, INCLUDING SOLECTRIA!

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Some of our trusted partners and customers

… Even More Solutions from the Industry's Best Inverter Lineup

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PV Inverters

Utility	External Transformer Inverters Megawatt Solar Stations	500-750 kW 1-2MW
Commercial	Central Inverters, 3-Phase String	50-100, 225-500 kW 14-28 kW
Residential	String Inverters	3.8-7.6 kW

String Combiners

Web-Based Monitoring

PVI 3800-7600TL

PVI 14-20TL
PVI 23-28TL

PVI 50-100KW

SGI 225-500PE

SGI 500XT

SGI 500XTM
SGI 750XTM

DC Design Considerations

String Sizing Recommendations

String Sizing

RECOMMENDATION #1

Use Max Allowable String Size to…

- **Reduced BOS Costs** - Fewer strings means fewer combiner boxes and fewer PV source and output circuits
- **Reduce System Losses** - fewer circuits and higher voltage/lower total current
- **Maximize Production for System Life**
  - Ensures string Vmp stays within the MPPT range of inverter for array life.
  - Protects from Vmp calc “shortcomings” and high AC voltage

Of course, using max. number of modules is not always possible or preferred for other reasons (complex layout, odd string size, carport…)

Next Stage in Design Evolution: 1000V Systems

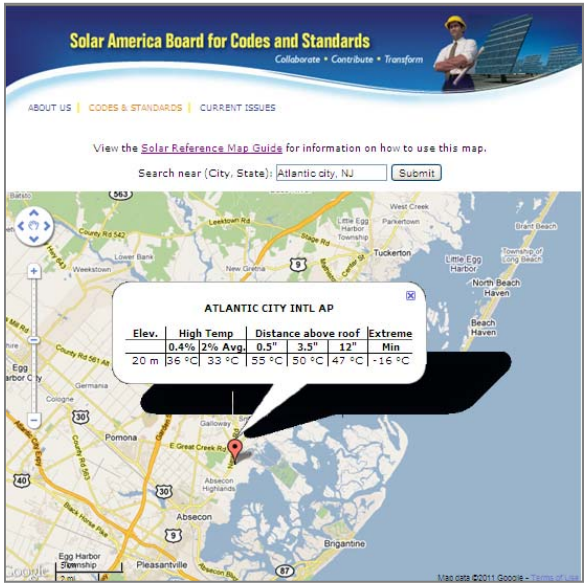
String Sizing

RECOMMENDATION #2

Use ASHRAE Low Temperature

(a.k.a. Extreme Annual Mean Minimum Design Dry Bulb Temperature)

- Often yields higher max string size
- Supported by:
  - NEC 2011 690.7(A) Informational Note
  - “Array Voltage Considerations”, B. Brooks, SolarPro Oct/Nov 2010
- **CHECK WITH INSPECTOR IN NEC 2008 OR 2005 LAND!!**
- SolarABC’s Map Tool



www.solarabcs.org/about/publications/reports/expedited-permit/map/

String Sizing – (example)

Use Solectria PV System Builder (www.solren.com)

- **Location:** Atlantic City, NJ
- **Array Size**: 600kW DC
- **Module:** Sharp NU-U235F1
- **Inverter:** PVI 500

Record Low/Average High (Traditional Approach)

-23° C/29° C

⇒ 13 Modules Per String

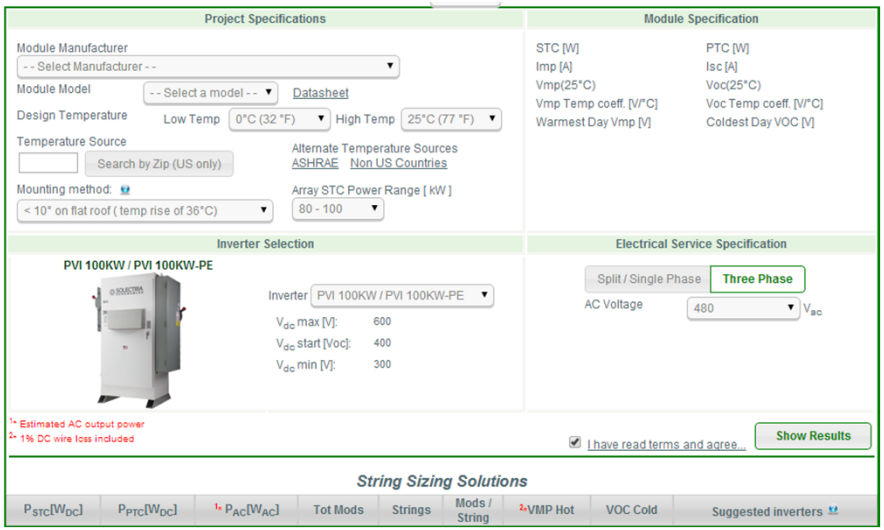
⇒ 196 Strings

ASHRAE

-16° C/33° C

⇒ 14 Modules Per String

⇒ 182 Strings



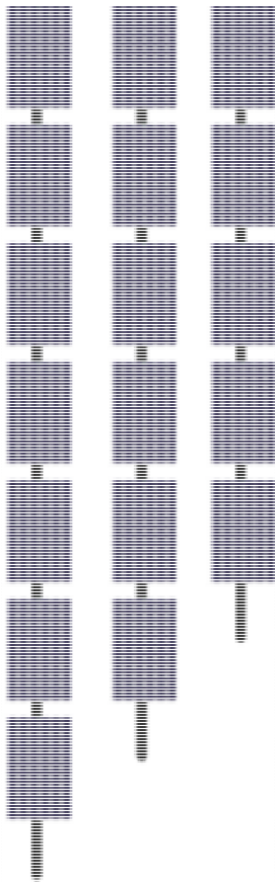
THAT'S ONE LESS 14-STRING COMBINER AND HOME RUN WIRING/CONDUIT!!

String Sizing - Example

String Sizing

RECOMMENDATION #3

- **Make sure that your string voltage is well above the min. MPPT voltage of the inverter**



Remember:

- **Voltage Drop** – The voltage at the inverter will be lower than the string voltage due to voltage drop.
- **Cell Temp** – Is an Estimate
  - Based upon “Average High” or “ASHRAE”
  - Include estimated racking adder
- **Different methods for calculating k_Vmp**
- **High Line Voltage** – Increases the Min. MPPT voltage

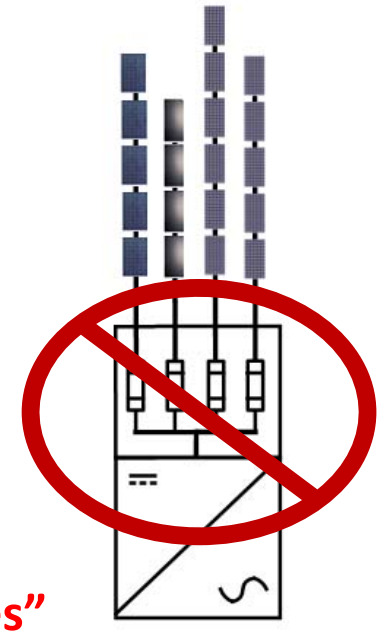
String Mismatch (Voltage Mismatch)

BEST PRACTICE:

Avoid combining different "Sting Types" to the same MPPT channel.

String Types

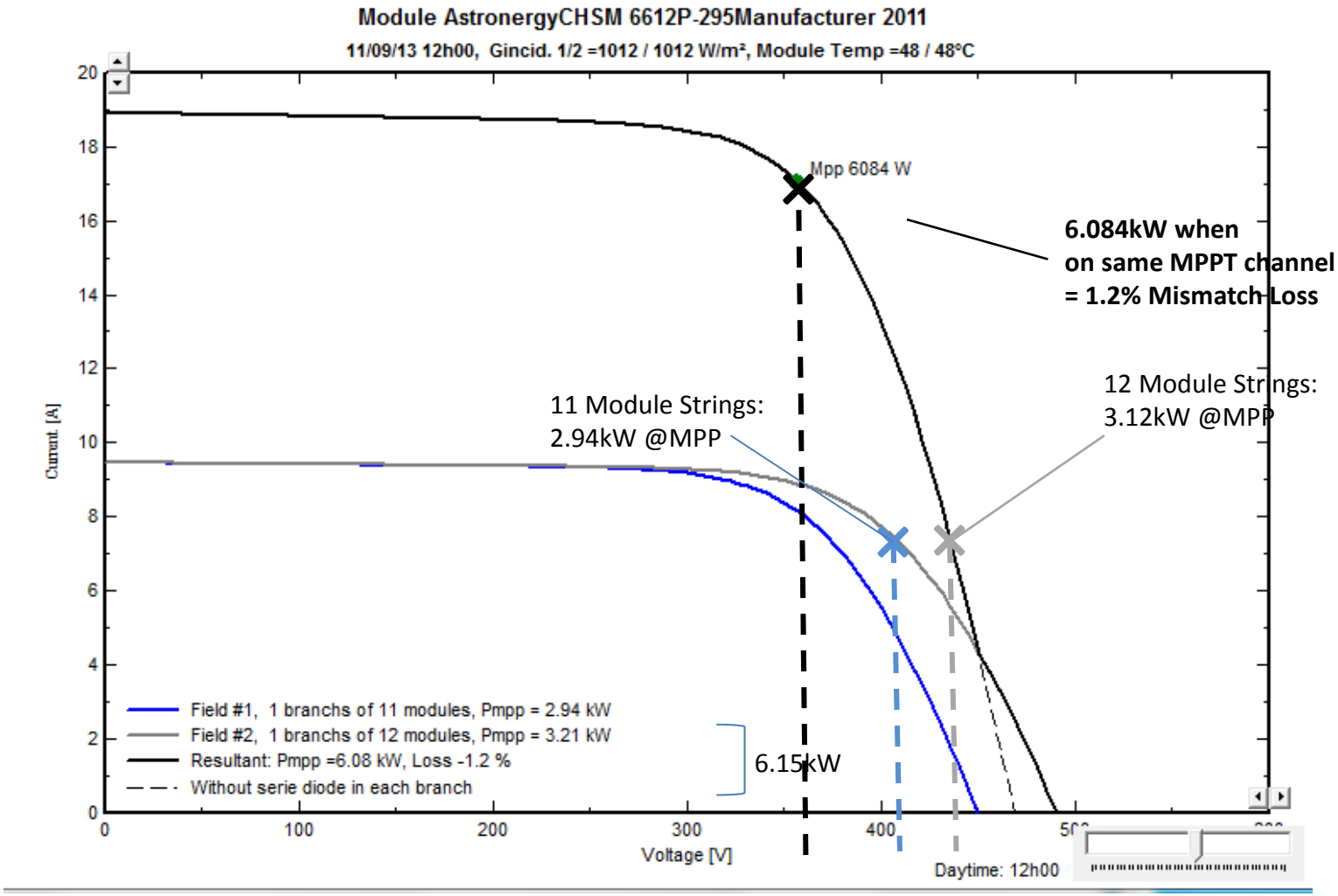
- String Size
- Tilt Angle
- Azimuth Angle (Orientation)
- Different module types
- New and Old of the same module
- Shaded and Unshaded Strings



Combining dissimilar strings results in String **"Mismatch Losses"**

(Each string type has a specific MPP voltage, but when combined in parallel all strings are forced to operate at the same voltage...)

String Mismatch (Voltage Mismatch)



Oversizing

Oversizing

What is the Array-to-Inverter Ratio?

- The ratio of Array's STC Nameplate Power to Inverter's Rated Power
- Also called: DC/AC Ratio, Oversizing Ratio, Overloading Ratio

Example:

Array: 120kW
Inverter: PVI 100KW

$$\frac{120kW}{100kW} = 1.2$$

…the Array-to-Inverter Ratio is 1.2 (120%)

120kW PV Array

PVI 100KW

Oversizing

Historically:

- Due to high module prices, optimal oversizing: 1.10 to 1.25
- Design Goal:
  - Optimize Annual Energy Harvest per Panel = Optimize Specific Yield (Annual kWh/kWdc)
  - Little to No clipping
  - Minimal shading

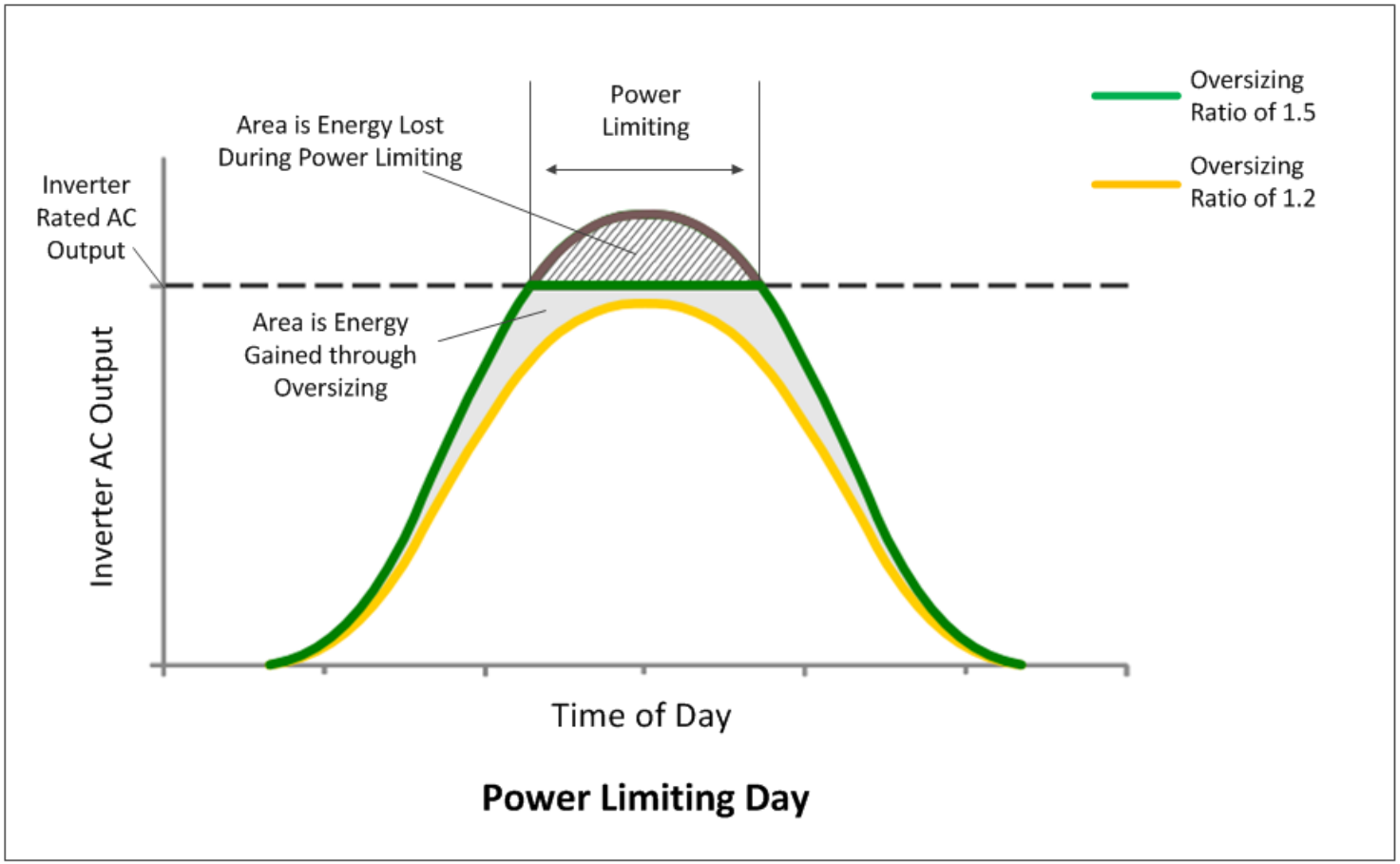
Today:

- Cheaper Module Prices
  - Larger array feeding a fixed size inverter results in greater production
  - Greater production across the same fixed AC costs
- Time-of-Use Utility Rates
  - Generate most energy when it has the most value

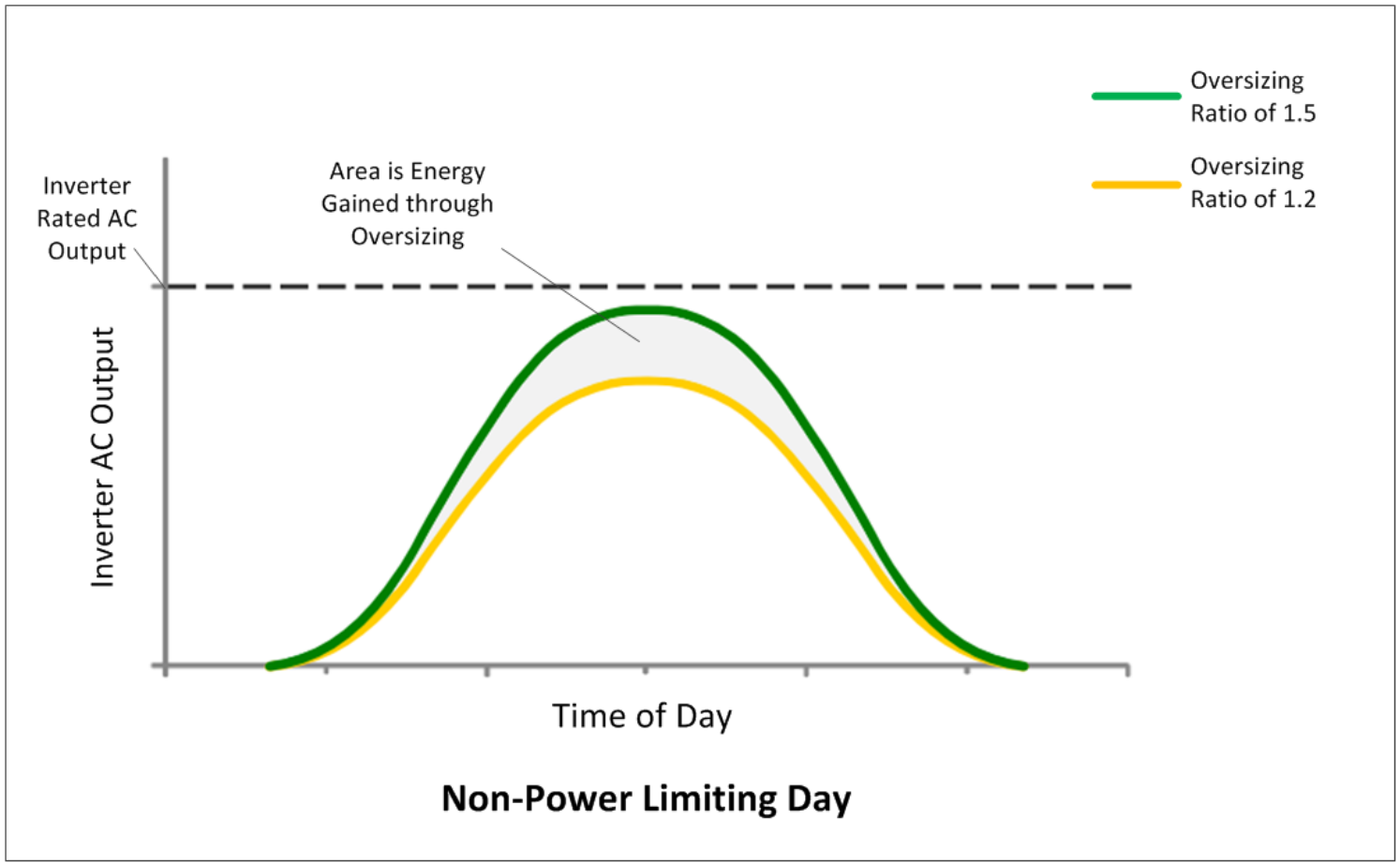
Designers are exploring vary tilt angle and power density and encroaching into shaded regions

Daily Output Profile: Clipping Day

- Oversized systems produce more energy
- Oversized systems match TOU rate structures



Daily Output Profile: Non-Clipping Day



How to determine "Optimal" Array to Inverter Ratio

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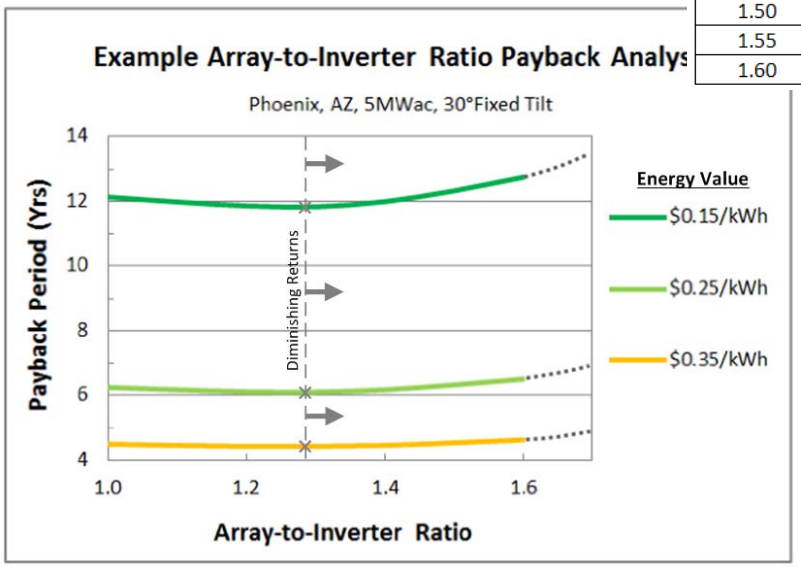
Perform Oversizing Analysis using simulation program (PVsyst, PV*SOL, SAM) => Feeds Financial Model

Array-to-Inverter Ratio	Array STC Power (MWdc)	Inverter Rated Power (MWac)	Annual Production (MWh/yr)	Specific Production (kWh/kW)	$/W	LCOE Real (¢/kWh)	Payback
1.00	5.00	5	9223	1845	$3.70	7.48	12.13
1.05	5.23	5	9656	1845	$3.69	7.44	12.05
1.10	5.50	5	10152	1845	$3.67	7.41	11.98
1.15	5.74	5	10579	1844	$3.65	7.39	11.92
1.20	6.01	5	11068	1843	$3.64	7.36	11.86
1.25	6.24	5	11482	1840	$3.62	7.35	11.83
1.30	6.51	5	11937	1834	$3.61	7.35	11.83
1.35	6.74	5	12300	1824	$3.60	7.37	11.87
1.40	7.01	5	12664	1806	$3.59	7.42	11.99
1.45	7.25	5	12950	1787	$3.58	7.48	12.13
1.50	7.52	5	13242	1762	$3.57	7.57	12.32
1.55	7.75	5	13415	1731	$3.56	7.68	12.58
1.60	7.98	5	13686	1714	$3.55	7.75	12.74



PVSYST PHOTOVOLTAIC SOFTWARE

PV*SOL

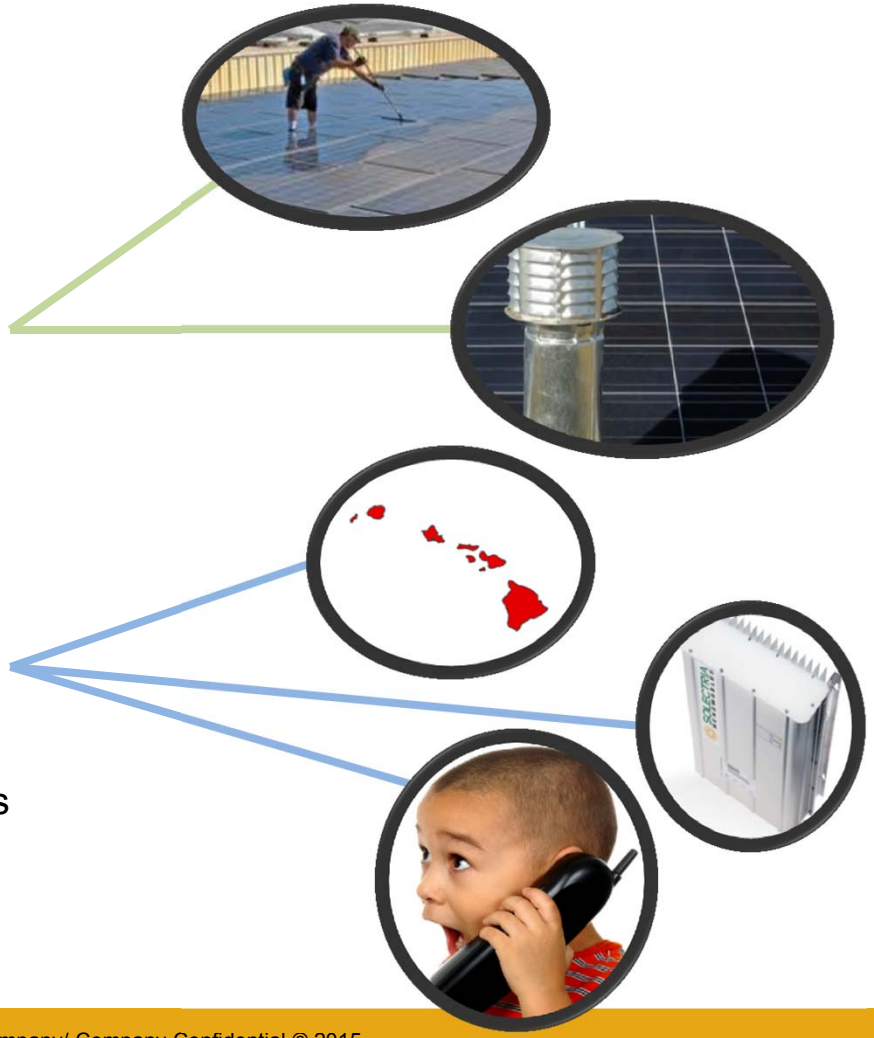
SYSTEM ADVISOR MODEL

Higher or Lower A-I Ratio?

The further away your system is from "Optimal" the Higher the "Best" Array-to-Inverter Ratio

HIGHER Array-to-Inverter Ratios:

- Large Commercial/Utility Scale Projects
- TOU Rate Structure
- Cheaper Modules
- Low/No Tilt Angle
- High Soiling/Don't want to clean
- Off-optimal orientation
- Shading (inter-row, obstructions)
- Fixed ACkW interconnection



LOWER Array-to-Inverter Ratios:

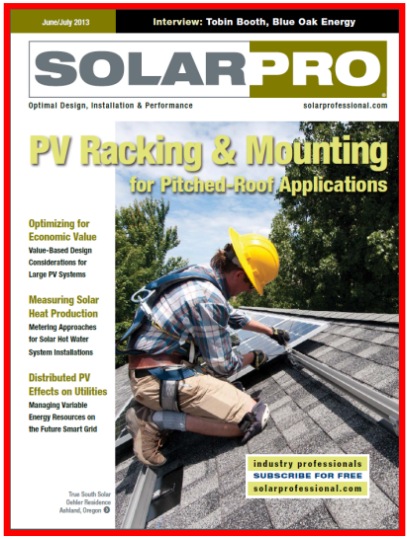
- High Altitude
- Constant "Cooler" temps year round
- Residential Systems, Light Commercial Systems
- Clipping???!!! Customers

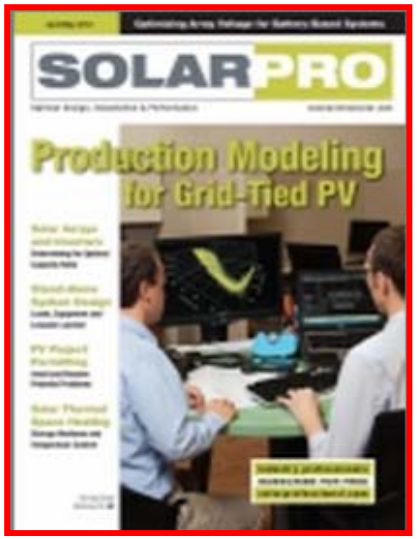
Oversizing Reverences

SolarPower World: "Supersize It," J. Fiorelli, M. Zuercher, June 2013

SolarPro Magazine: "Designing for Value in Large-Scale PV Systems," G. Everts and M. LeDucq, June/July 2013

SolarPro Magazine: "Optimal PV-to-Inverter Sizing Ratio," A. Gregg, C. Adcock, B. Brooks, April/May 2010





Voltage Drop

Voltage Drop

DC and AC conductors are sized to meet:

- Code Requirements (NEC) …..Safety
- Voltage Drop Requirements ….. Performance/Efficiency

Best Practices for Voltage Drop

- DC Voltage Drop – Limit to 1-1.5%*
- AC Voltage Drop – Limit to 0.5 to 1%*

Voltage drop specs are often called out in RFP Spec.

*See next slide

Voltage Drop

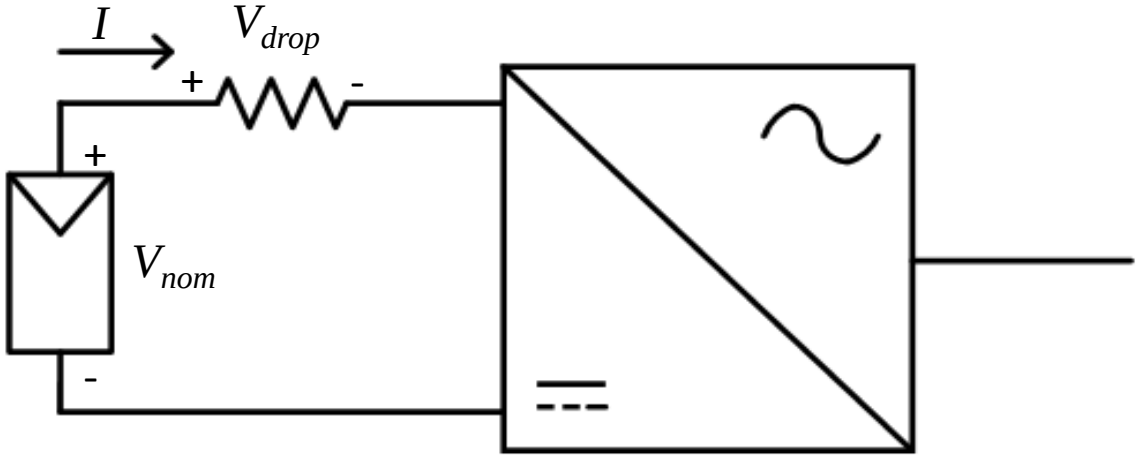
*Of course, there are always exceptions….

Why Limit Voltage Drop?

Reduce Resistive Losses

Voltage Drop % is a Power Loss Fraction.

$$Voltage\ Drop\ \% = \frac{V_{drop}}{V_{nom}} = \frac{V_{drop} \times I}{V_{nom} \times I} = \frac{P_{loss}}{P_{nom}} = 1\%$$

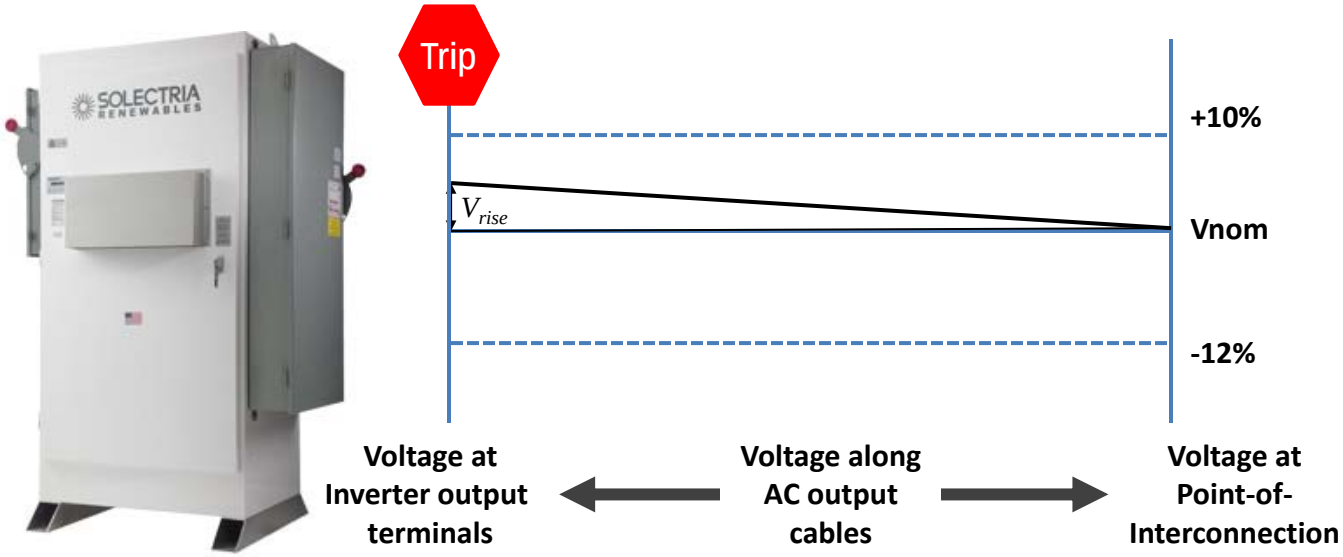


1% Voltage Drop means DC circuits are 99% Efficient (at max power… more efficient at lower power)

Why Limit Voltage Drop?

Minimize Voltage Rise

The inverter sees the grid voltage plus the AC Voltage Drop. If grid voltage is high and voltage drop is high >>> ***Nuisance Tripping***



DC Design – Overcurrent Protection

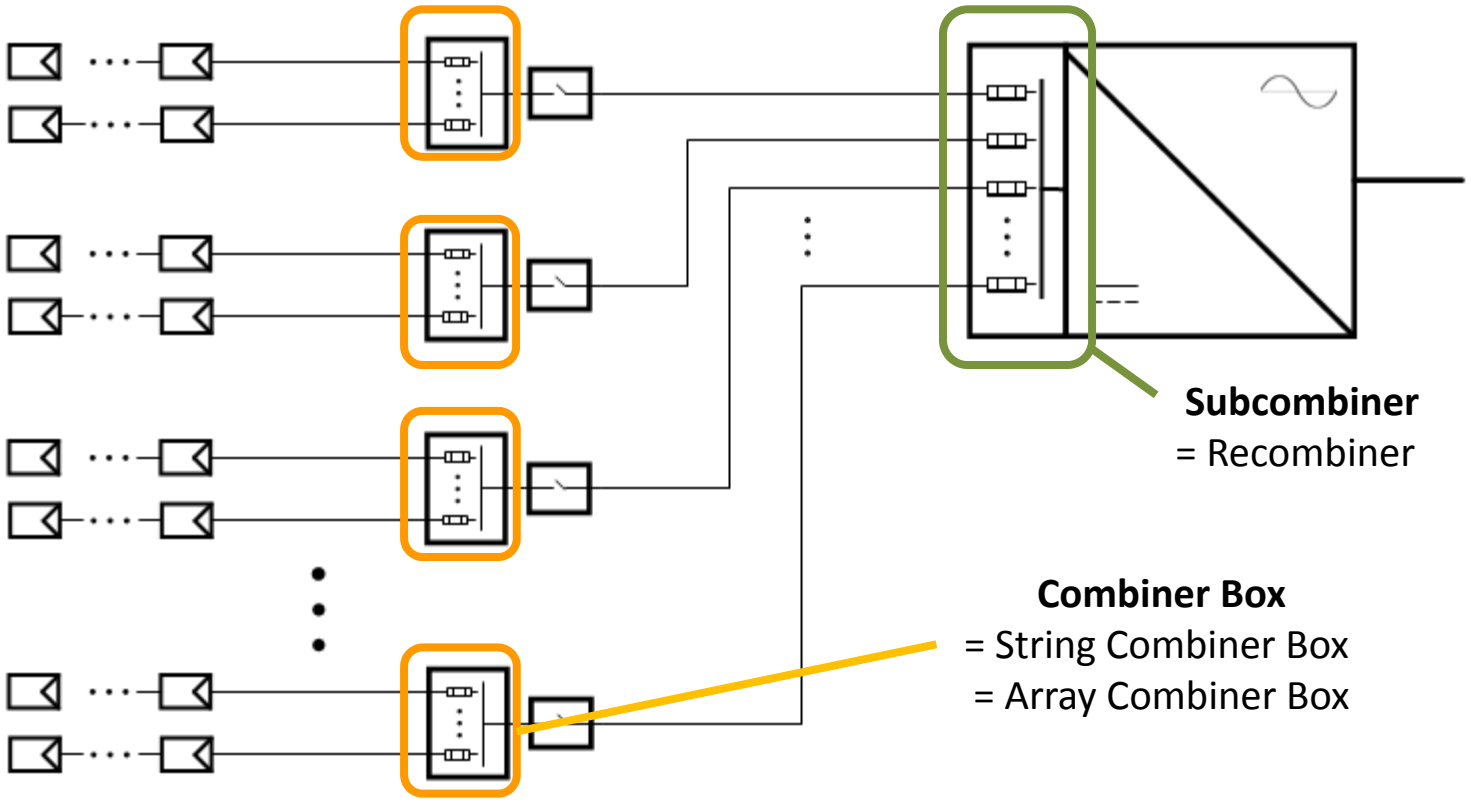
DC Overcurrent Protection

DC OCPD…Fancy Name for:

Fuse **Circuit Breaker**

LOCATION: **Combiner Boxes** and **Subcombiner Boxes**

FUNCTION:



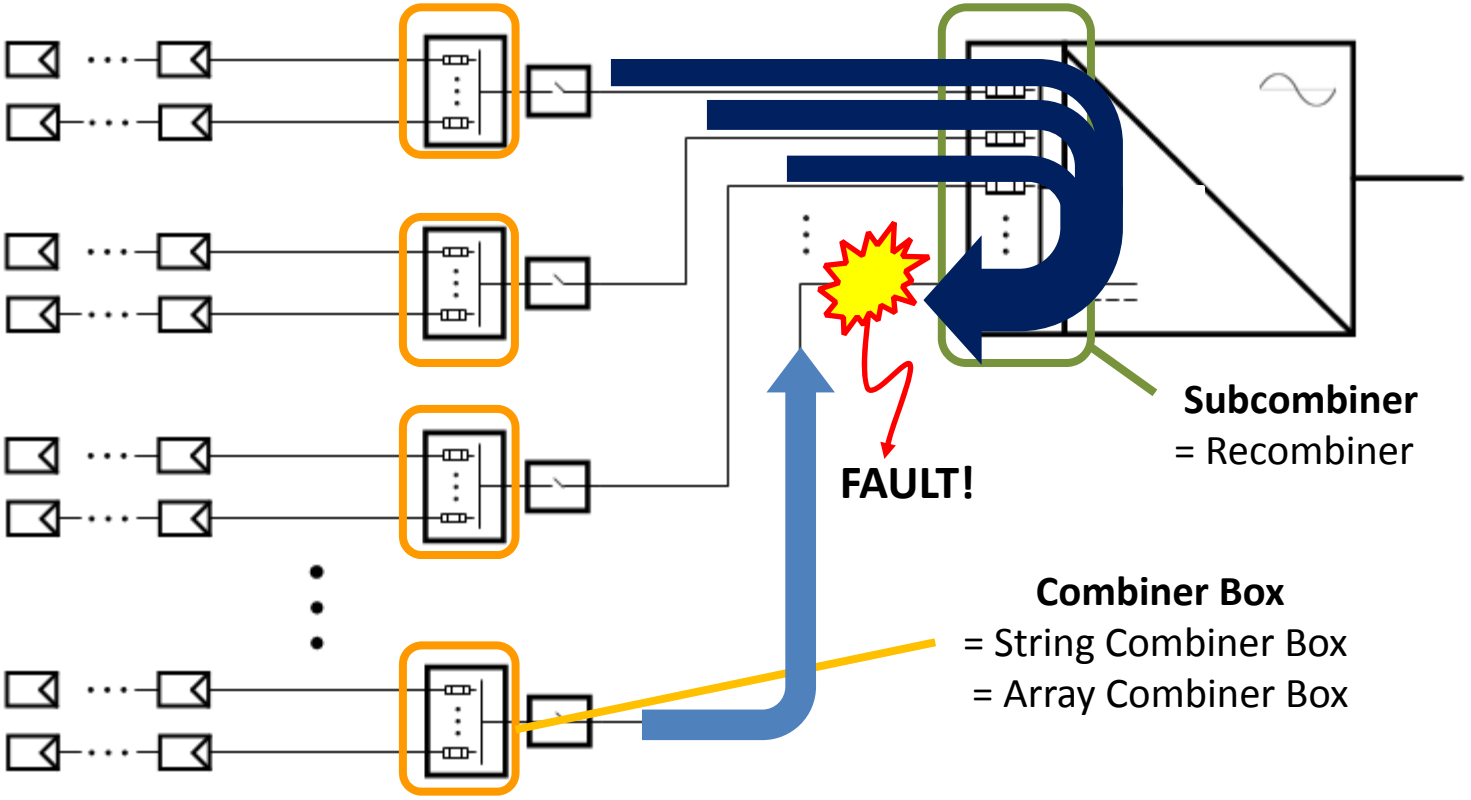
DC Overcurrent Protection

DC OCPD…Fancy Name for:

Fuse **Circuit Breaker**

LOCATION **Combiner Boxes** and **Subcombiner Boxes**

FUNCTION: **Protects cables**



DC Overcurrent Protection

$$Min.OCPD\ Size = \mathrm{n} \times Isc \times 1.25 \times 1.25$$

1.56

[NEC 690.8]

Number of String Feeding the OCPD

Module Short Circuit Current

1.25 Factor for Increased Irradiance

1.25 for OCPD Derating

Example Calcs:

Isc = 8.46

What is the min. size string fuse?

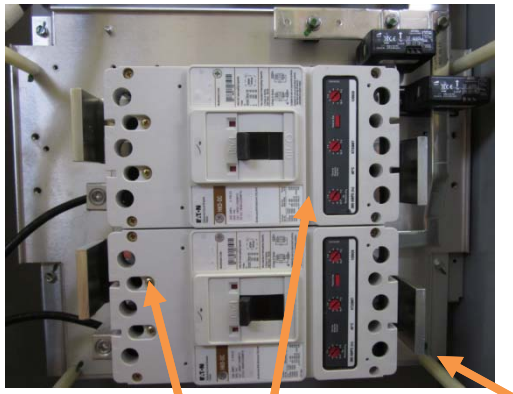
1 x 8.46 x 1.56 = 13.2A .....=> 15A

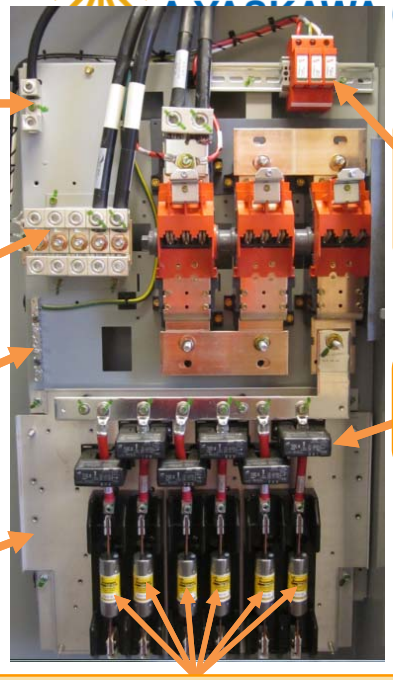
What is min. size fuse for 12 string combiner box?

12 x 8.46 x 1.56 = 158.4.....=> 175A

Select next standard fuse size up in NEC 240.6

PVI 50-100KW Subcombiner Options





Ground Bars

PV Negative

Ground Bars

DC Surge arrestor

SolZone Sensors

PV Positives, breaker option (2 positions, 300A fuses)

DC DISCONNECT With SUBCOMBINER

PV Positives, fuse option (6 positions, 100A fuses)

SPECIFICATIONS	FUSED POSITIONS	FUSE RANGE
PVI 50/60/75/85/100KW		
Fuses	2	225 A, 250 A, 300 A
	2, 3, 4	110 A, 125 A, 150 A, 175 A, 200 A
	2, 4, 6	70 A, 80 A, 90 A, 100 A
	6, 8	40 A, 50 A, 60A
Breakers	2	225 A, 250 A, 300 A
	2, 3, 4	110 A, 125 A, 150 A, 175 A, 200 A
	2, 3, 4, 5, 6, 7, 8	40 A, 50 A, 60A, 70 A, 80 A, 90 A, 100 A

SGI DC Disconnect Connection

SGI 225/250/266/300		Positions Fuse Ra
Fuses	6	225 A, 250 A, 300 A, 350 A, 400 A
	12	110 A, 125 A, 150 A, 175 A, 200 A
	24	70 A, 80 A, 90 A, 100 A
Breakers	6	225 A, 250 A, 300 A, 350 A, 400 A
	12	110 A, 125 A, 150 A, 175 A, 200 A
SGI 500/500PE/500XT		
Fuses	8	225 A, 250 A, 300 A, 350 A, 400 A
	16	110 A, 125 A, 150 A, 175 A, 200 A
	32	70 A, 80 A, 90 A, 100 A
Breakers	8	225 A, 250 A, 300 A, 350 A, 400 A
	16	110 A, 125 A, 150 A, 175 A, 200 A

Current Transducers (CT's)

8 Breaker Option (7, 400A; 1, 350A)

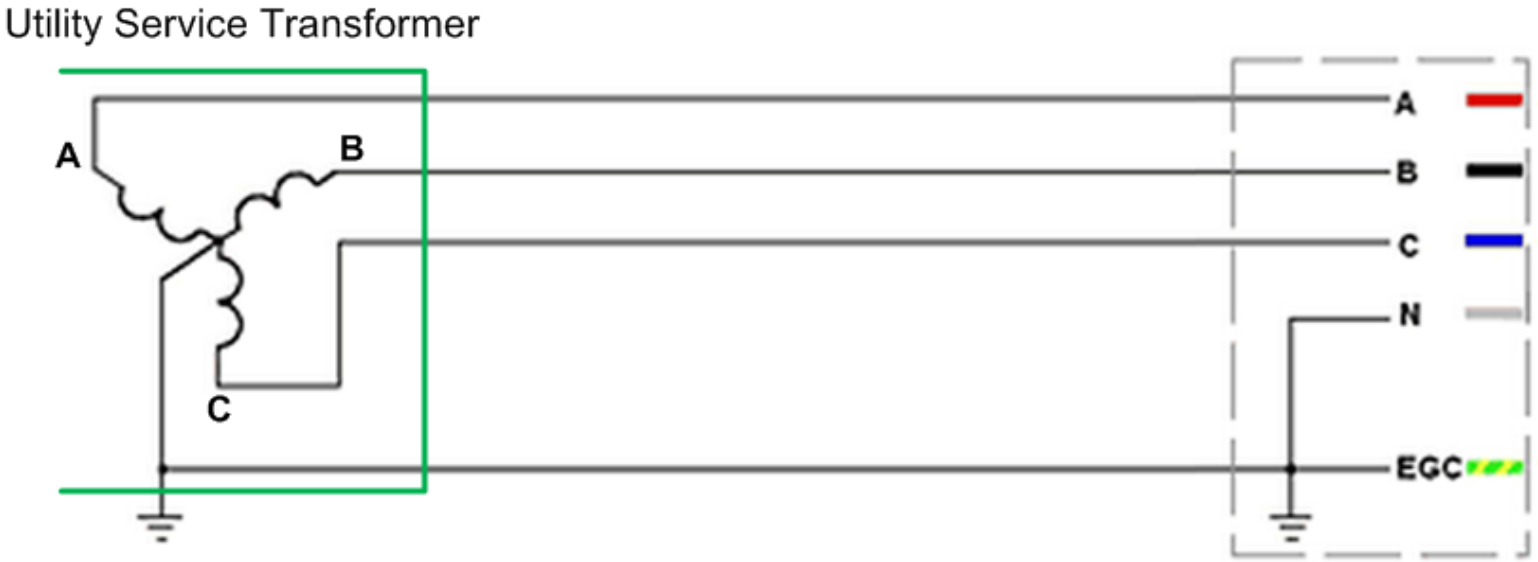
16 Fuse Option (4, 150A; 4, 125A; 8, 175A)

AC Design

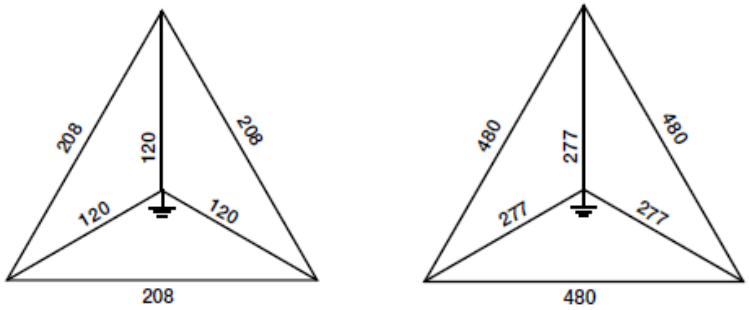
Commercial Service Types

Commercial Service Types: COMMON

3-Phase, Four-Wire Grounded Wye

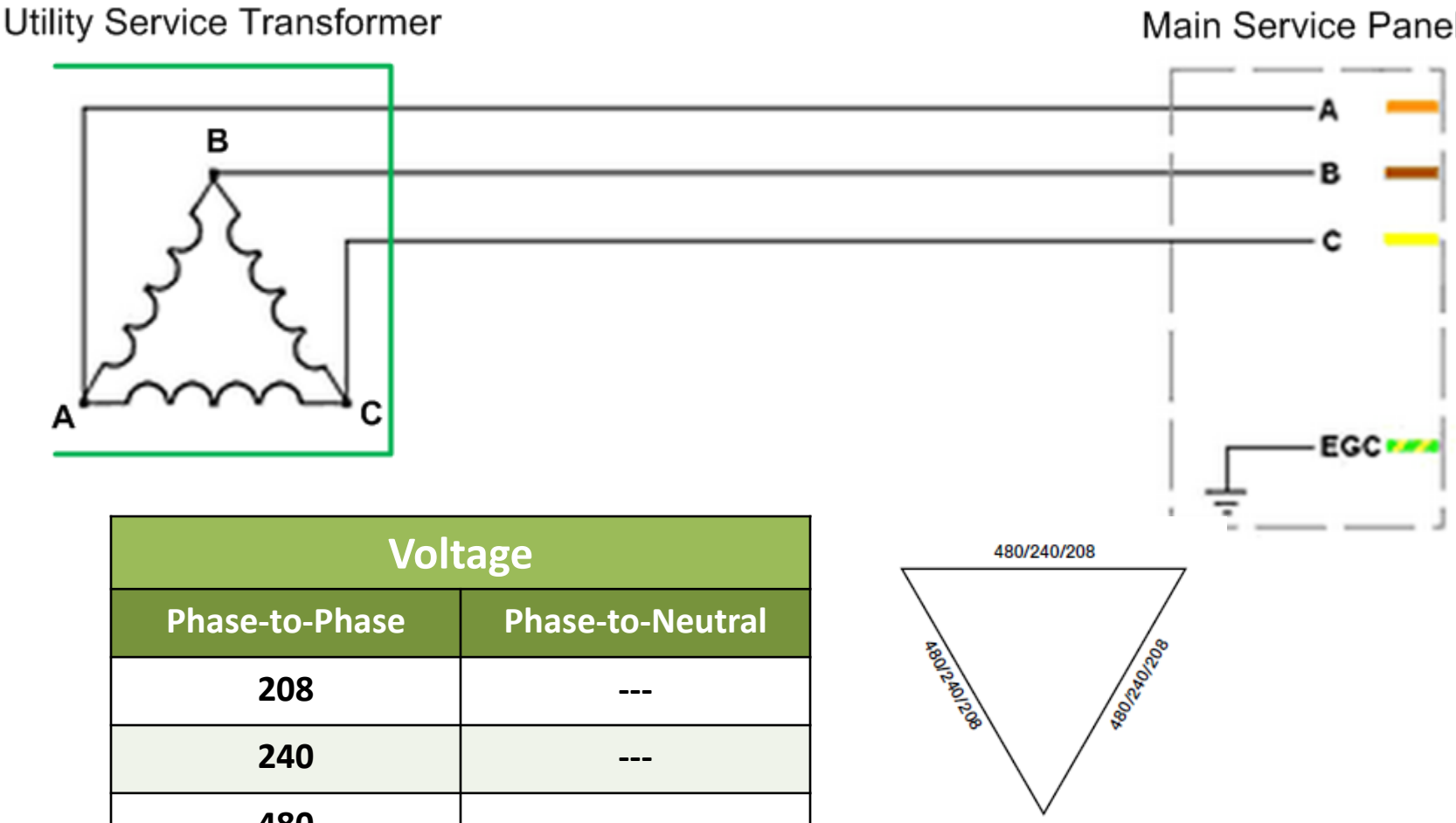


Voltage	
Phase-to-Phase	**Phase-to-Neutral**
208	**120**
480	**277**



Commercial Service Types: COMMON

3-Phase, Three-Wire Unrounded Delta



Voltage	
Phase-to-Phase	**Phase-to-Neutral**
208	**---**
240	**---**
480	**---**

Commercial Service Types: UNCOMMON

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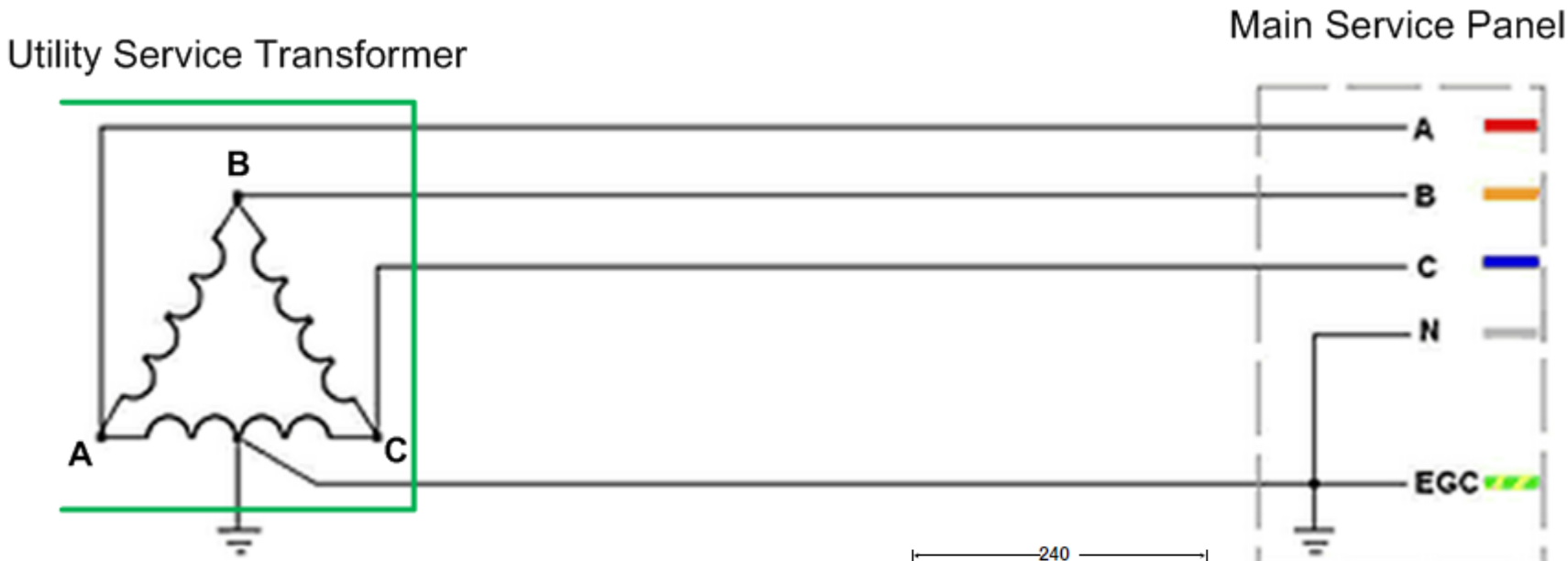
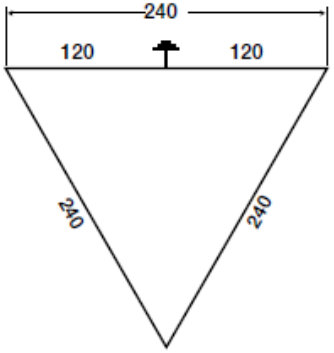
High-Leg Delta (Red Leg, Wild Leg, Bastard Led Delta, Crazy Leg)



Voltage	
Phase-to-Phase	**Phase-to-Neutral**
240	**120 (A-to-N)** **120 (C-to-N)** **208 (B-to-N)**



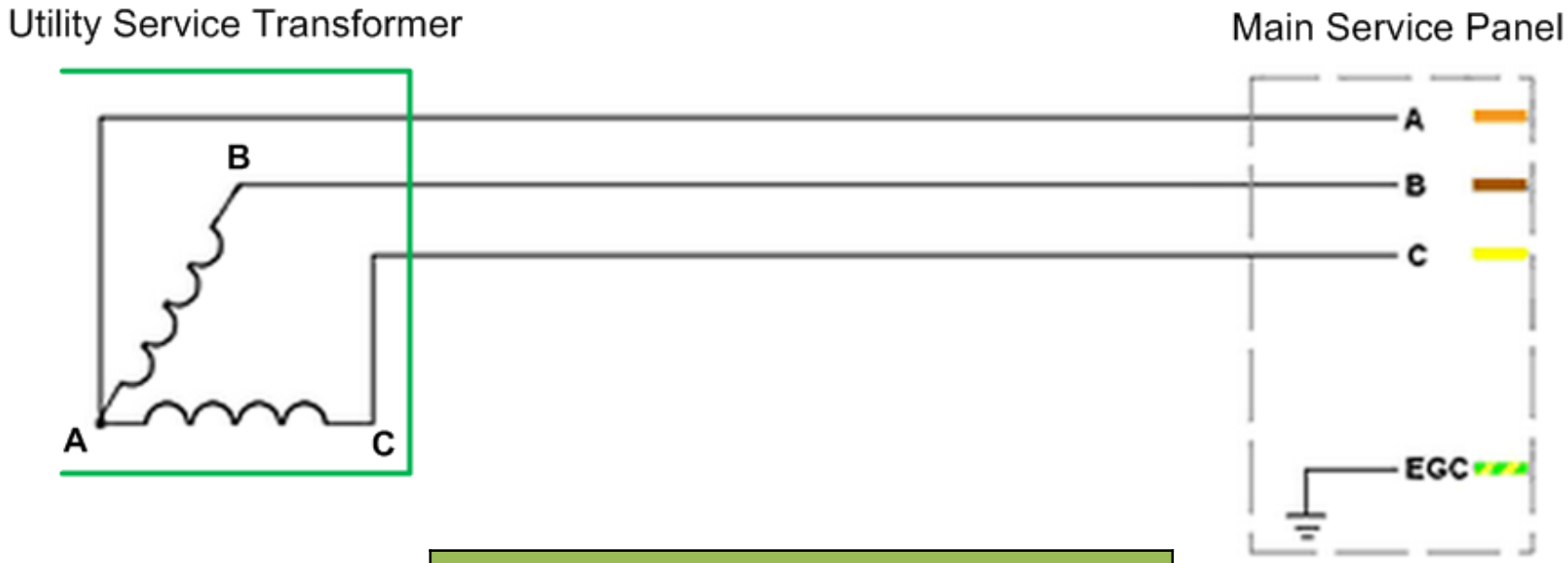
Commercial Service Types: UNCOMMON

Corner Grounded Delta

Voltage	
Phase-to-Phase	**Phase-to-Neutral**
240	**---**
480	**---**

Commercial Service Types: UNCOMMON

Open Delta



Voltage	
Phase-to-Phase	**Phase-to-Neutral**
240	**---**
480	**---**

Commercial Service Types:

SERVICE TYPE	NOTES	SUPPORTED?
Grounded Wye	Most common type of 480V, 208V service	Y
Ungrounded Delta	Common for 480V, 240V, 208V motor control centers	Y
High-Leg Delta	240V service sometimes found in agricultural and older urban areas	Y
Corner Grounded Delta	Uncommon	N
Open Delta	Uncommon	N

Commercial Service Types:

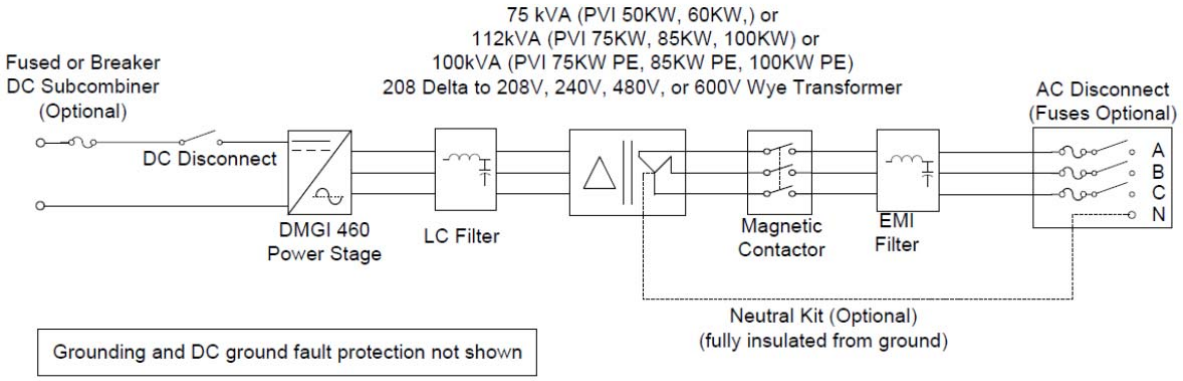
How to confirm the electrical service type?

- Transformer/Transformer Nameplate
- Call Utility
- Have qualified person measure all voltages line-to-line and line-to-ground

…Also confirm kVA rating of utility transformer…

Is a Neutral Required?

- Solectria inverters output balance three-phase current, as a result a neutral is not required for inverter operation
- If required by a utility (for effective grounding or establishing ground reference), Solectria PVI 50-100 and SGI 225-500 are available with 4-Wire Option, where neutral connection point is solidly connected to the isolation transformer neutral point.
- When connecting the inverter as a 4-wire device currents may flow on neutral due to voltage imbalance and harmonics on the distribution line feeding the site.
- Size Neutral conductor cable equal to line conductors.



Example Inverter Block Diagram (from PVI 50-100KW Manual)

What About on TL Inverters???

- 3 Phase Solectria TLs often require a neutral reference.
  - The PVI -20 TL is the only inverter in the 3 phase TL family that can work with a 480V Delta or WYE
  - The PVI-14, 23, 28 TL inverters do require a neutral reference.
  - The neutral IS NOT a current carrying conductor! > Can be sized differently than other conductors.

Bonding Jumper between ground and the neutral terminal has been tested and CAN work but not recommended.

- Likelihood that installers will double up wire in terminals
- Has been know to not always provide the appropriate neutral reference.

Solectrial Recommendation: Plan on a neutral conductor for sensing

AC Design - Interconnections

Interconnections

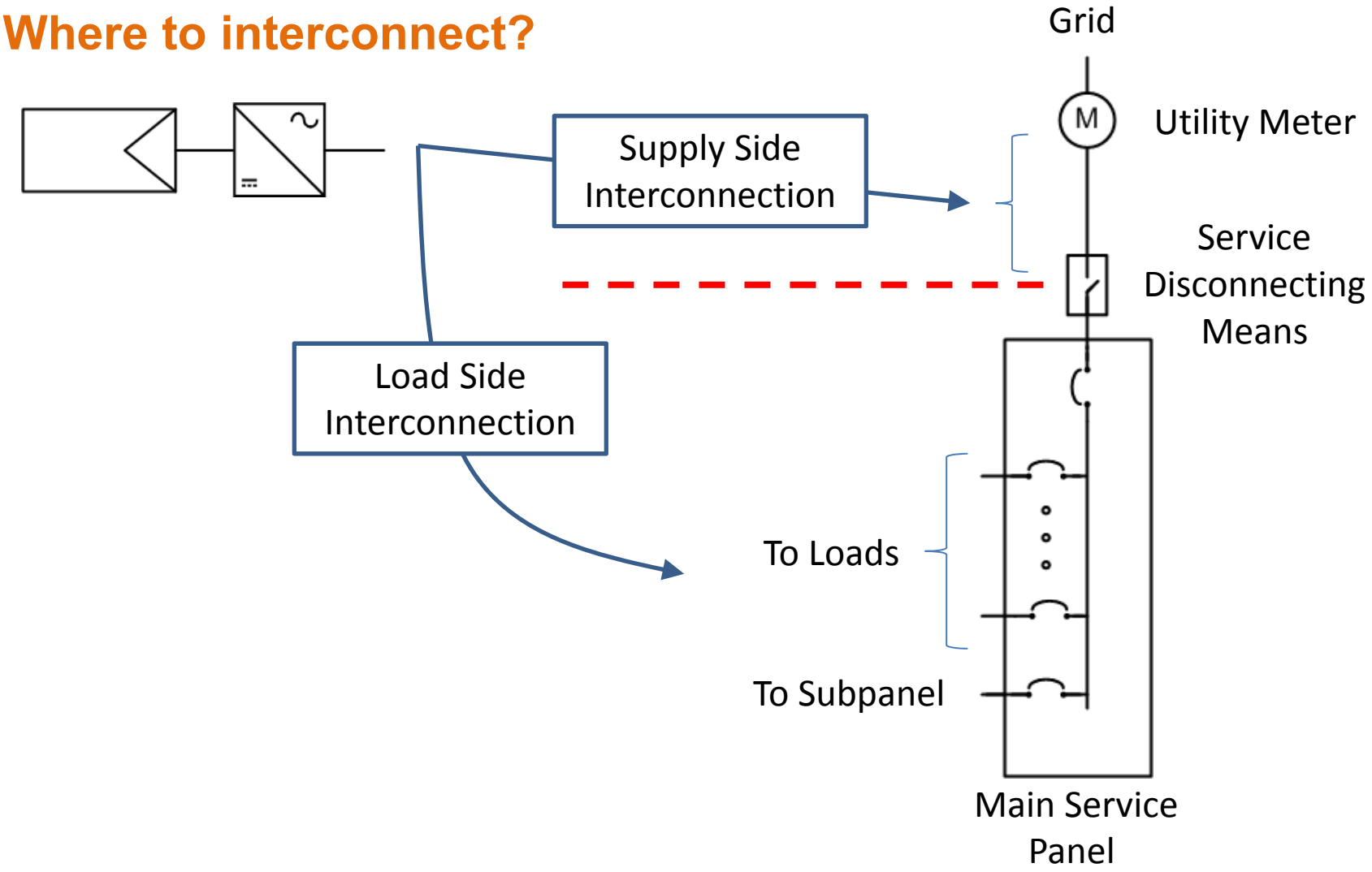
One of the factors that can limit the size of a project….

Limiting Factors (Design Constraints)

- Interconnection
  - Existing Electrical Infrastructure (Service Rating, Utility Transformer, Interconnection Panel…)
  - Utility
- Space/Area
- Budget
- Utility

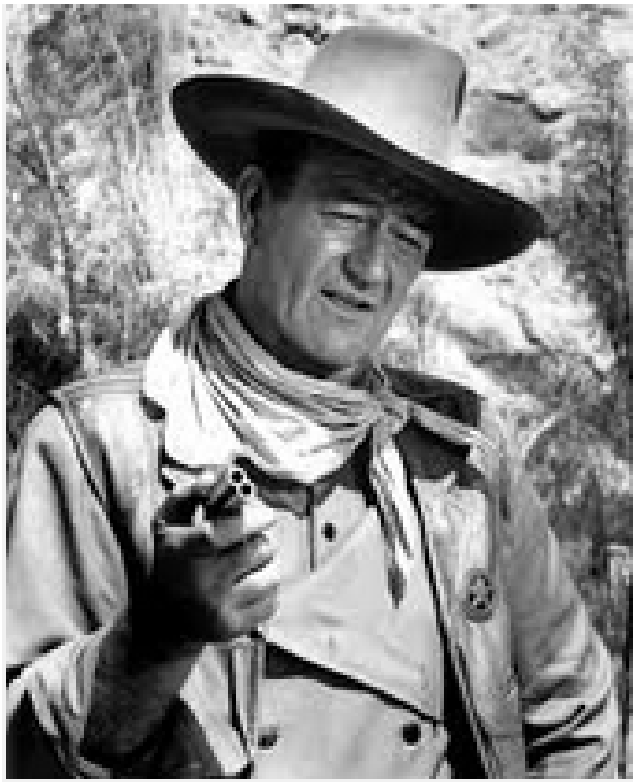
Interconnection Types

Where to interconnect?



Rules of Interconnections

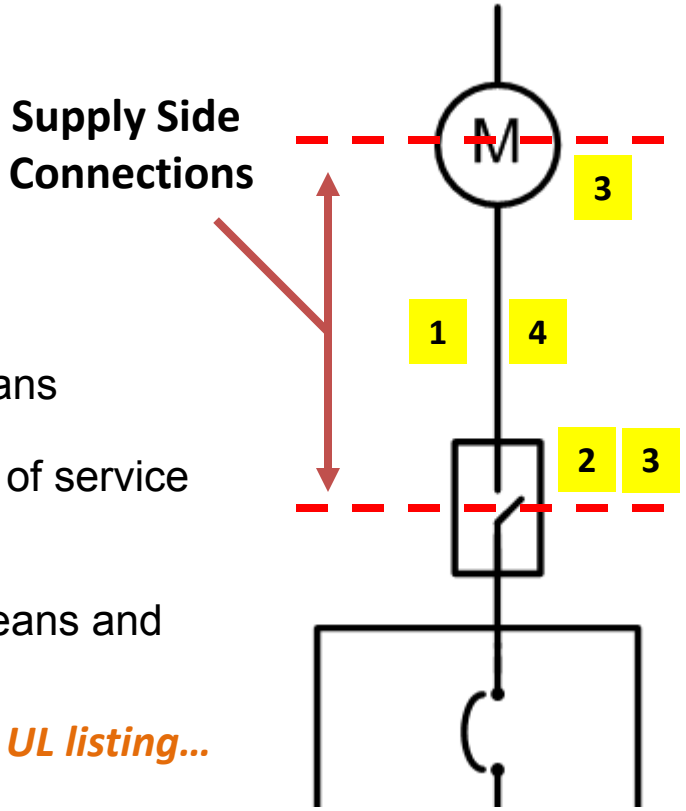
- NEC 2011 and 2014 – Found in 705.12
- NEC 2008 – Found in 690.64



Them's the rules!

Supply Side Connections

- = “Line Side Connection” = “Line Side Tap”
- Between Utility Meter and Service Disconnecting Means
- Connection made via:



1. Splicing Utility Feeder Conductors
2. Tapping bus bars on line side of service disconnecting means
3. Double Lugging on load side of utility meter or on line side of service disconnect
4. Junction Box between meter and service disconnecting means and installing junction box with terminal block

Check with manufacturer to find out what is allowed per UL listing…

Work with the utility b/c you’ll have to disconnect power…

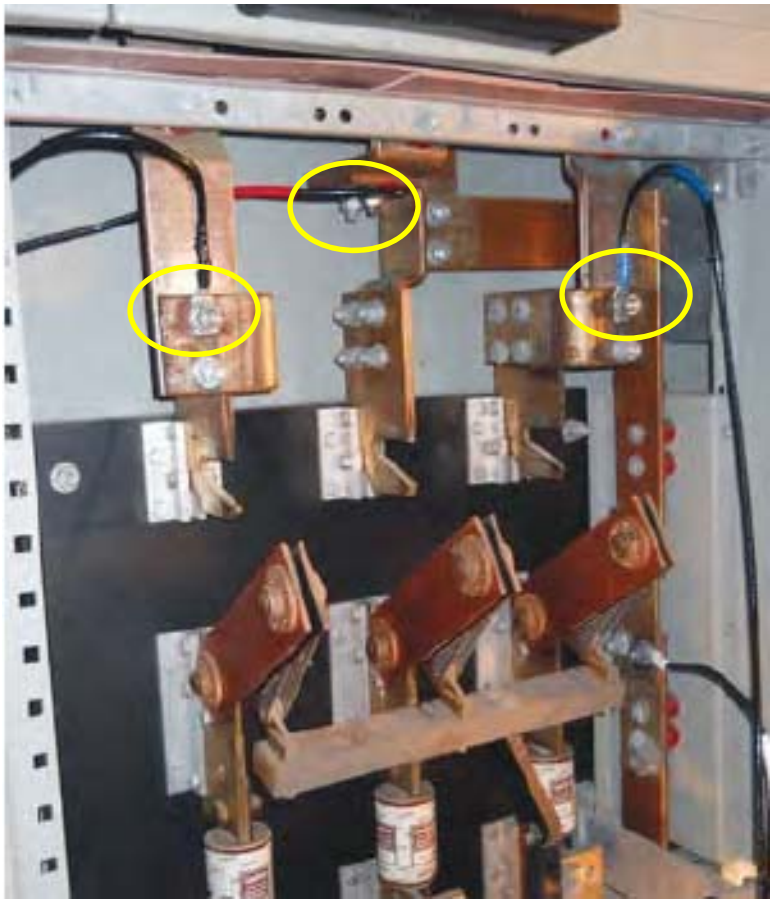
Supply Side Connections

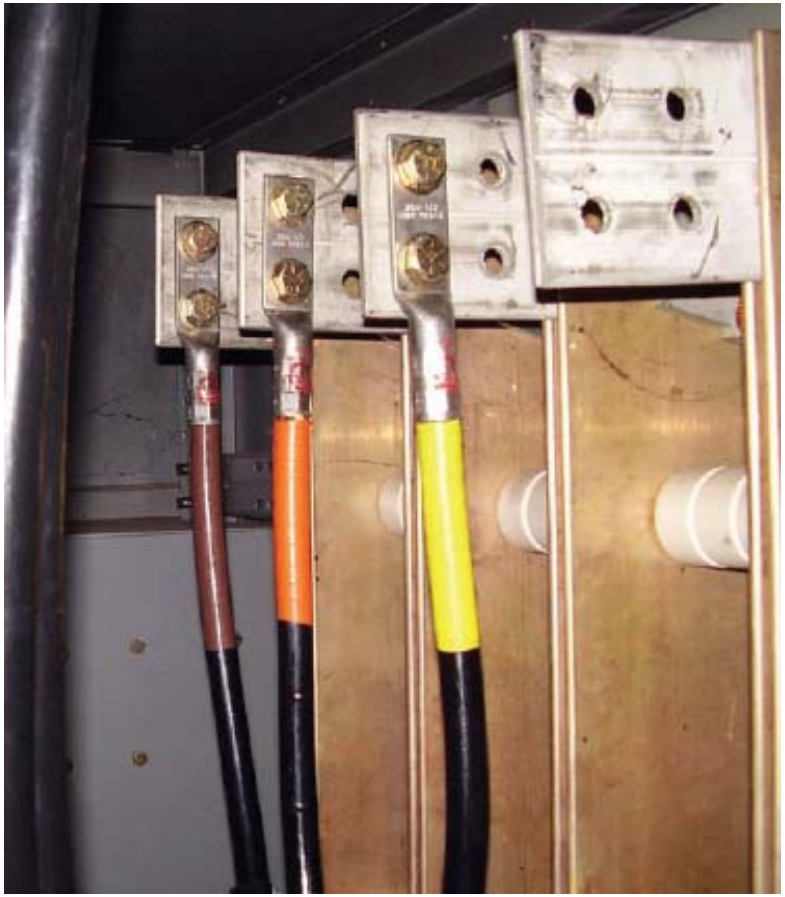
1. Splicing Utility Feeder Conductors

Insulation Piercing Tap Connector

Supply Side Connections

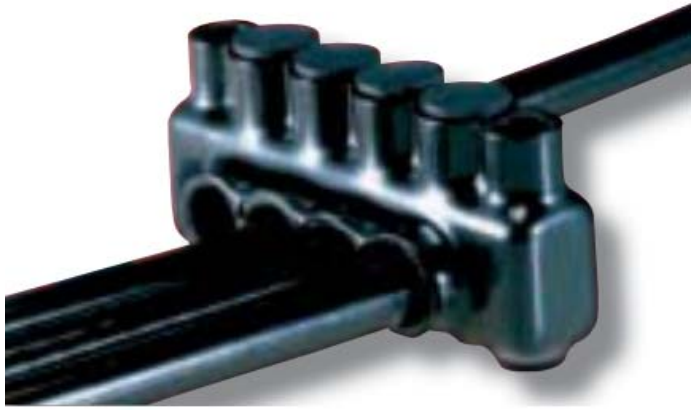
2. Tapping bus bars on line side of service disconnecting means



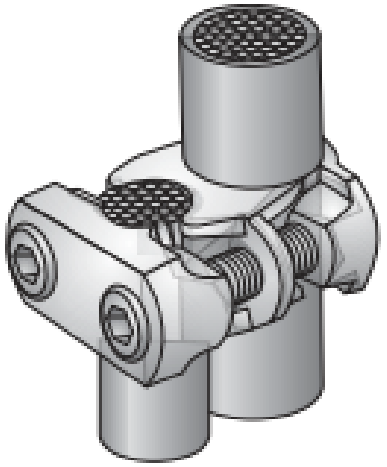


Supply Side Connections

3. Junction Box between meter and service disconnecting means and installing junction box with terminal block



Polaris
Insulating Terminal Block



Gutter/Parallel Tap
Connector

Supply Side Connections (Cont.)

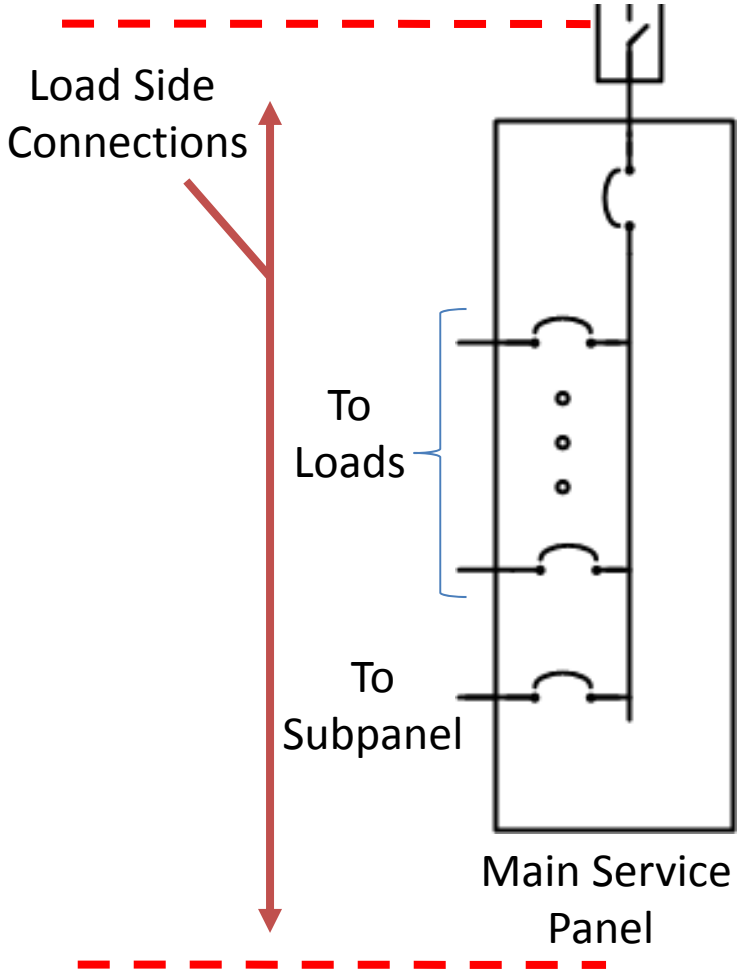
- Must also follow rules of NEC 230 “Services”
- Service disconnecting means shall have of at least 60A rating (230.79(D)) (Smaller fuses can be used)
- Six Switch Rule (230.71)?
- Overcurrent protection must be integrated or adjacent to the disconnecting means (230.91)
- Min conductor size of #8 Cu and #6 Al between point of connection and disconnect (230.23(B), 230.31(B)) (60A disco will require #2 terminals anyways)

OTHER RULES

- kAIC of overcurrent protection devices must exceed available fault current from the service (110.9 and 110.10)
- **LIMITING FACTOR:** Sum of overcurrent protection devices from power producing sources can’t exceed the rating of the service (705.12(A))
- **CHECK WITH YOUR UTILITY** for additional requirements (ex. Lockable disconnect, Location… Labeling)

Load Side Connections

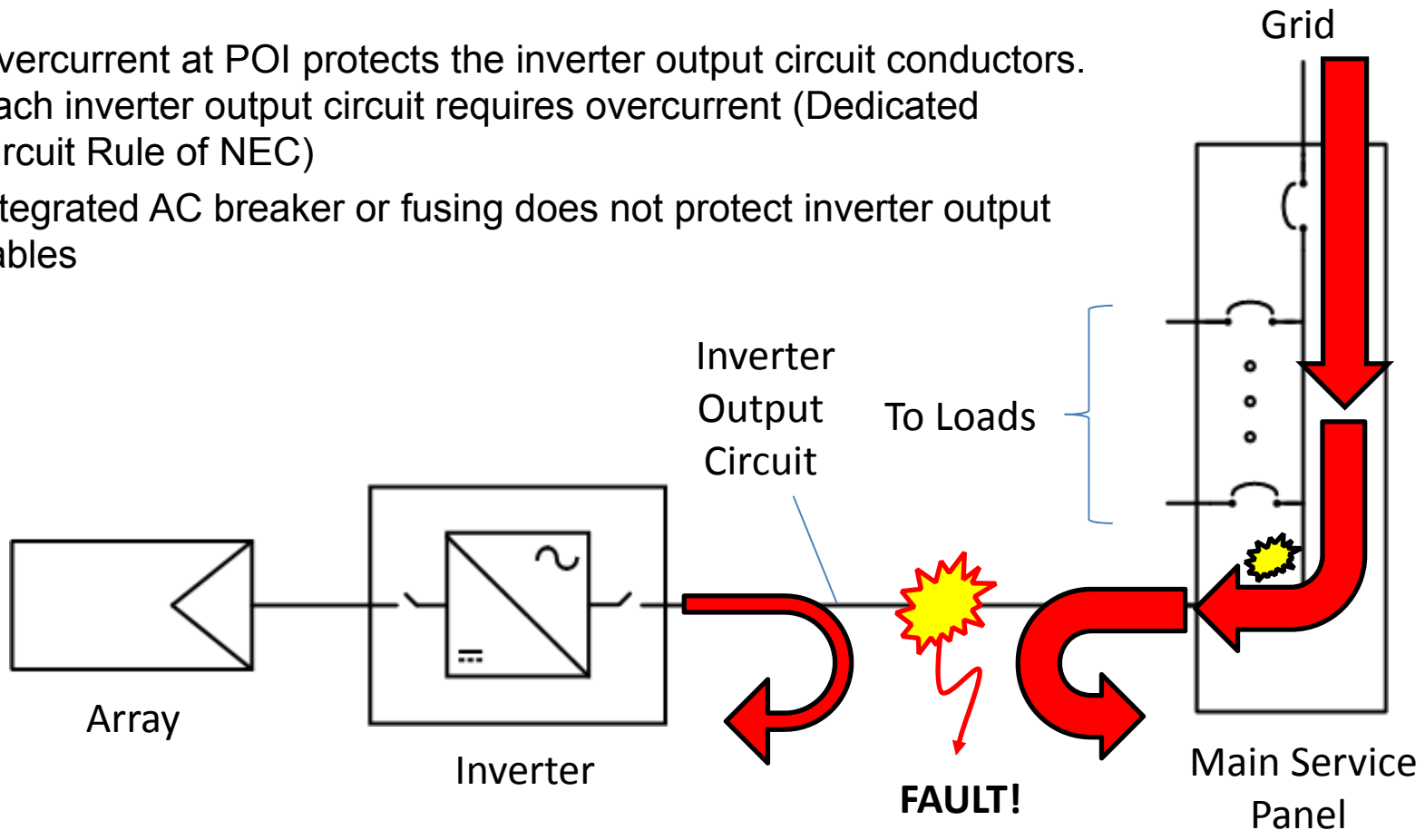
- NEC 705.12(D)
- Typically backfeeding a breaker
  - Breaker must be suitable for backfeeding
- Connection can be made in any distribution equipment (subpanel)
- Dedicated circuit breaker/fused disconnect
- 120% Rule – Breakers from sources feeding a panel can exceed panel rating by 120%
  - Panel must be labeled that it is supplied by multiple sources
  - Can downsize the main breaker in some cases
  - 120% Does not apply to combining panel
  - When 120% rule limits system size (supply side connection)
- Ground fault breaker must be suitable for backfeed



Understanding Interconnections

What does this tell us?

- Overcurrent at POI protects the inverter output circuit conductors.
- Each inverter output circuit requires overcurrent (Dedicated Circuit Rule of NEC)
- Integrated AC breaker or fusing does not protect inverter output cables



Other Design Topics

Ungrounded Systems

Ungrounded Systems

- Also called *"Floating Systems,"* but not this type!!!

Far Niente Winery, Oakville, CA, Napa Valley, ~400kW across land and lake

3-P String vs. Central Inverters

There are many considerations…

- DC Wiring
- DC Wiring Type
- Combiner Boxes
- AC Combining Panel
- AC Collection System
- Mounting (wall vs. pad)
- Communications Wiring
- Monitoring Granularity
- Ground Fault
- Arc Fault
- PID
- Full Power Temp
- Wire Coloring
- Wiring Isolation?
- Central Point of Utility Control
- Weight
- Shipping Cost
- Efficiency
- Oversizability
- MPPT Range
- String Balancing
- NEMA Rating
- Design Flexibility
- Failure Points/Part Count
- Noise
- Permitting
- AC Voltage
- 1000Vdc Module?
- DC Disconnects
- Revenue Grade Metering
- Utility Acceptance
- Protective Relaying
- Remote Shutdown
- Mismatch Losses
- MPPT Range
- Commissioning
- Service
- O&M

PVI 14TL, 20TL

PVI 50-100KW

Topics Covered

- Examine $/W vs. kW for String and Central Architectures
- Architecture Considerations
  - Performance
  - Monitoring
  - Design
  - Other (Code, Safety, PID, EG)

Project Specific Variability

- Inverter Pad/Mounting Costs
- Monitoring/Metering Level
- Home runs length (Roof-to-ground length)
- Arc-fault
- Ground Fault
- Rapid Shutdown
- Effective Grounding
- PID

Why 480Vac?

- DC circuits are sized to:
  - 1.25 x 1.25 x Short Circuit Current =
  - 1.25 x 1.25 x 1.1 x DC Rated Current =
  - 1.72 x “Rated Current”
- AC circuits are sized to:
  - 1.25 x Rated Current
- 3-phase system is better use of conductor than a 1-phase system even at 1000V
- DC Combining gear is more expensive than AC combining gear
- Run favors AC even considering ground conductor and *communications cable/conduit*.
- Exception: Very long run (due to need to upsize for voltage drop)

AC run has:

- Less Cable Volume
- Smaller conduits

Why 480Vac - Example

Module:	290	W
Isc:	8.64	A
String Size:	18	modules
No. Strings:	8	strings
kWdc	41.8	kWdc
kWac	34.8	kWac

	POWER CABLES										
	Min. Ampacity	Min. Cable - Alumium, 90C	Ampacity	$/ft	No. Conductors	Subtotal, $/ft	Cross Sectional Area Per Cable (mm2)	Cross Sectional Area Total (mm2)	Min. Ground Cable (Al)	$/ft	Total, $/ft
1000V	108.0	1AWG	115	0.800	2	1.60	42.4	84.82	4AWG	0.545	2.15
480V	52.3	6AWG	55	0.325	3	0.98	13.3	39.90	6AWG	0.325	1.30

	POWER CONDUIT			COMMUNICATIONS					TOTAL
	Conductors	Min. Conduit (EMT)	$/ft	Cable	$/ft	Conduit	$/ft	Total $/ft	$/ft
1000V	2 x 1AWG, 1 x 4AWG	1.25"	2.82	NA	$0.00	NA	$0.00	$0.00	**$4.97**
480V	4 x 6AWG	3/4"	0.96	CAT 5	$1.00	1/2"	$0.62	$1.62	**$3.88**

Project Specific Variability

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- Monitoring/Metering Level
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Performance

3ϕ-String Inverters

- Efficiency 0% to 1% CEC Efficiency Gain
- *Minor Benefit* Lower Mismatch Losses
- *Minor Benefit* Lower Start Voltage
- Array may be susceptible to PID
- Downtime: More failures/shorter duration/duration of downtime may vary (higher percentage of the array that down, the short the downtime)

Central Inverters

- Array not susceptible to PID
- Downtime: Less failures/shorter duration/greater percentage of the system down

Design Considerations

3ϕ-String Inverters

- String Sizing/Layout Flexibility Tied to More/Smaller MPPT Zones
- Standardize designs with a certain product

Central Inverters

- Greater sub-array size flexibility tied to subcombiner fuse size increments
- Oversizing flexibility allows optimization array-to-inverter ratio
- Granular inverter increments with Solectria PVI/SGI

Design Considerations

- 3ϕ-String Inverters have an 8 string input
- Racking designed around 8 strings per row allows for scalable “cookie cutter” designs

Design Considerations

30MW: Qty. 504- PVI 82kW Inverters

- Depending on system size, a distributed approach can still be achieved with “Central” inverters.
- Redundancy is based on number of inverters, not inverter kW rating.

Design Considerations

1.1MW: PVI 95kW Inverters

- 3ϕ-String Inverters installed in carports made inaccessible require additional planning for service

New/Imminent Code Requirements

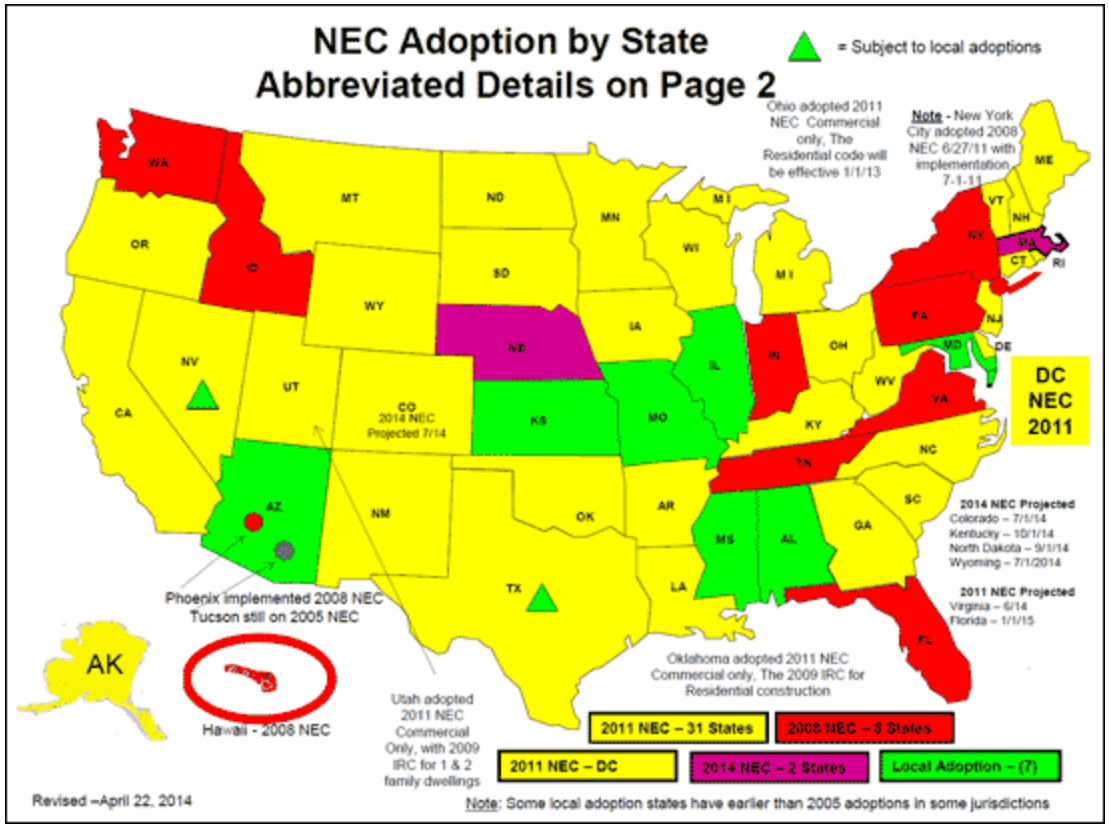
NEC 2011

- Arc Fault (690.11)
- Fuse Servicing Disconnects (690.16)

NEC 2014

- Grounded Conductor Ground Fault (690.5)
- Rapid Shutdown (690.12)

NEC 2014 Adoption



State	Projected Effective Date
Alabama	June 2014 (for the Alabama Electrical Contractors Board for testing purposes only)
Alaska	TBD
Arkansas	TBD
Colorado	July 1, 2014
Connecticut	TBD
Georgia	January 1, 2015
Hawaii	TBD
Idaho	July 1, 2014
Iowa	January 1, 2015
Kentucky	July 1, 2014
Maine	July 1, 2014
Massachusetts	In effect as of January 1, 2014
Michigan	To be determined
Minnesota	July 1, 2014
Montana	September 1, 2014
Nebraska	July 15, 2014
New Hampshire	January 1, 2015
New Jersey	TBD
New Mexico	July 1, 2014
North Carolina	TBD
North Dakota	September 1, 2014
Ohio	January 1, 2015
Oklahoma	TBD
Oregon	October 1, 2014
Rhode Island	July 1, 2014
South Dakota	July 1, 2014
Texas	September 1, 2014
Utah	To be determined
Vermont	June 1, 2014
Washington	July 1, 2014
Wyoming	July 1, 2014

- MA and NB are the ONLY states that have adopted 2014 code thus far
- NEC 2014 adoption varies state by state
- By the end of 2014, 18 states plan to adopt NEC 2014

Ground Fault Detection

- 3ϕ-string inverters have residual ground fault detection.
  - Shorter DC runs decreases likelihood of ground fault.

- 2014 NEC requires grounded conductor (Blind-spot) ground fault detection.

- During ground fault only 3ϕ inverter is taken offline rather than the entire array.
  - Better system uptime
  - More focused troubleshooting

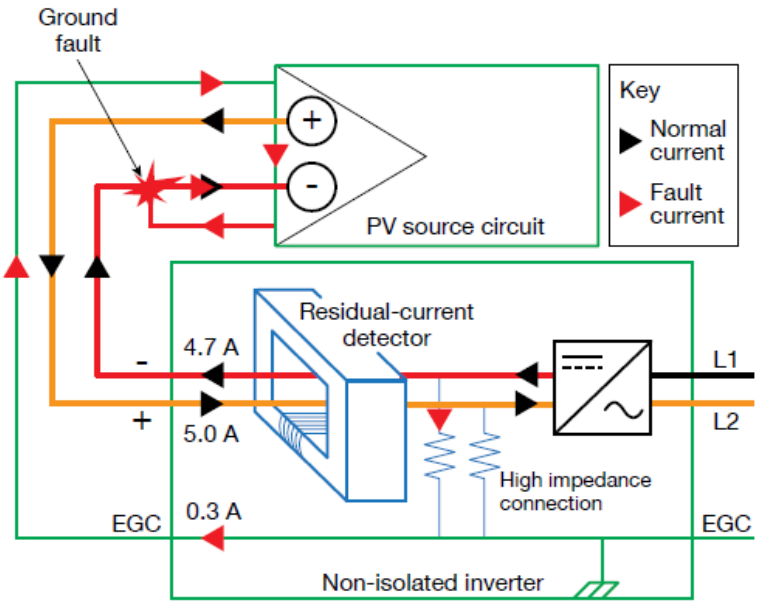
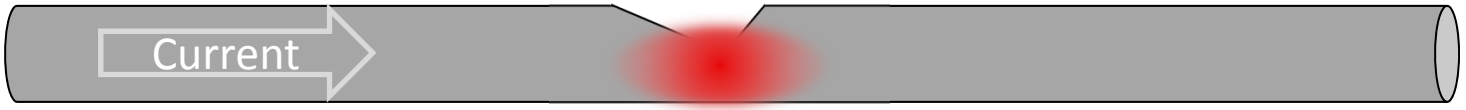


Figure from "Ungrounded PV Power Systems in the NEC," SolarPro, Aug./Sept. 2012

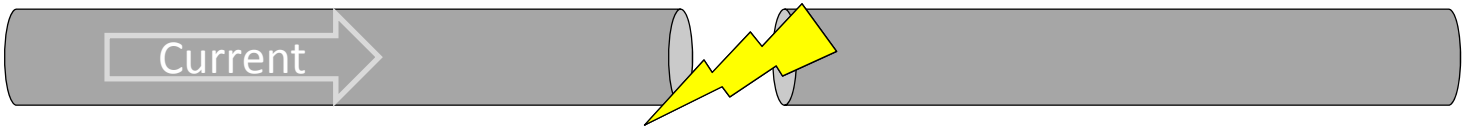
Arc-Fault Detection

What is an arc-fault?

- Healthy Wire



- The same amount of current must flow through a smaller conductor
- Conductor heats up and eventually melts



- Air Ionizes and plasma allows current to flow across the gap
- Temperatures can reach 9000 degrees Fahrenheit

690.11 ARC-Fault Circuit Protection (Direct Current)

- Photovoltaic Systems with dc source circuits, dc output circuits, or both, operating at a PV system maximum system voltage of 80 volts or greater, shall be protected by a listed (dc) arc-fault circuit interrupter, PV type, or other system components listed to provide equivalent protection. The PV arc-fault protection means shall comply with the following requirements:

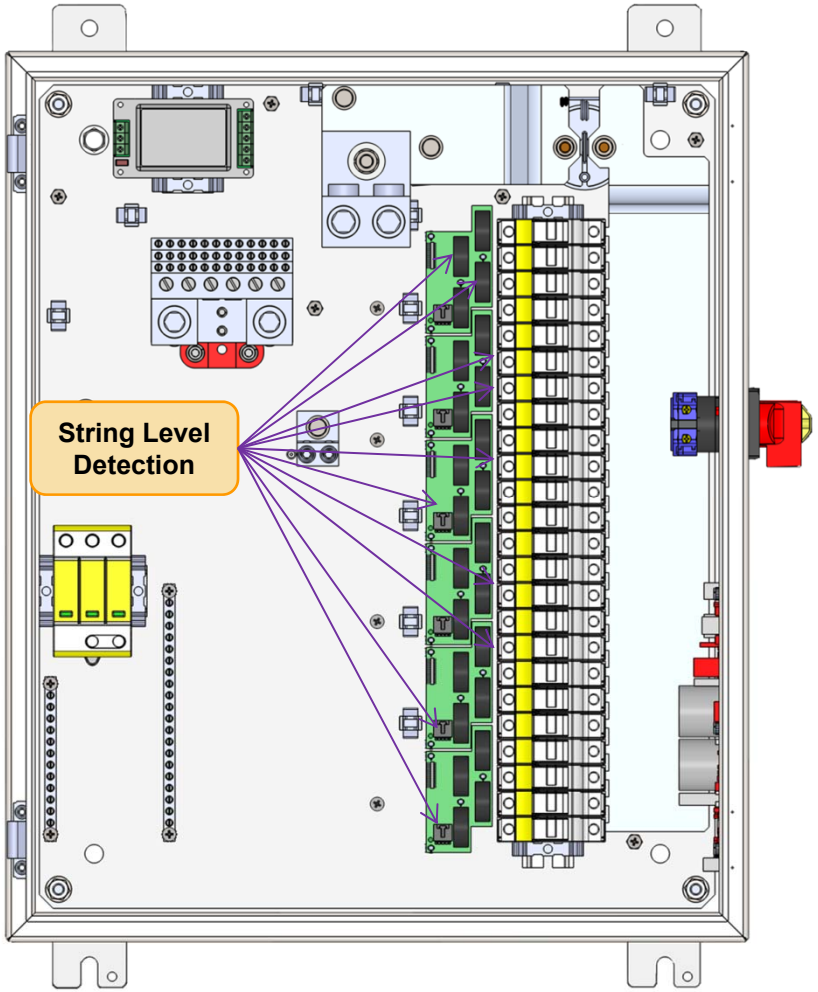
(1) The system shall detect and interrupt arcing faults resulting from a failure in the intended continuity of a conductor, connection, module, or other system component in the dc PV source and dc PV output circuits.

(2) The system shall require that the disabled or disconnected equipment be manually restarted.

(3) The system shall have an annunciator that provides a visual indication that the circuit interrupter has operated. This indication shall not reset automatically.

Maximize SNR to Minimize Nuisance Tripping

- NEC 690.11 requires manual reset
- Every arc-fault trip requires a truck roll
- ARCCOM has undergone 1 year of product compatibility testing to minimize nuisance tripping.
- Single sensor, reflection based technology is significantly more prone to nuisance tripping and more costly to maintain



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✓ ARCCOM is listed to UL1699B

(2) The system shall require that the disabled or disconnected equipment be manually restarted.

✓ ARCCOM must be manually restarted

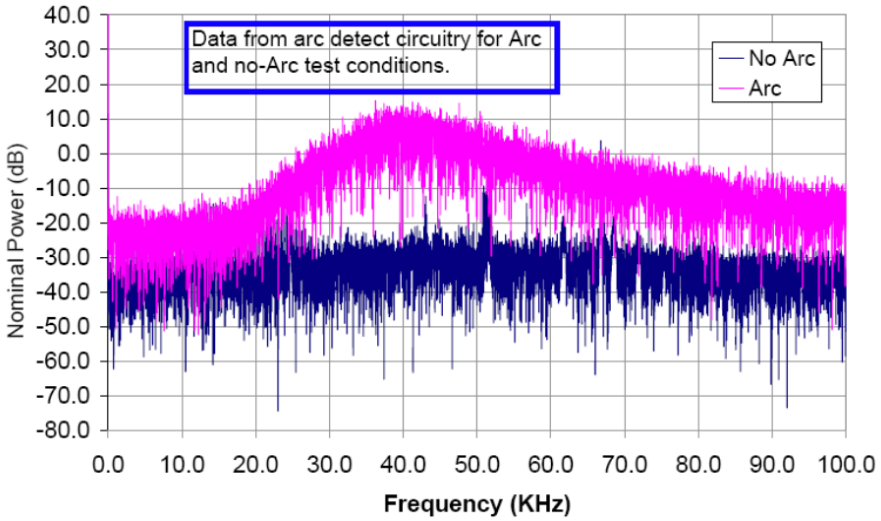
(3) The system shall have an annunciator that provides a visual indication that the circuit interrupter has operated. This indication shall not reset automatically.

✓ ARCCOM includes audible buzzer, LEDs, and auxilary contact

Arc-Fault Detection

- 3ϕ-String Inverters have integrated arc-fault detection.
  - Fault is isolated to one inverter

- Central inverters require arc-fault combiners
  - Fault is isolated to the arc-fault string combiner



Source- *Implementing Arc Detection in Solar Applications*
Brett Novak, Texas Instruments

690.12 (C) Facilities with Rapid Shutdown

- NEC 690.12 (C) states: PV system circuits installed on or in buildings shall include a rapid shutdown function that controls specific conductors in accordance with 690.12(1) through (5) as follows:

(1) Requirements for controlled conductors shall apply only to PV system conductors of more than 1.5m (5 ft) in length inside a building , or more than 3m (10 ft) from a PV array.

(2) Controlled Conductors shall be limited to not more than 30V and 240 volt-amperes within 10 seconds of rapid shutdown initiation.

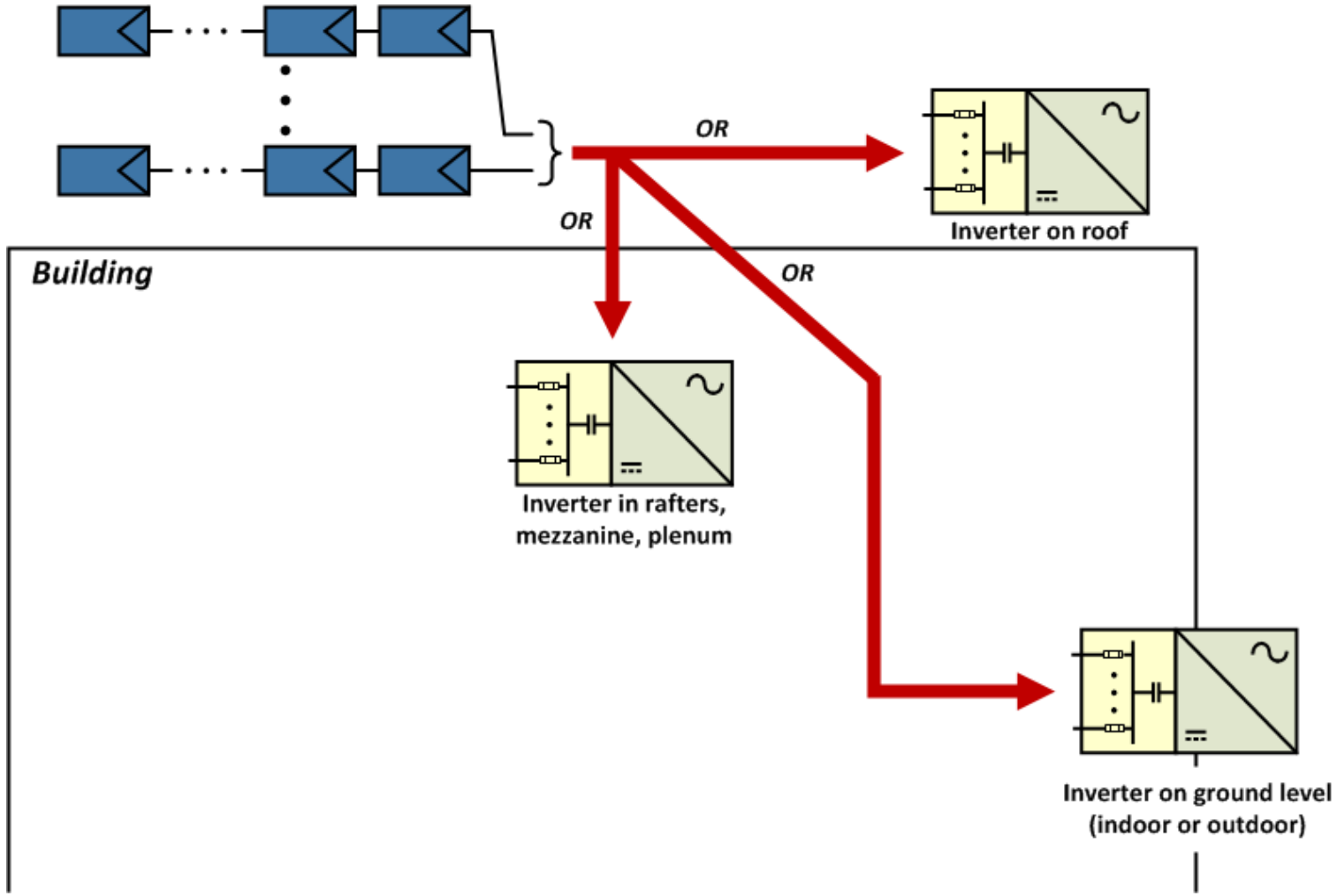
(3) Voltage and power shall be measured between any conductor and ground

(4) The rapid shutdown initiation methods shall be labeled in accordance with 690.56(B)

(5) Equipment that performs the rapid shutdown shall be listed and identified.

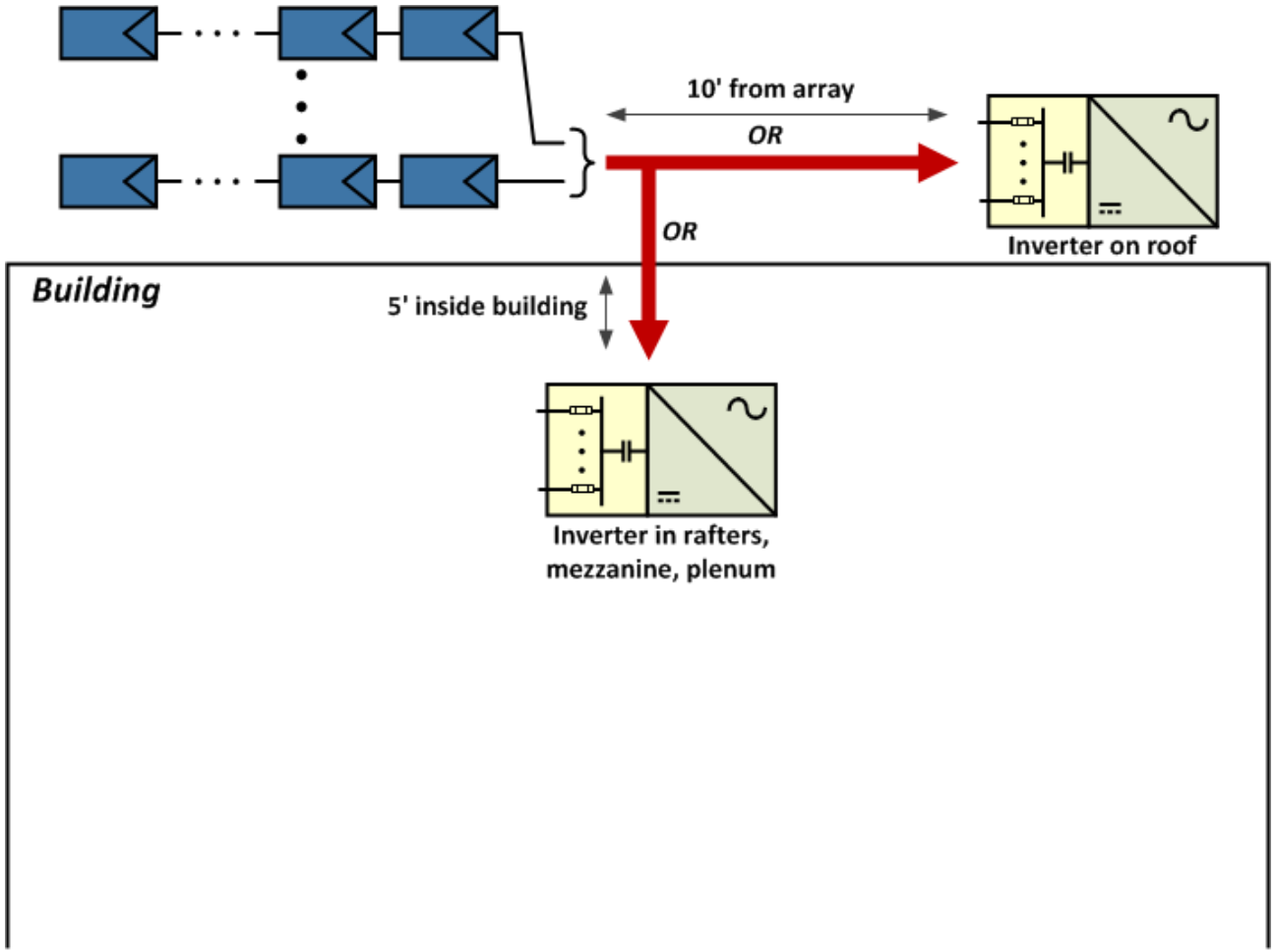
2011 NEC – Rapid Shutdown Not Required

Rapid Shutdown does not impact string inverter location

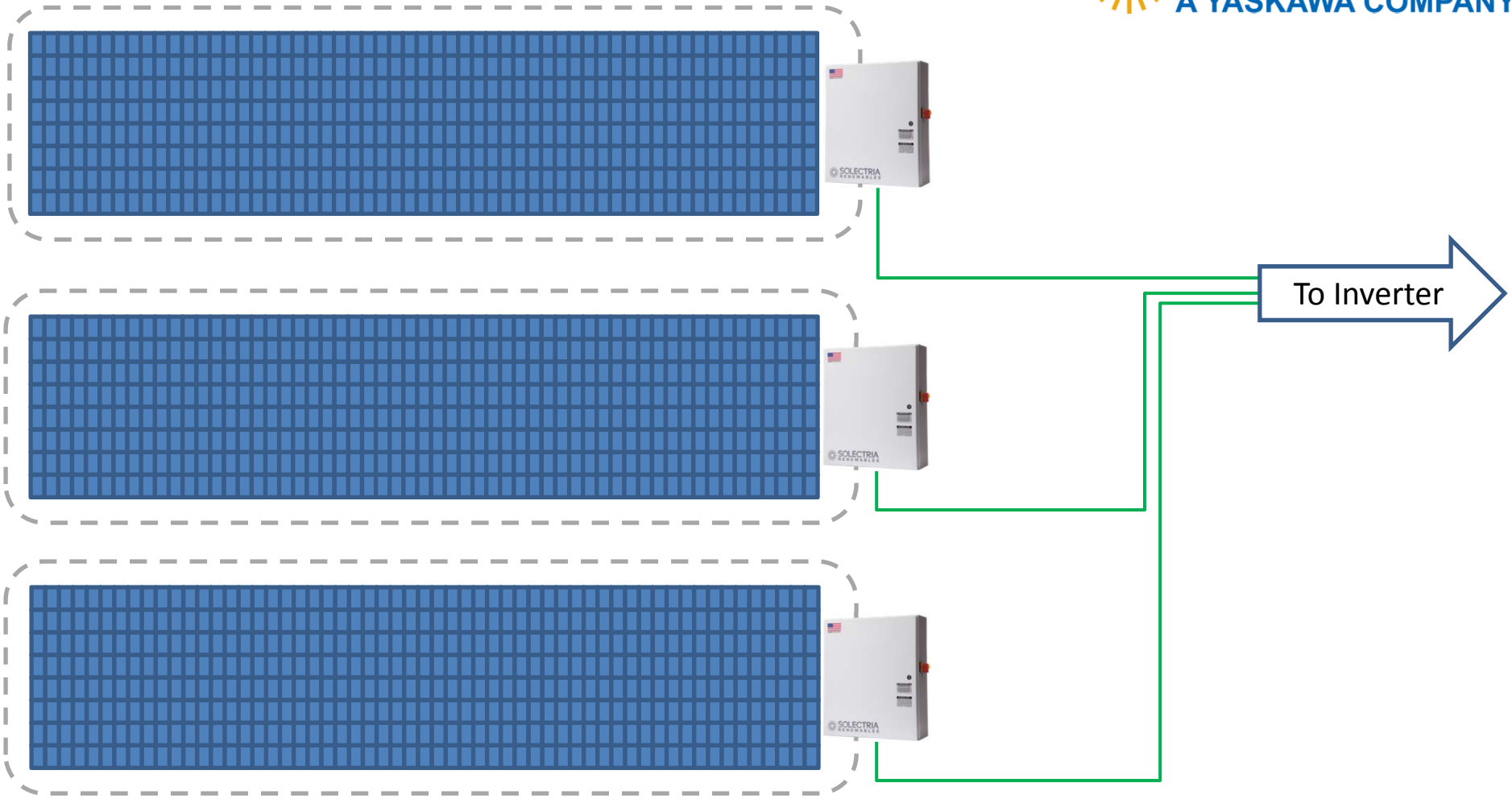


2014 NEC Compliance by Shutdown at String Inverter

Rapid Shutdown restricts string inverter location. Difficult servicing.



Rapid Shutdown Controlled Conductors



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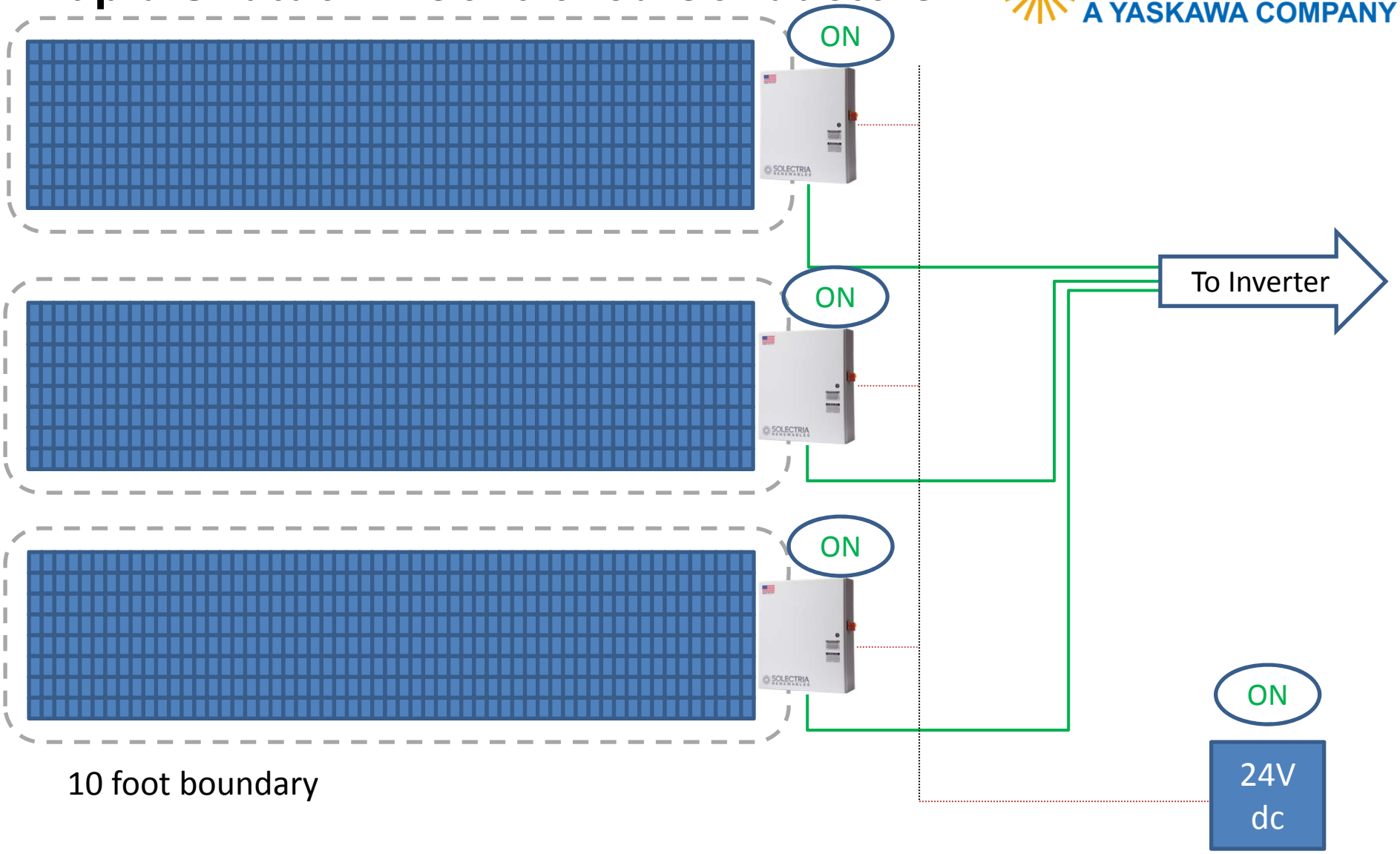
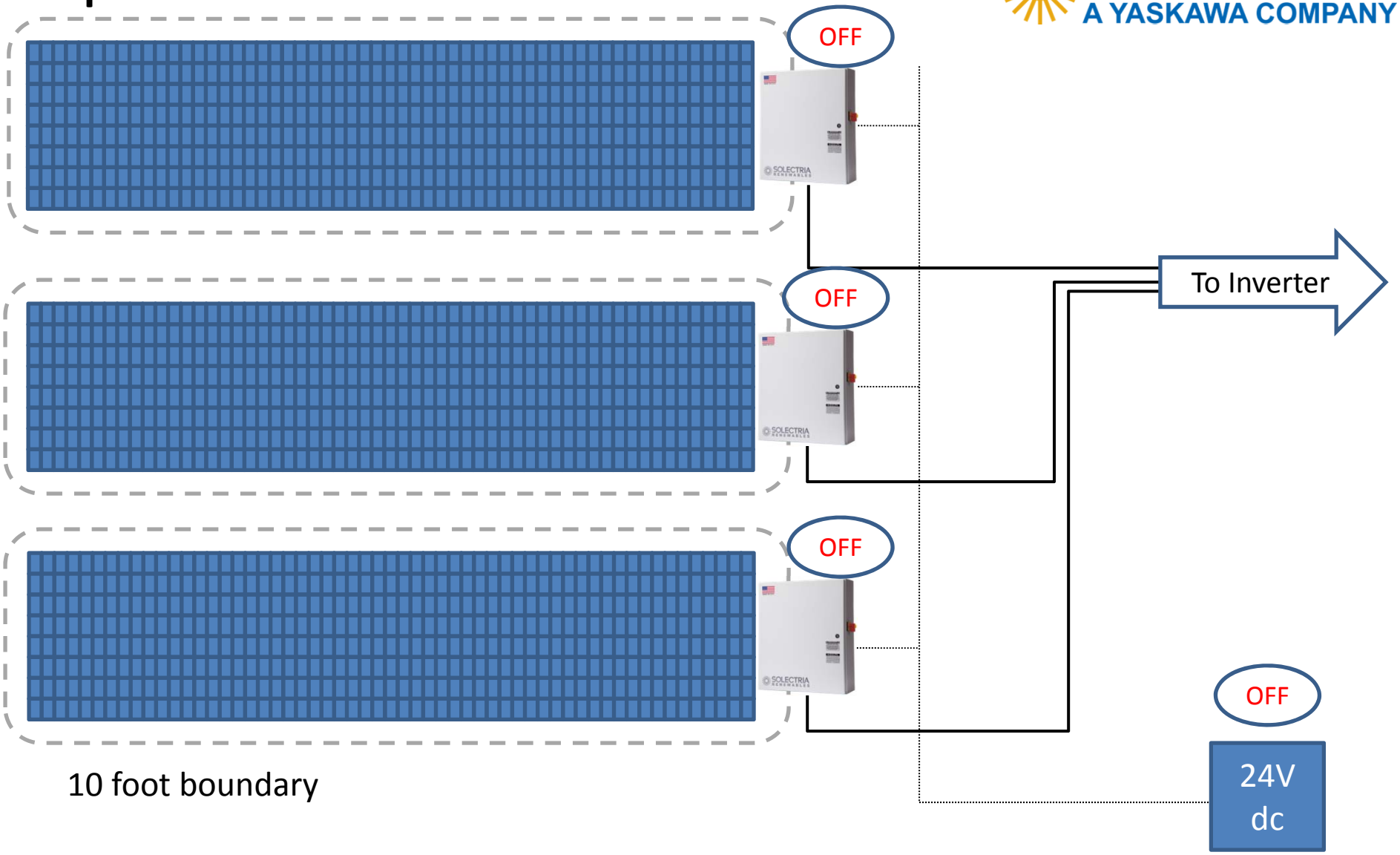


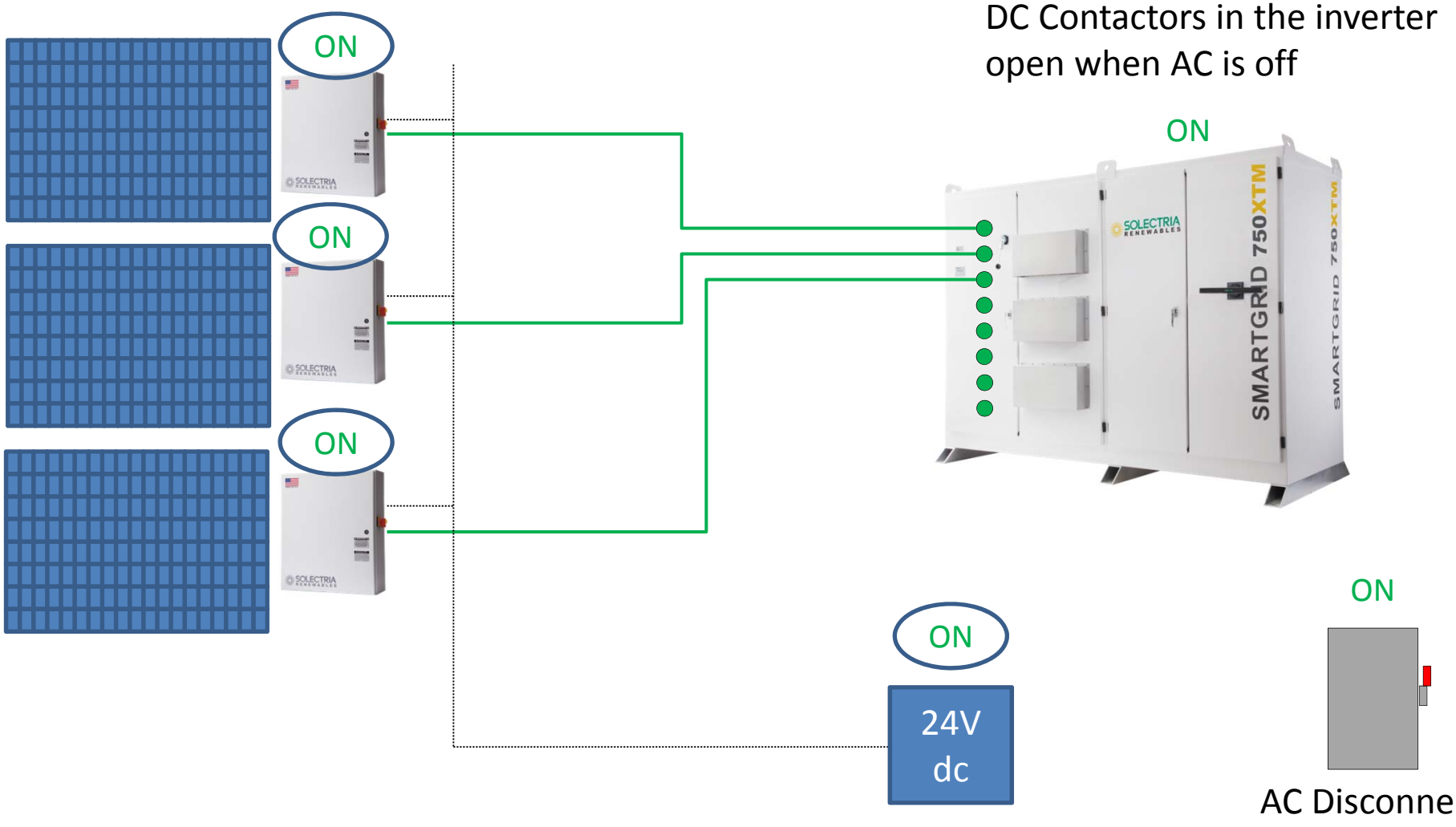
Rapid Shutdown Controlled Conductors



DC Bus Capacitance

SGI, SGI XT, and SGI XTM all have DC Vacuum Contactors

DC Contactors in the inverter open when AC is off



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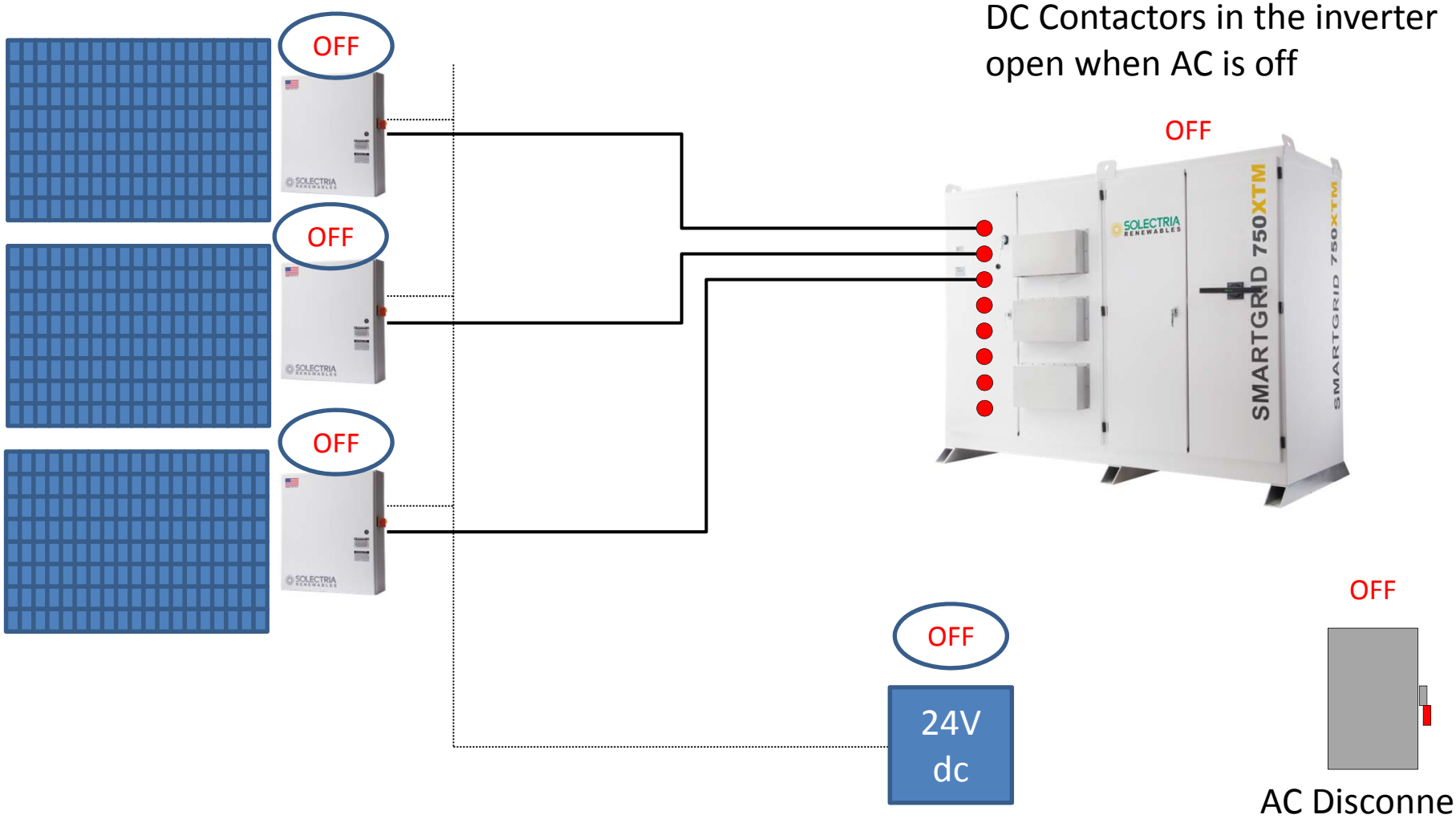
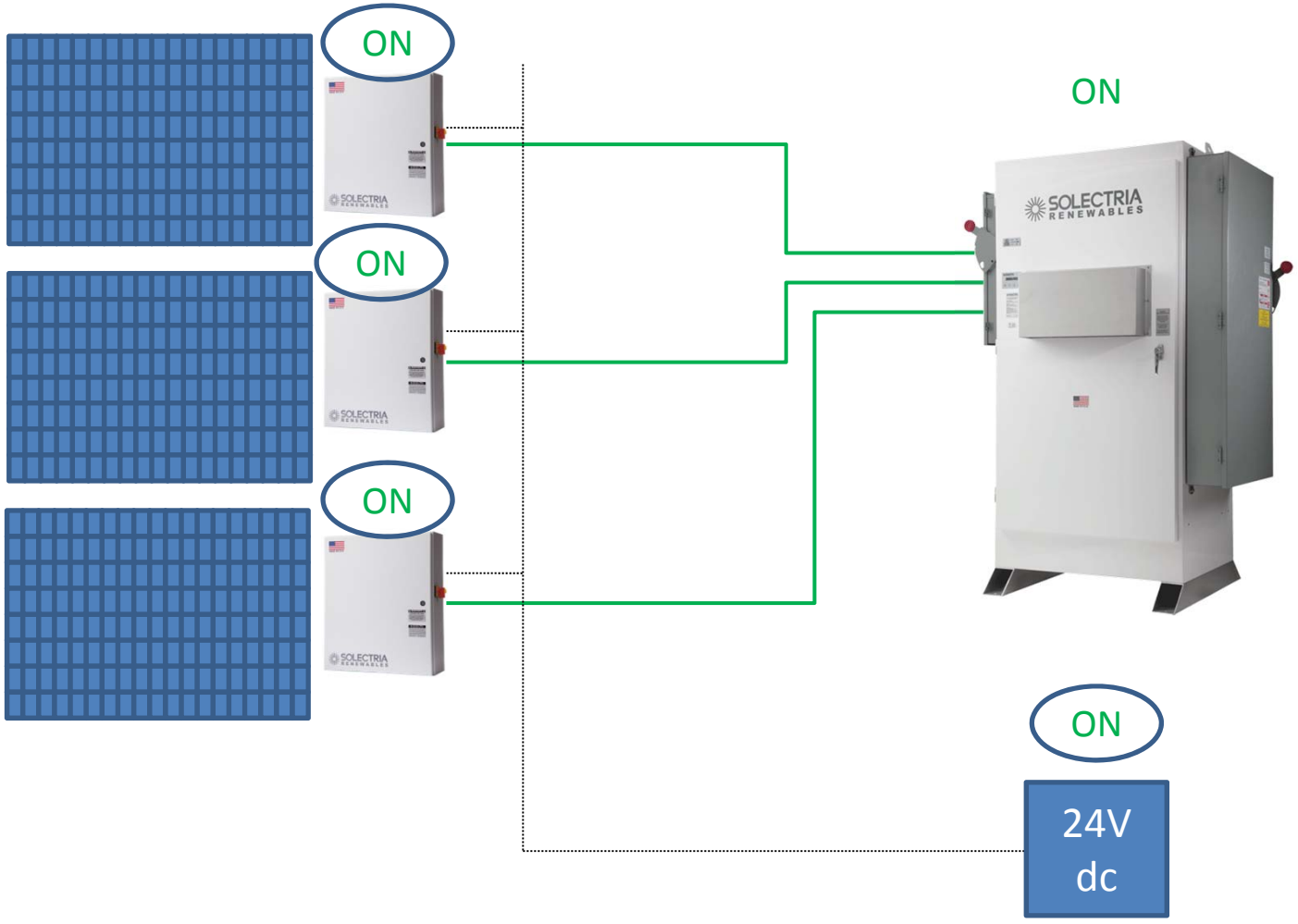


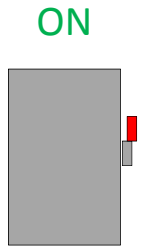
DC Bus Capacitance

PVI does not have DC Vacuum Contactors



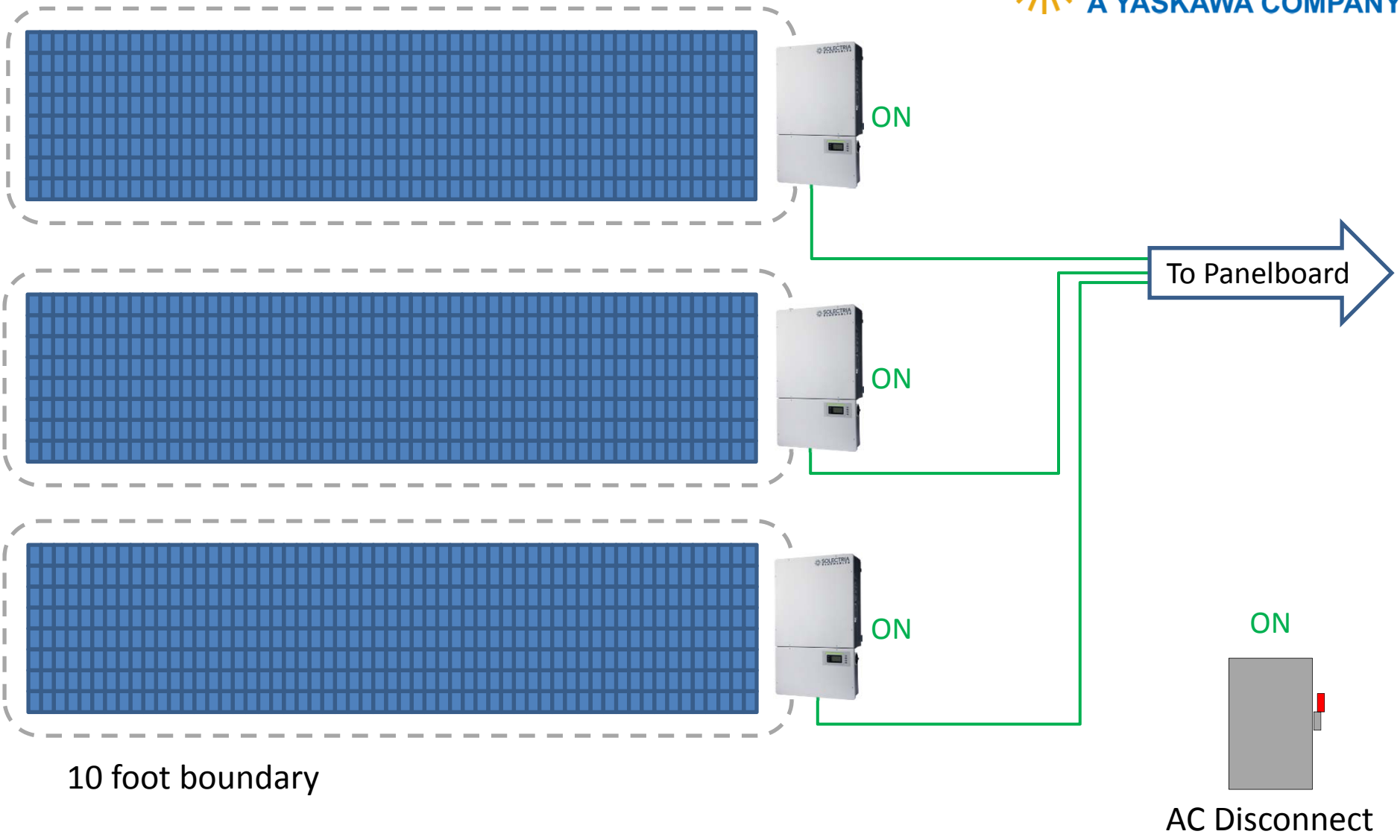
DC Bus Capacitance must discharge within 10s

PVI does this in 2.5s

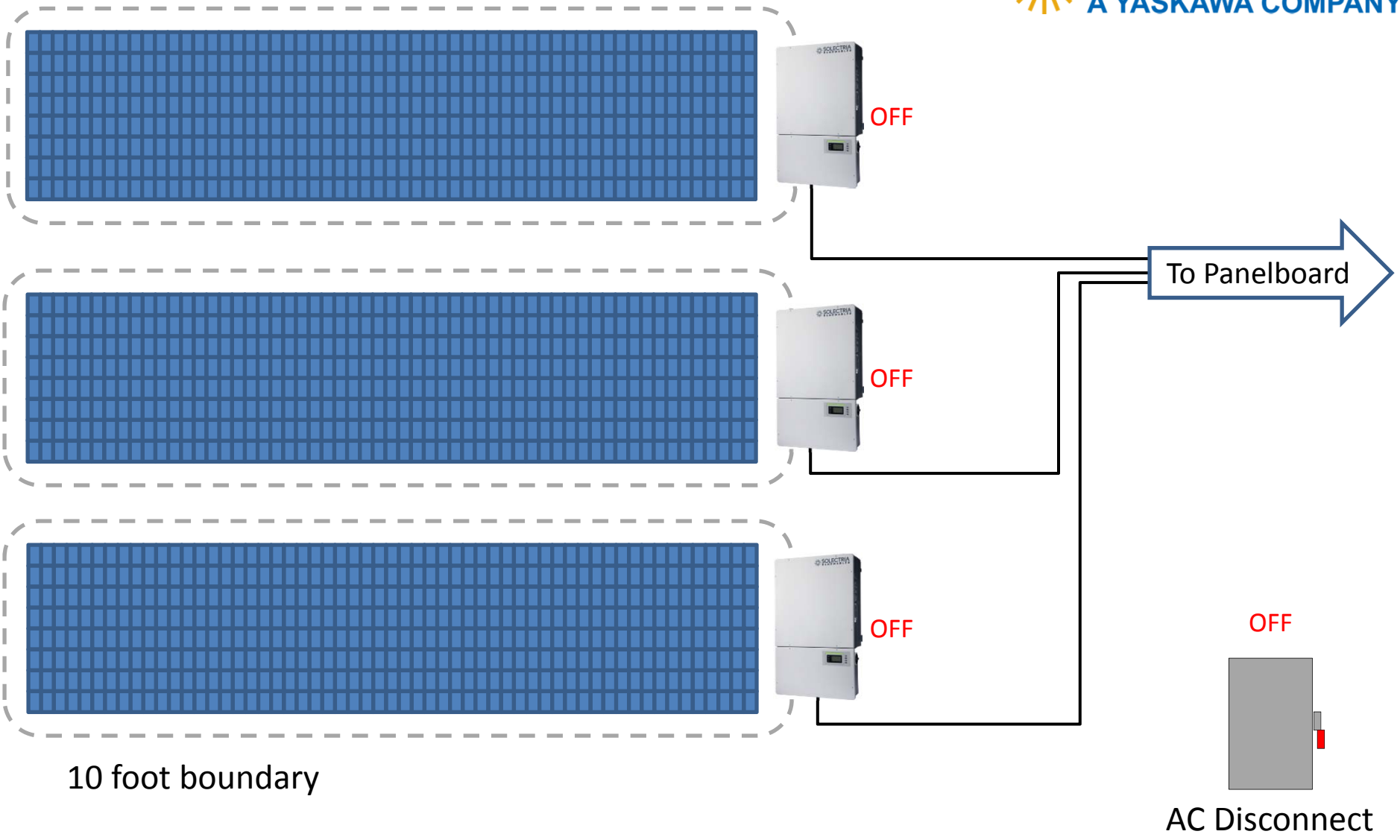


AC Disconnect

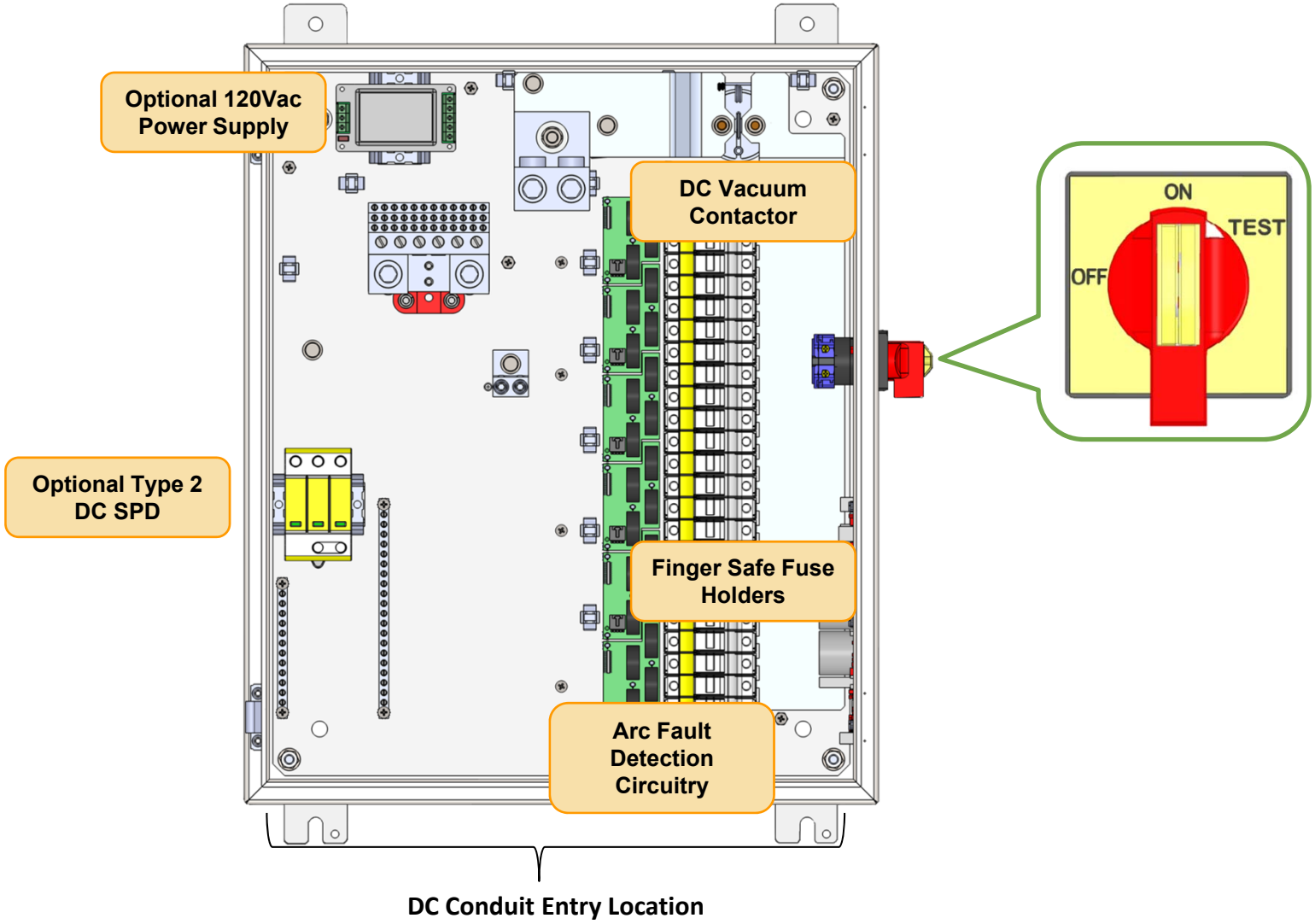
Controlled Conductors with 3-Phase String Inverters



Controlled Conductors with 3-Phase String Inverters



Inside the ARCCOM



690.12 (C) Facilities with Rapid Shutdown

SOLECTRIA A YASKAWA COMPANY

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✓ Achieved by Inverter/ ARCCOM placement

(2) Controlled Conductors shall be limited to not more than 30V and 240 volt-amperes within 10 seconds of rapid shutdown initiation.

✓ Achieved by Inverter Shutdown or DC Contactors in the ARCCOM

(3) Voltage and power shall be measured between any conductor and ground

✓ No shorting out or free-floating the array to achieve 30V

(4) The rapid shutdown initiation methods shall be labeled in accordance with 690.56(B)

✓ Provide a placard with the prescribed phrasing

(5) Equipment that performs the rapid shutdown shall be listed and identified.

✓ TL Inverters and ARCCOM are listed

690.56 Identification of Power Sources

(C) Facilities with Rapid Shutdown Buildings or structures with both utility service and a PV system complying with 690.12 shall have a permanent plaque or directory including the following wording:

PHOTOVOLTAIC SYSTEM EQUIPPED WITH RAPID SHUTDOWN

The plaque or directory shall be reflective, with letters capitalized and having a minimum height of 9.5mm (3/8 in.), in white on red background.

PHOTOVOLTAIC SYSTEM EQUIPPED WITH RAPID SHUTDOWN

Where do you put this?

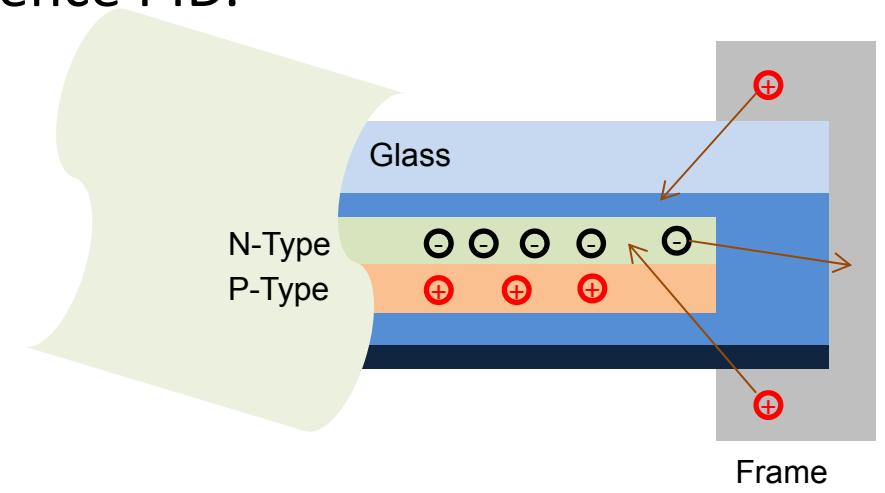
Potential Induced Degradation (PID)

3ϕ-String Inverters – Ungrounded Arrays/Bipolar

- Ungrounded arrays may be susceptible to PID.
- PID "offset" box can be used to reverse the effects of PID

Central Inverters – Grounded Arrays

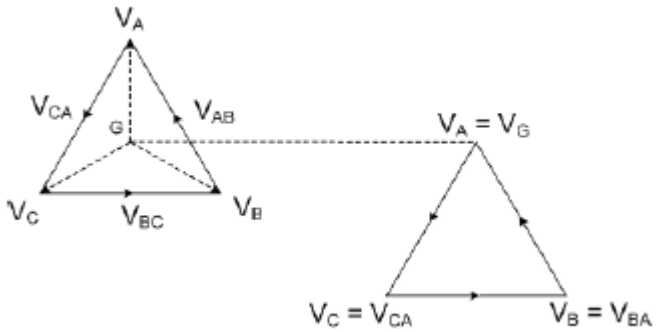
- Grounded Arrays do not experience PID.



Effective Grounding

3ϕ-String Inverters

- Require grounding transformer for effective grounding



Central Inverters

- Can be effectively grounded via 4-wire solid ground (neutral kit), 4-wire impedance ground (grounding reactor), 3-wire with grounding transformer

Smart Inverter Functions

…PF adjustment, Ramp Rate, Curtailment, Volt-VAR

3ϕ-String Inverters

- Have smart inverter functions
- Multiple points of communication and control

Central Inverters

- Have advanced smart inverter functions
- Single point of communication and control

Service and Warranty

3ϕ-String Inverters

- Service Frequency: More points of failures => More visits (may not be more frequent)
- Smaller percentage of system effected
- Duration of Downtime: Shorter
- Service: “Rip and Replace,” Replacing on roof may be a challenge.

Service and Warranty

Central Inverters

- Service Frequency: Fewer points of failure => Fewer visits
- Larger percentage of system effected
- Duration of Downtime: Longer
- Service: Manufacturer Trained Rep
- Warranty: 5 year

What Architecture is Best?

- The “best” architecture is the one that optimizes the financial performance of the project.
- Financial performance is determined by:

  ✓ Engineering Cost

  ✓ Installation Cost (Equipment and Labor)

  ✓ Performance/Uptime

Answer: It depends. Best architecture will be project specific.

Advanced Inverter Features

Remote Shutdown

Why remotely shut down the inverter?

- Utility control
- Disabling inverter during back-up generator operation
- Integrating with Relaying
    - AC Relaying - Protective Relaying
    - DC Relaying - Residual ground fault detection systems
- Integration with BMS/Sprinkler System

Remote Shutdown

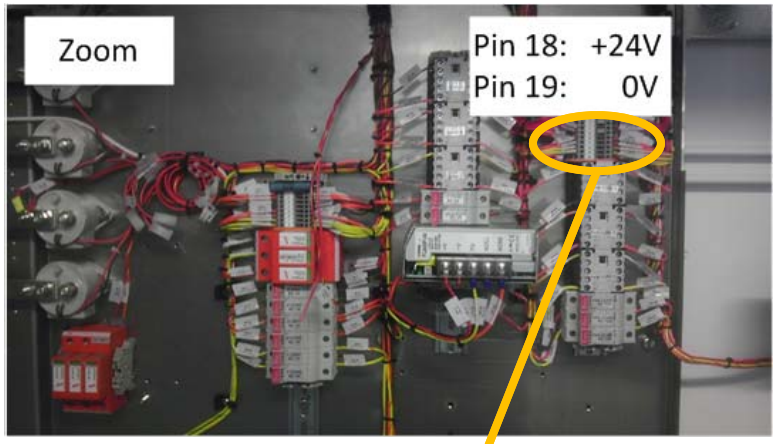
- PVI 50-100 and SGI 225-500 inverters come standard with a 24V isolated Digital Input terminals to shut down the inverter

- How is works:
  - Apply 24V to terminals → Inverter shuts down
  - Remove 24V from terminals → Inverter waits for 5min of stable grid, then resumes conversion

- Shutdown rate is adjustable - 4 sec (default), As fast as 0.16s

- Other options for remote shutdown
  - Modbus RTU/RS-485
  - Shunt Trip (not available in all models)

Remote Shutdown



24V Remote Shutdown Terminals

Solectria Commercial Inverter Solutions

PVI 14TL & PVI 20TL

Industry Buzz...

"Transformerless?" **Yes!**

For "Ungrounded/Floating Arrays?" **Yes!**

"3-Phase String?" **Yes!**

Models

PVI 14TL – 14kWac (600Vdc, 208Vac)

PVI 20TL – 20kWac (600Vdc, 480Vac)

PVI 14TL/20TL Features

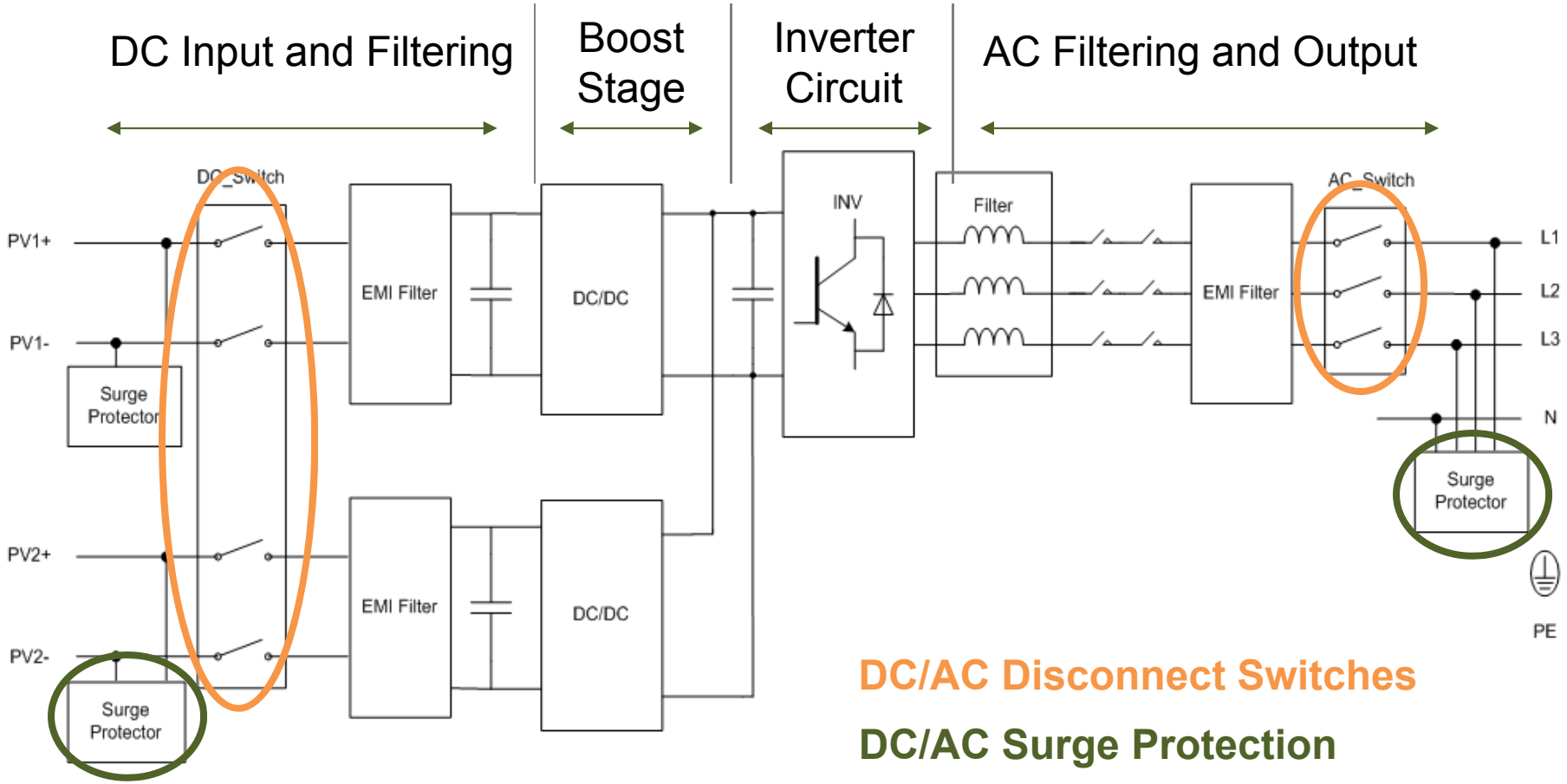
- 600 or 1000 VDC
- Best-in-class efficiency
- Three-phase transformerless inverters
- Quick and easy installation
- Dual MPP tracking zones
- Wide MPPT range
- Lightweight, compact design
- Modbus communications
- User-interactive LCD
- Wall mount configuration

Options
- o Integrated DC fused string combiner
- o DC arc-fault protection
- o Web-based monitoring

Applications

- Light Commercial Systems
- Systems with Multiple Tilt Angles/Orientations
- Complex Layouts
- Limited Space for Central Inverter
- Carports
- Utility Scale Trackers

Inverter Topology

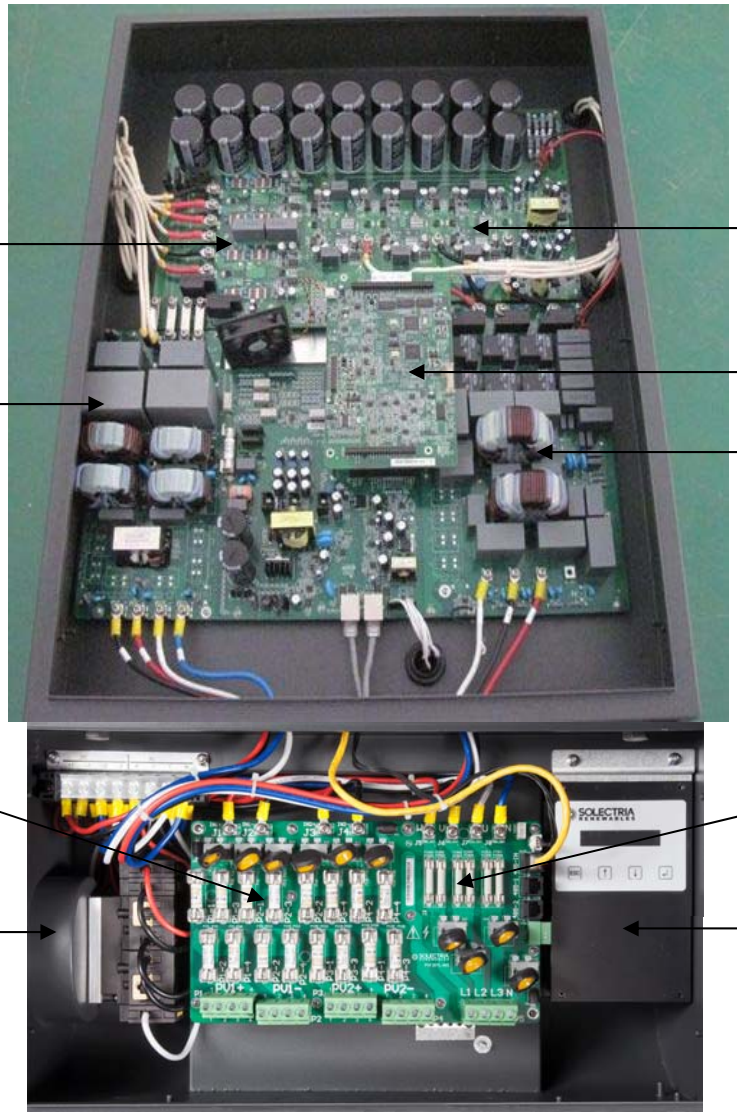


DC/AC Disconnect Switches

DC/AC Surge Protection

**DC +/- Fusing Not Shown*

Design



Boost Circuits

DC filter

Inverter

Main control board

AC filter

DC string fuses and surge arrestors

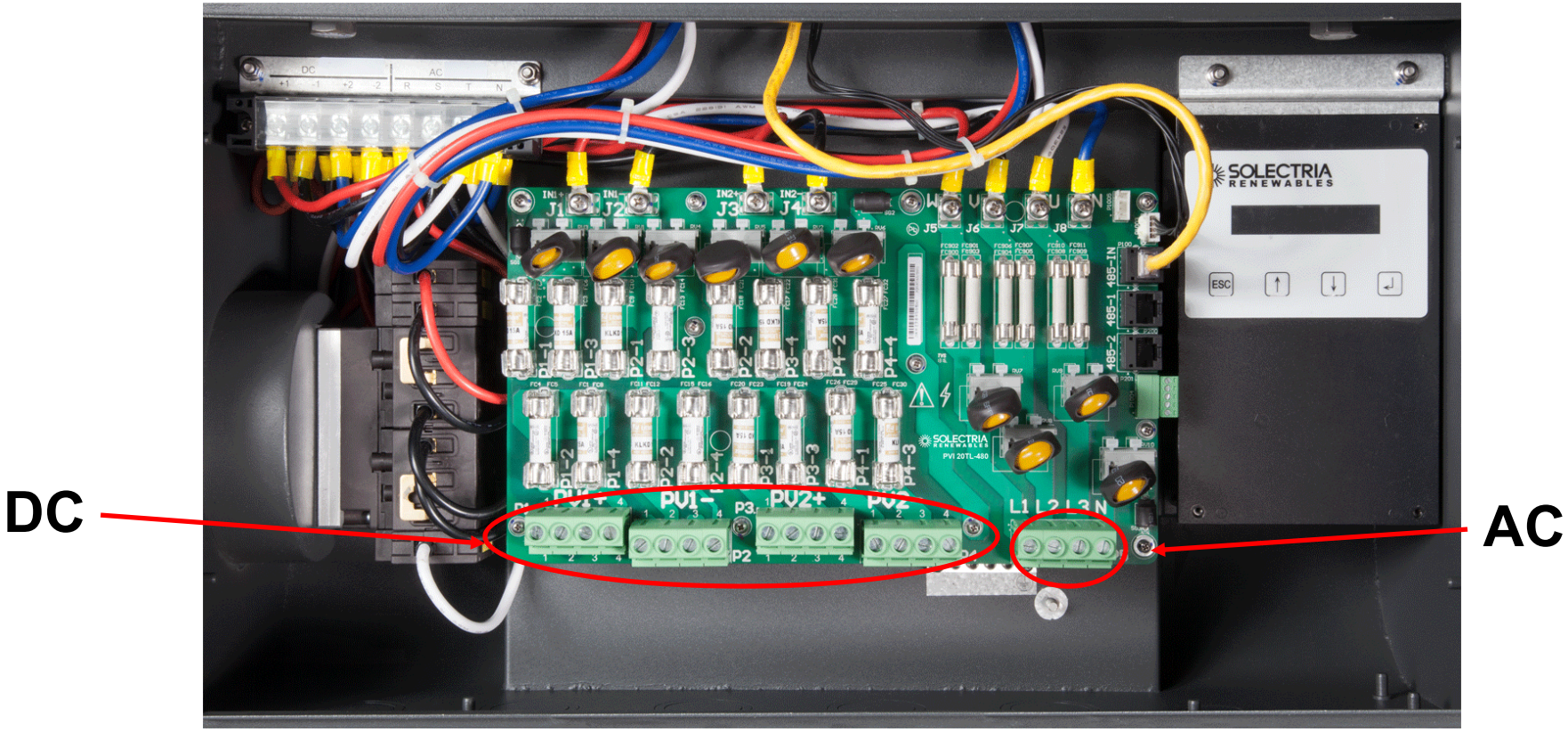
DC/AC Switch

AC fuses and surge arrester

SolrenView Web Monitoring Hardware

**DC Fuse Pullers Not Shown*

Wiring Box



DC and AC Wiring Connection Terminals

DC Fuse Pullers Not Shown

Electrical/Performance Benefits

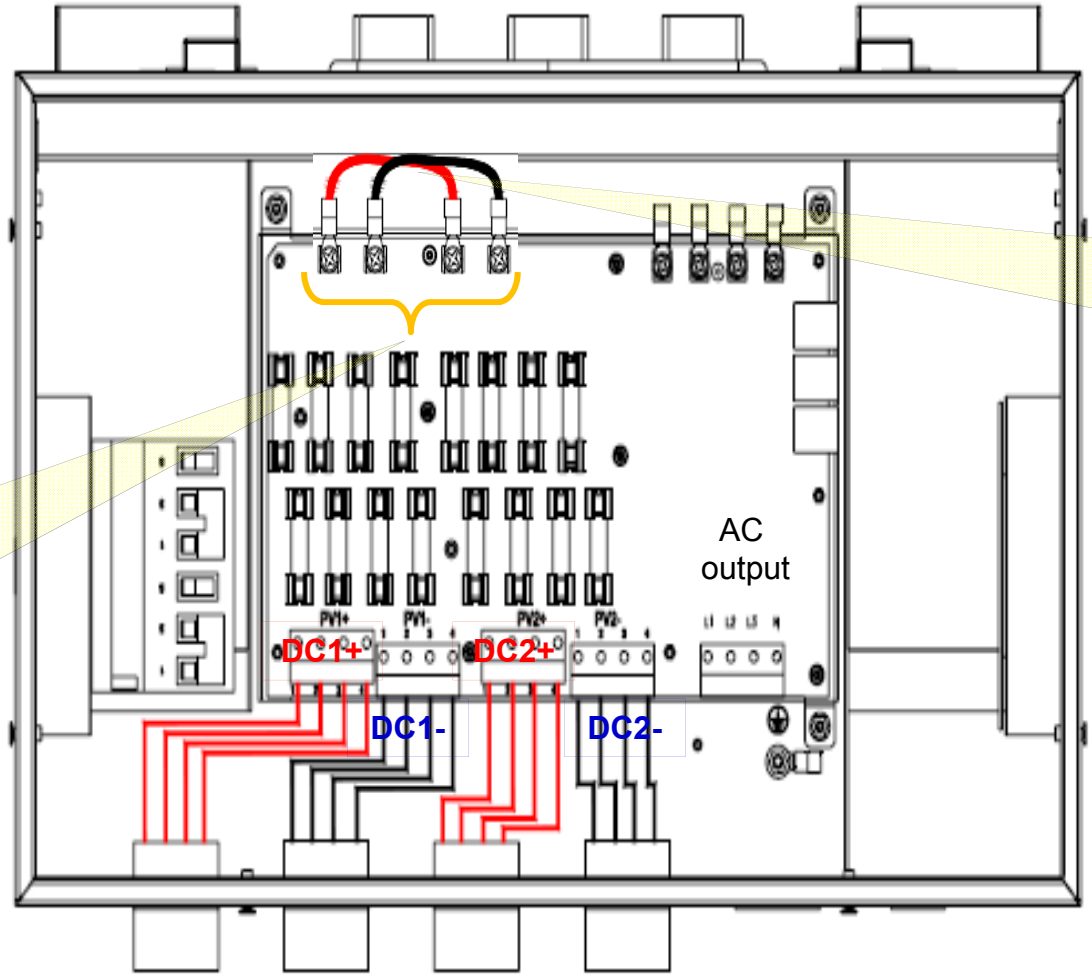
- High CEC and Peak Efficiencies
- Dual MPPT Zones

  PVI 14TL >>> 2 x 7kW MPPT Zones

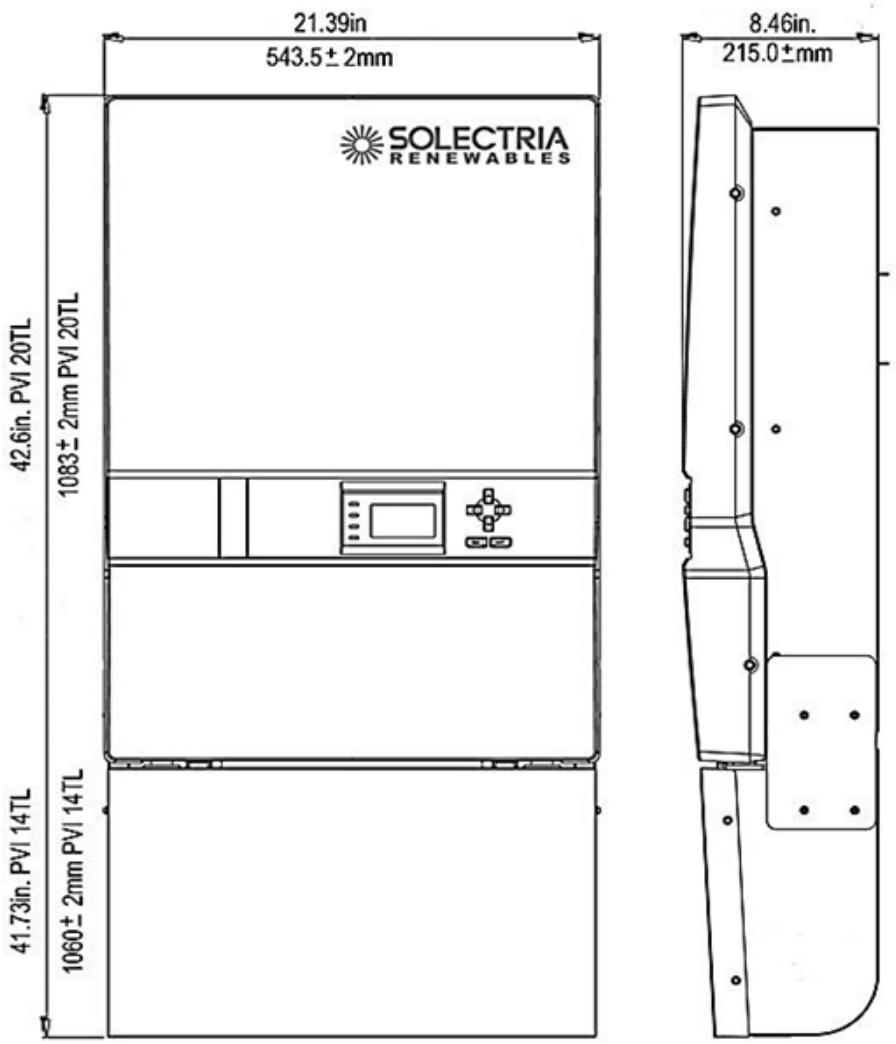
  PVI 20TL >>> 2 x 10kW MPPT Zones

  - Design Flexibility – Strings of different tilt, orientation, length, module type per zone
  - Increased Performance – Reduced mismatch losses
- Solutions for 208V and 480V 3-Phase Services
- Connect to DELTA or WYE Services
- Connect as 4 or 3-Wire Device (No neutral required)
- <2W Tare/Standby Losses
- Class III DC and AC Surge Protection (standard)

Additional Field Flexibility



Compact and Lightweight



Weight:

141 lbs (PVI 14TL)

132 lbs (PVI 20TL)

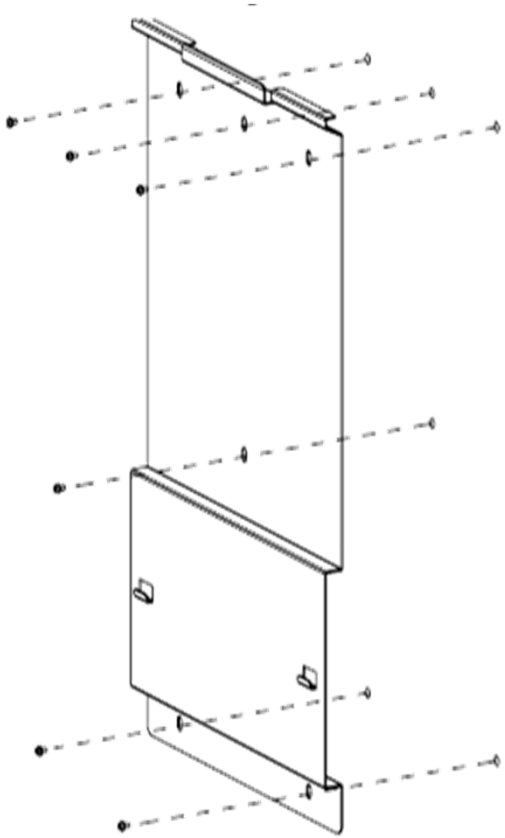
Can be lifted and mounted by two people!

Mount to:

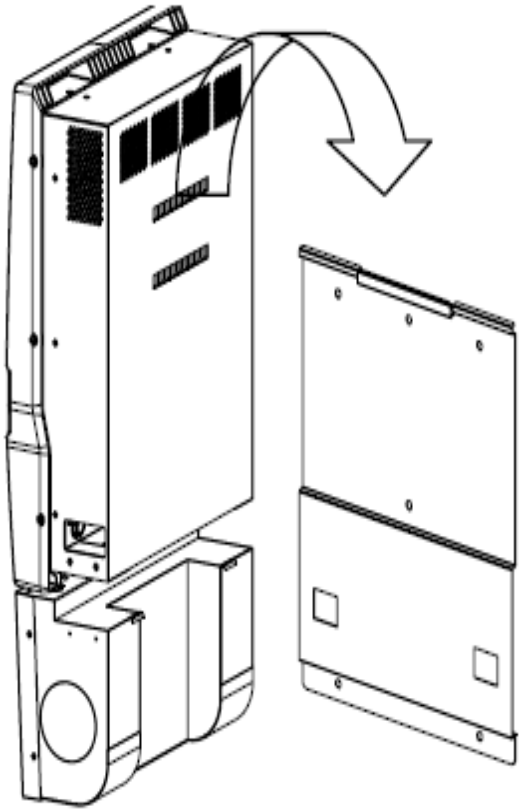
Exterior, Interior, or Parapet Walls, Racking Structure, Carport Frame

Save on inverter pad cost!

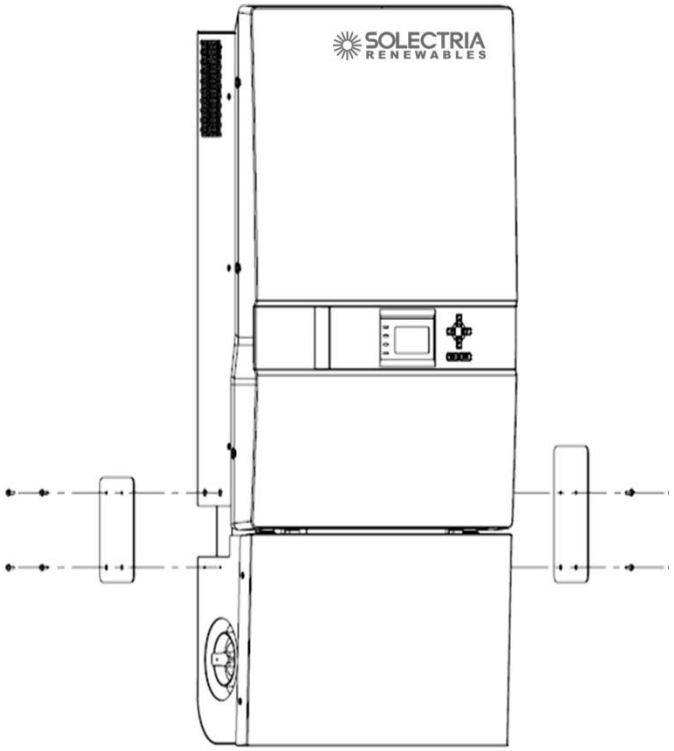
Easy to Install



1



2

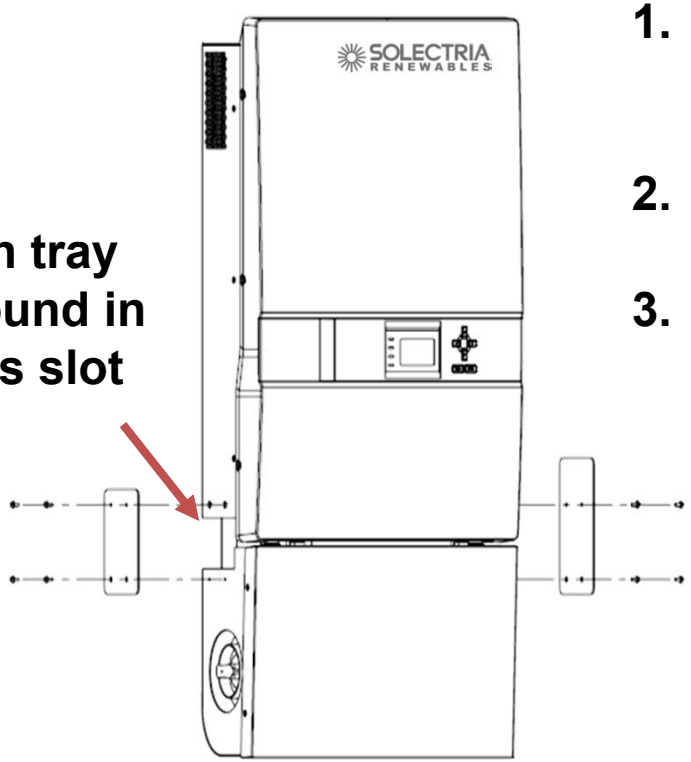


3

Cooling Air-Flow

Fan Tray Maintenance

Fan tray is found in this slot

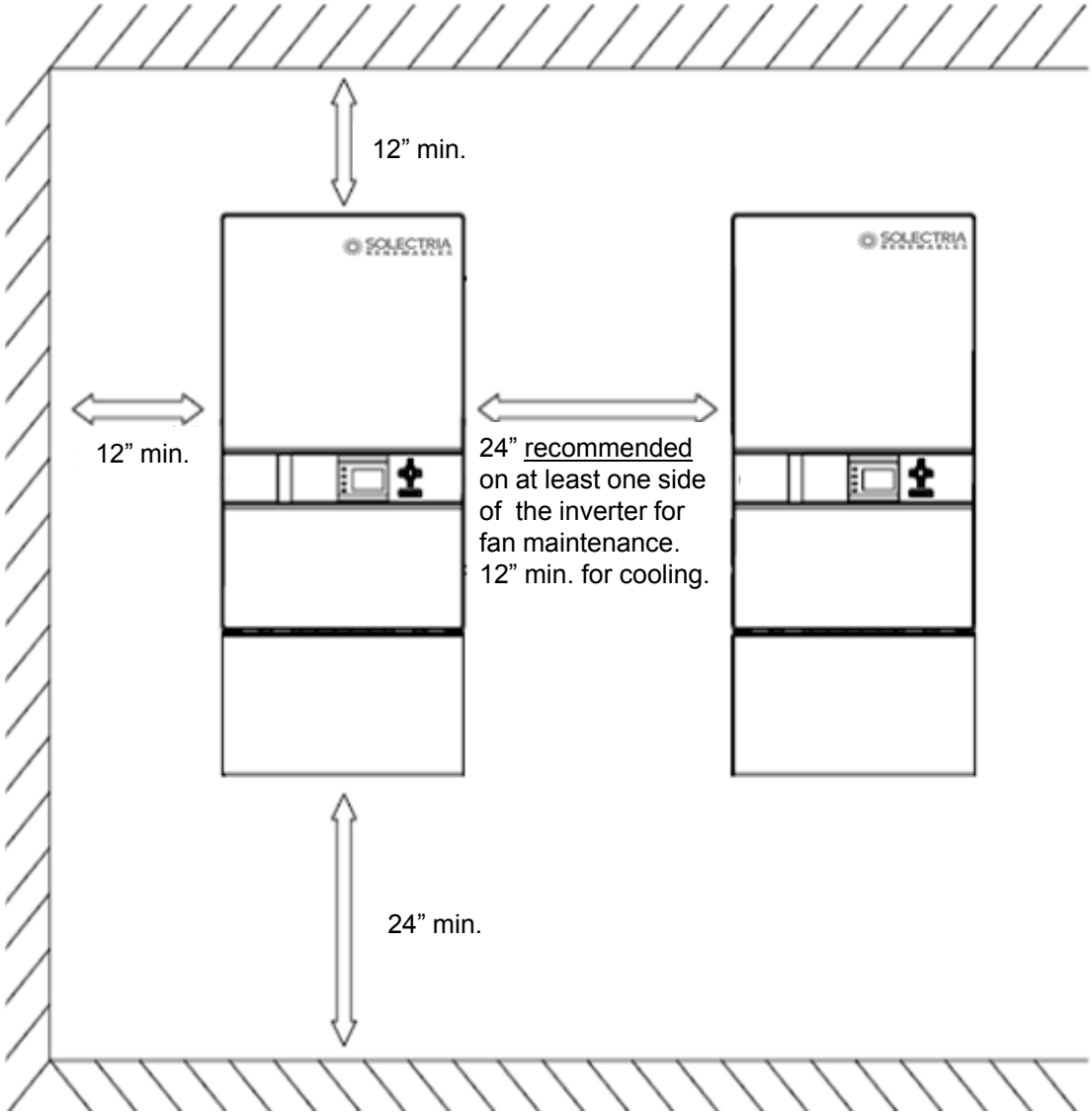


1. **Remove hardware, connectors, and tray. Tray slides out from ether side.**
2. **Clean tray with a dry cloth.**
3. **Re-install tray, connectors, and hardware**

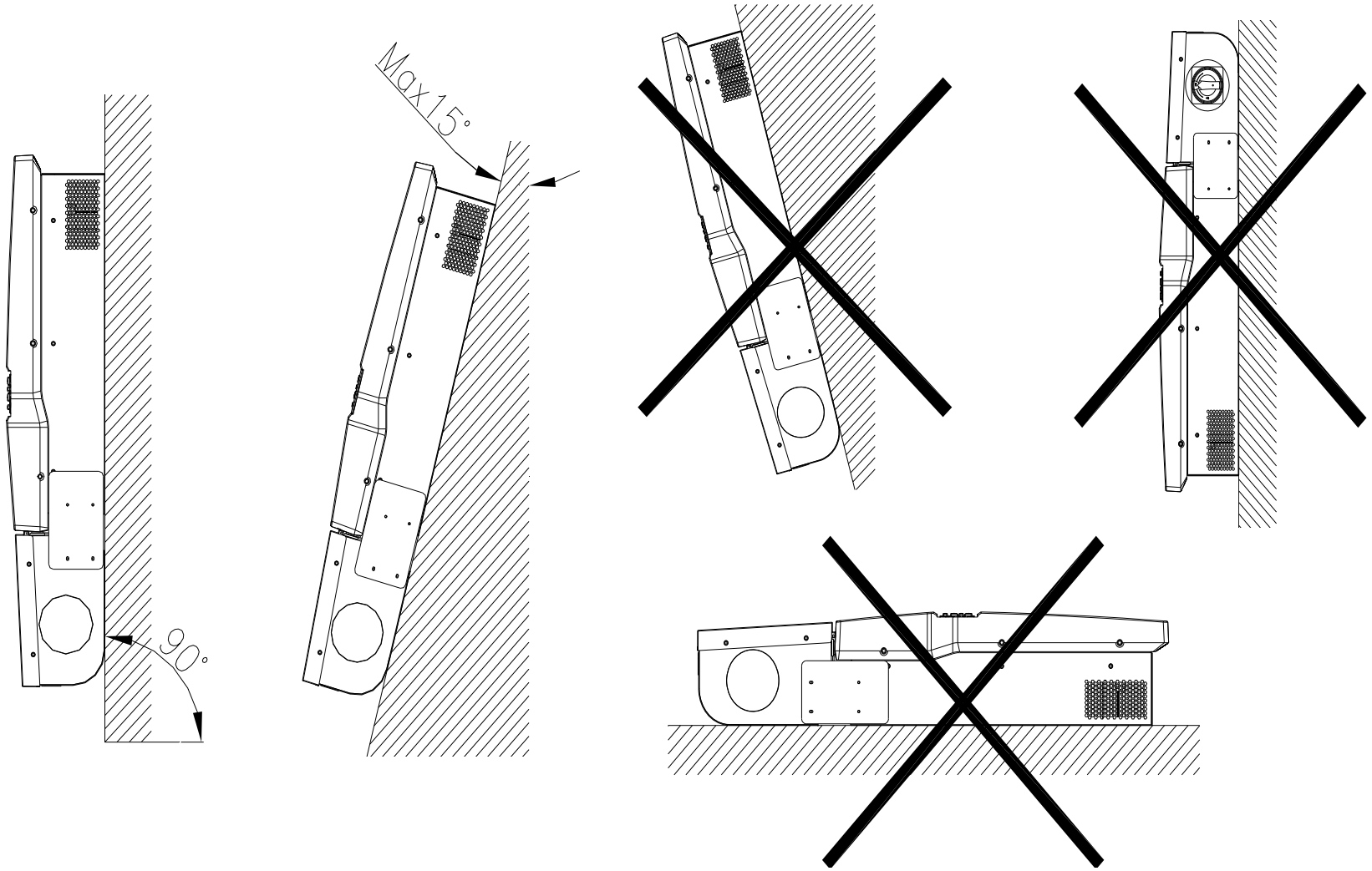
Recommended Maintenance Interval:

6 months,
More frequently in dusty environments

Clearance Requirements



Tilt Angle Considerations



Engineered to Maximize Uptime

Choice of swapping entire inverter or only top section for service.

Replacement unit is provided for field swap of down unit.

Standard 10 year warranty (15 and 20 year options available)

NEC Compliance

PVI 14TL and 20TL are listed to UL1741 for use with ungrounded/floating arrays (only)

Ungrounded systems must comply with NEC 690.35: “Ungrounded Photovoltaic Power Systems”

Intertek

LISTING CERTIFICATE

The following Company/ product(s) is listed for use with the ETL/eETL Listed Mark(s).

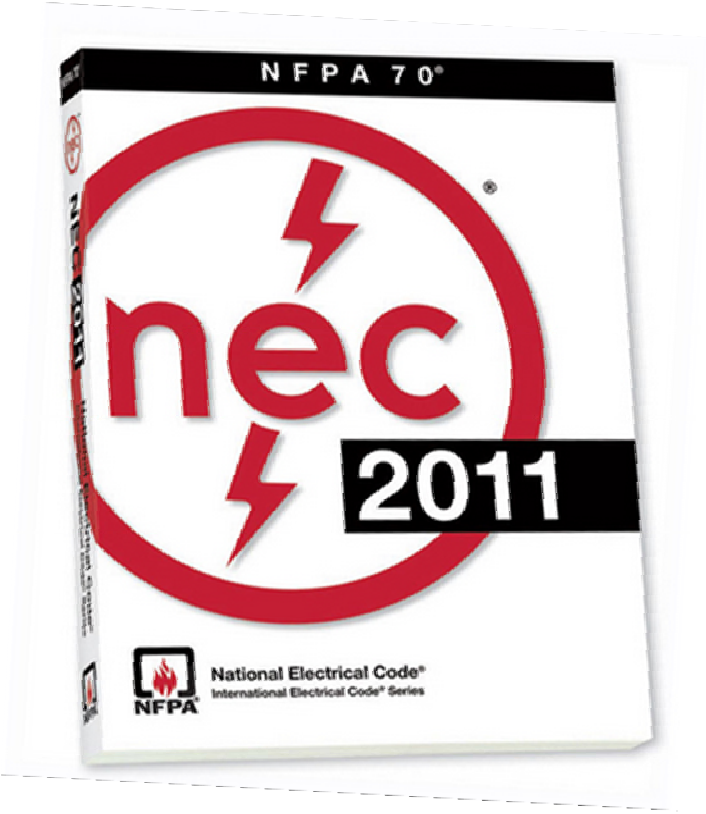
Standard(s): UL Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources, UL 1741, Second Edition, January 28, 2010 & General Use Power Supplies, CSA C22.2 No.107.1-01 dated September, 2001, Reaffirmed 2006 with Interim Certification Requirements for Utility-Interconnected Inverters - Technical Information Letter (T.I.L.) No. I-43, dated January 21, 2011

Company: Solectria Renewables, LLC - Lawrence, MA USA

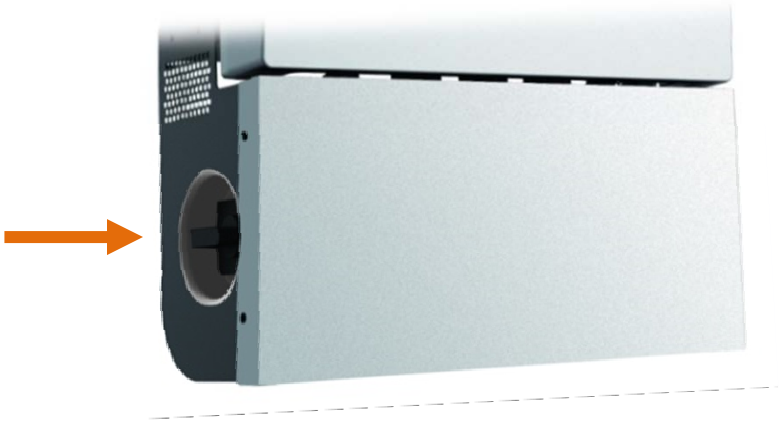
Product(s): Grid-Tie PV Inverter

Model(s): PVI 2011-480

Date: June 25, 2013

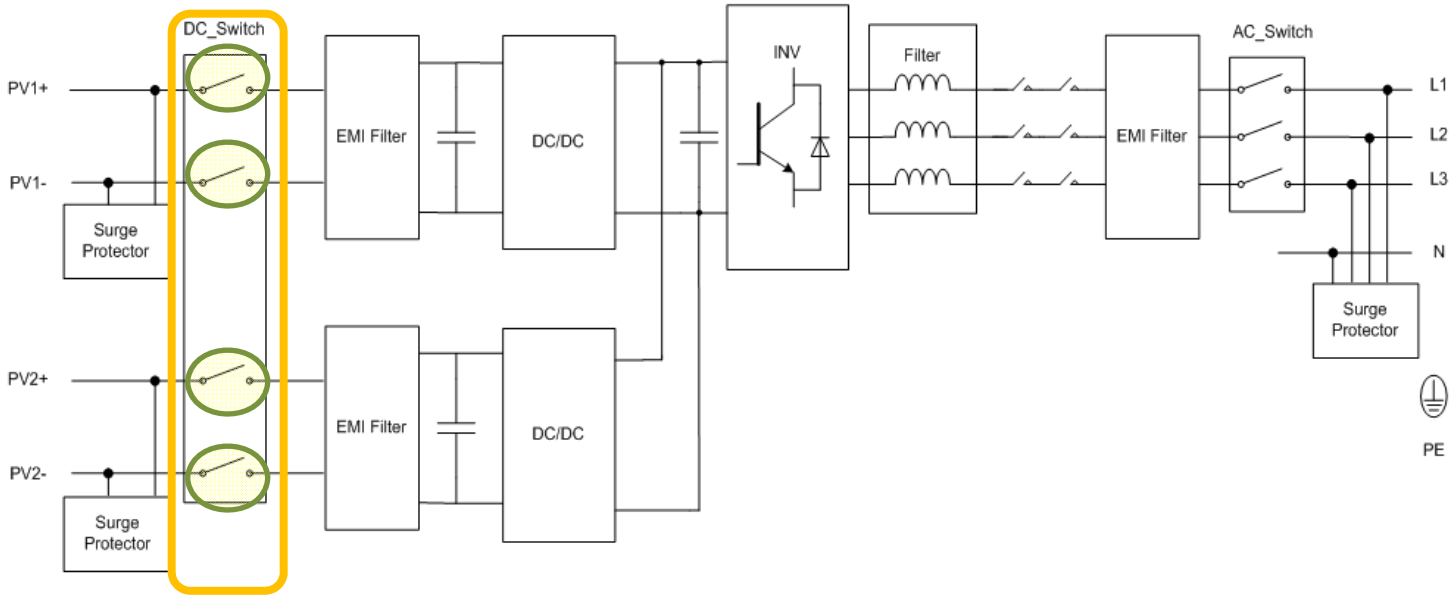


NEC Compliance – Key Requirements



Disconnecting Means

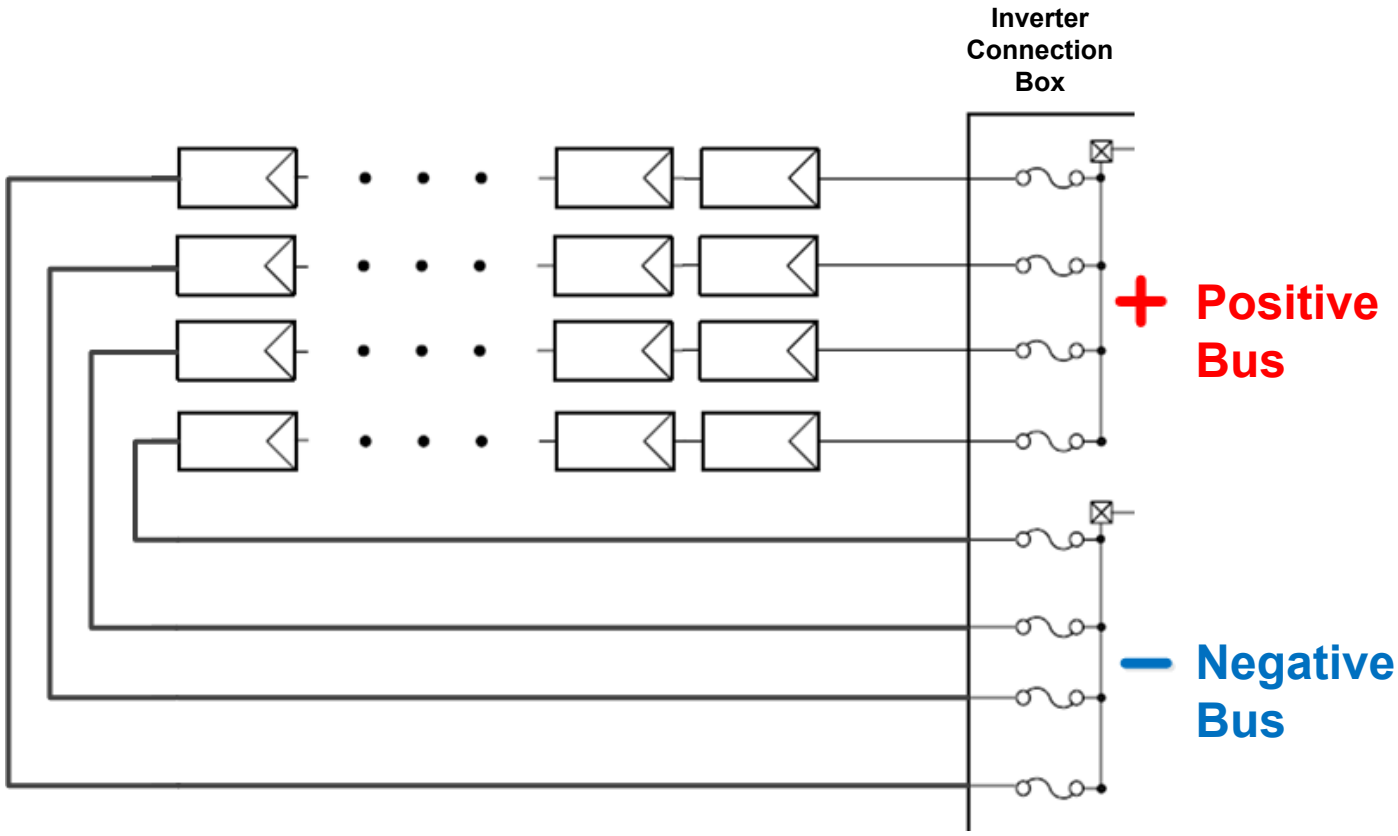
Integrated DC Disconnect opens both (+) and (-) Poles of the Array. [690.35(A), 690.13]



NEC Compliance – Key Requirements

Overcurrent Protection

Fusing on both (+) and (-) inputs [690.35(B), 690.9].



** Only 1 MPP tracker shown*

NEC Compliance – Key Requirements

Overcurrent Protection

Fuse Serviceability via Integrated Fuse Pullers [690.16(B)].

Connection Box –
Fuse Pullers NOT Shown

Connection Box –
Fuse Pullers Shown

NEC Compliance – Key Requirements

Ground Fault Protection

Two Methods Utilized

1. Differential/Residual Ground Fault Detection
2. Impedance Check, Both (+) to ground and (-) to ground

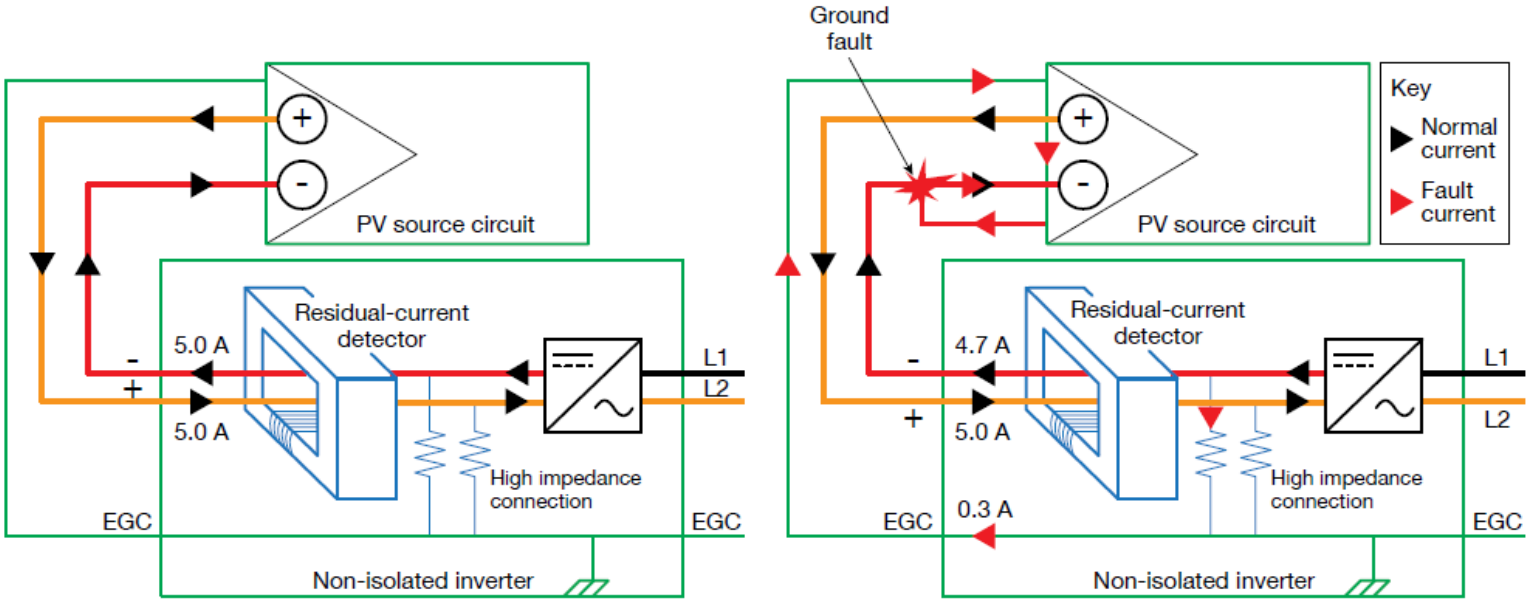


Figure from "Ungrounded PV Power Systems in the NEC," SolarPro, Aug./Sept. 2012

NEC Compliance – Key Requirements

Other System Requirements

- Even though array is “Ungrounded,” DC Equipment Grounding of metal frames, racking, exposed metal parts is still required

- PV Wire on module and exposed cable instead of USE-2 [690.35(D)]

SOLRENVIEW

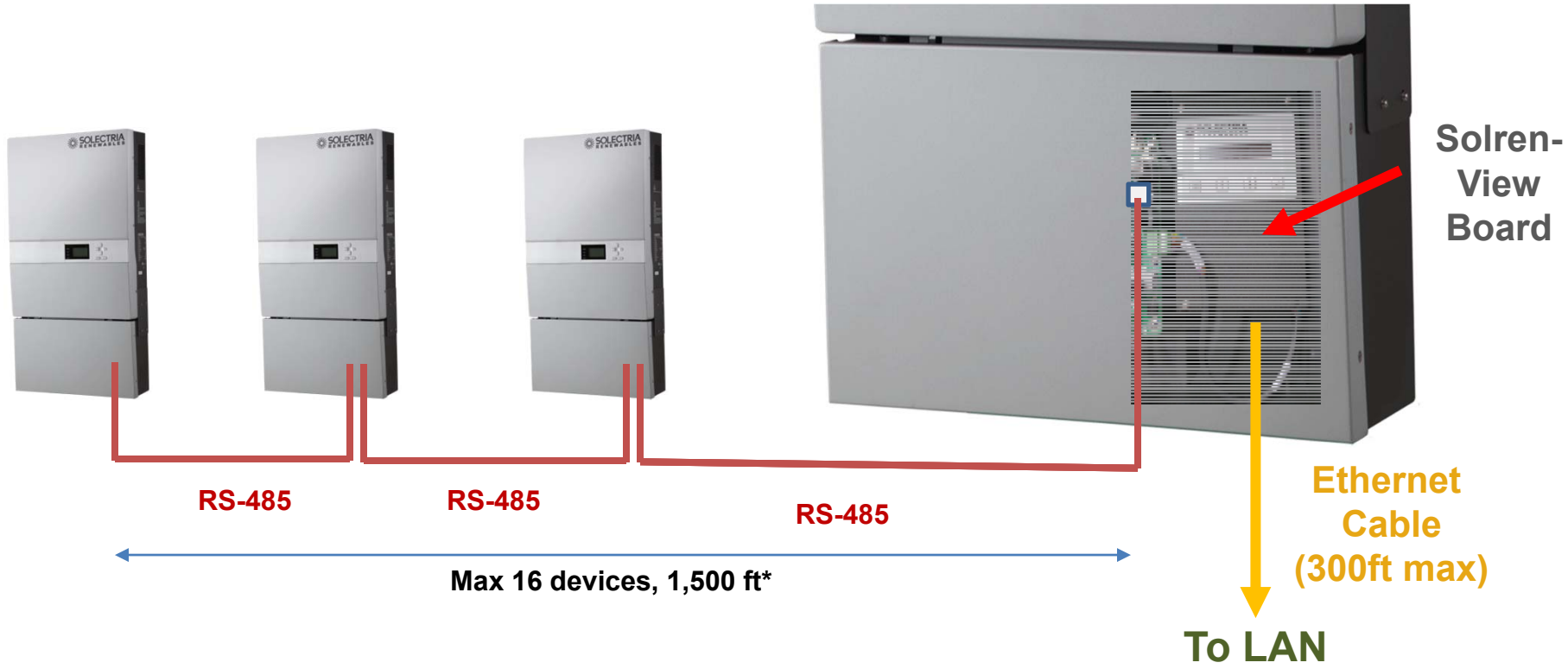
SOLECTRIA
A YASKAWA COMPANY

Solectria's Web Based Monitoring Software

- **Benefit:** Work with one company for monitoring and inverter
- **Benefit:** Site visibility by Solectria Service and Apps for troubleshooting system issues
- Download Data
- Create email fault notifications (email or SMS)
- Kiosk View - **Standard**
- **Upgrade Options:** Reporting Services (with Revenue Grade Meter)

Configuration 1: Daisy Chaining via Modbus RTU/RS-485

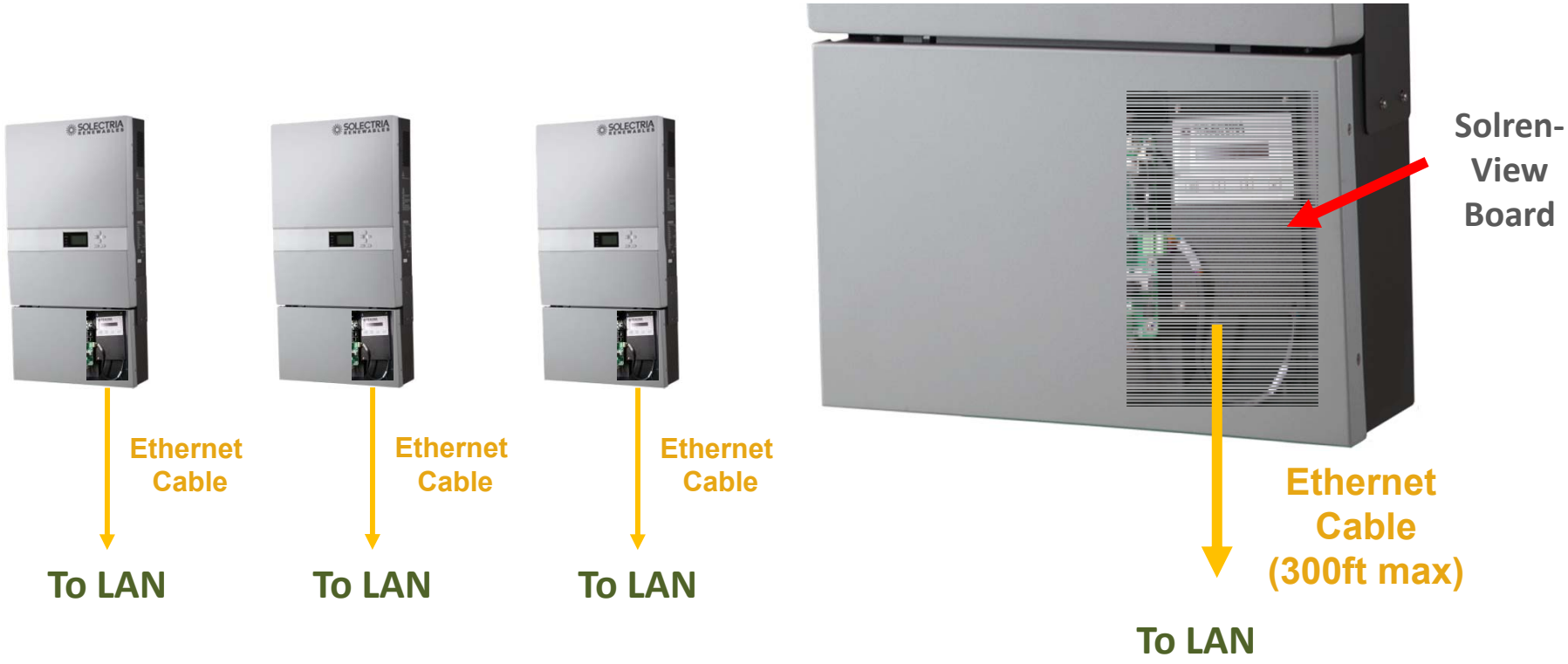
- Requires at least one PVI TL with SolrenView Board.
- All inverters are displayed on same SolrenView site



*Longer network length possible in low noise environment or with isolator/repeaters

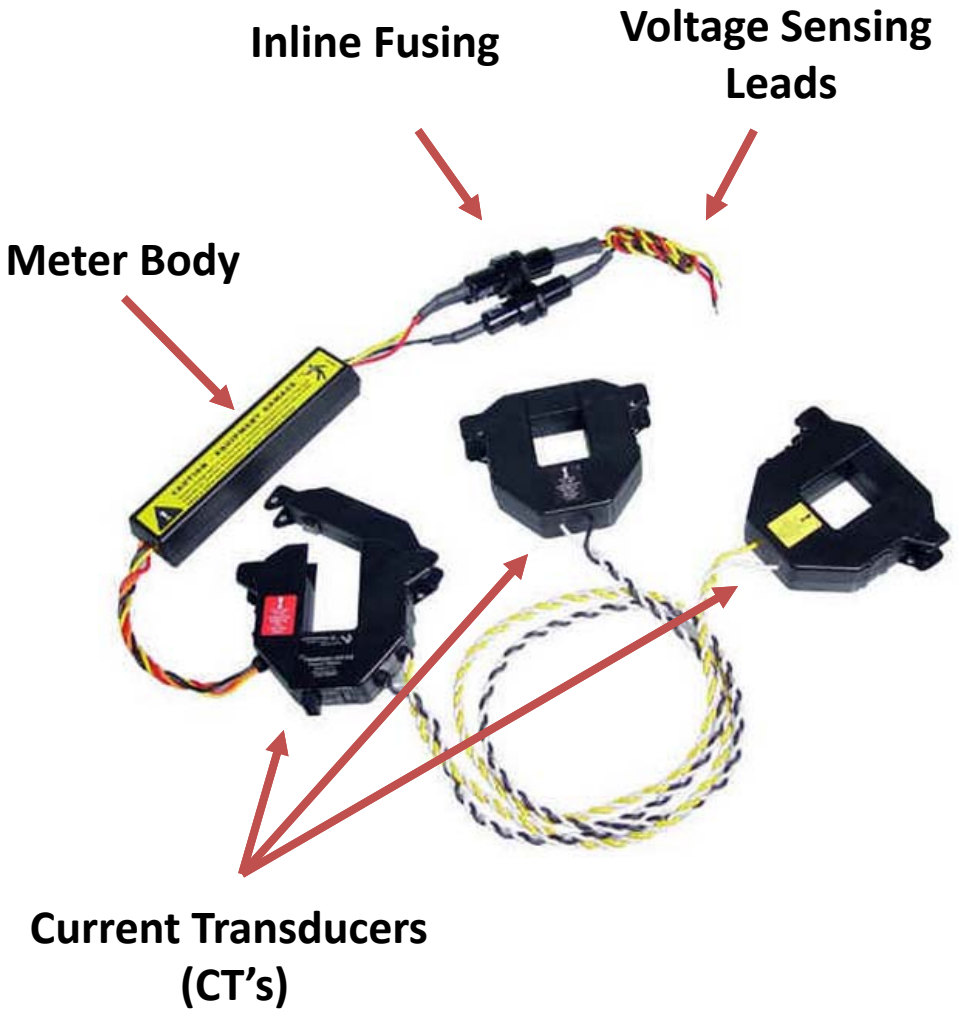
Configuration 2: Ethernet Connection to Each Inverter

- Designer/Installer may choose to make direct Ethernet connection directly to each inverter
- Requires SolrenView board in each inverter
- All inverters are displayed on the same SolrenView Site

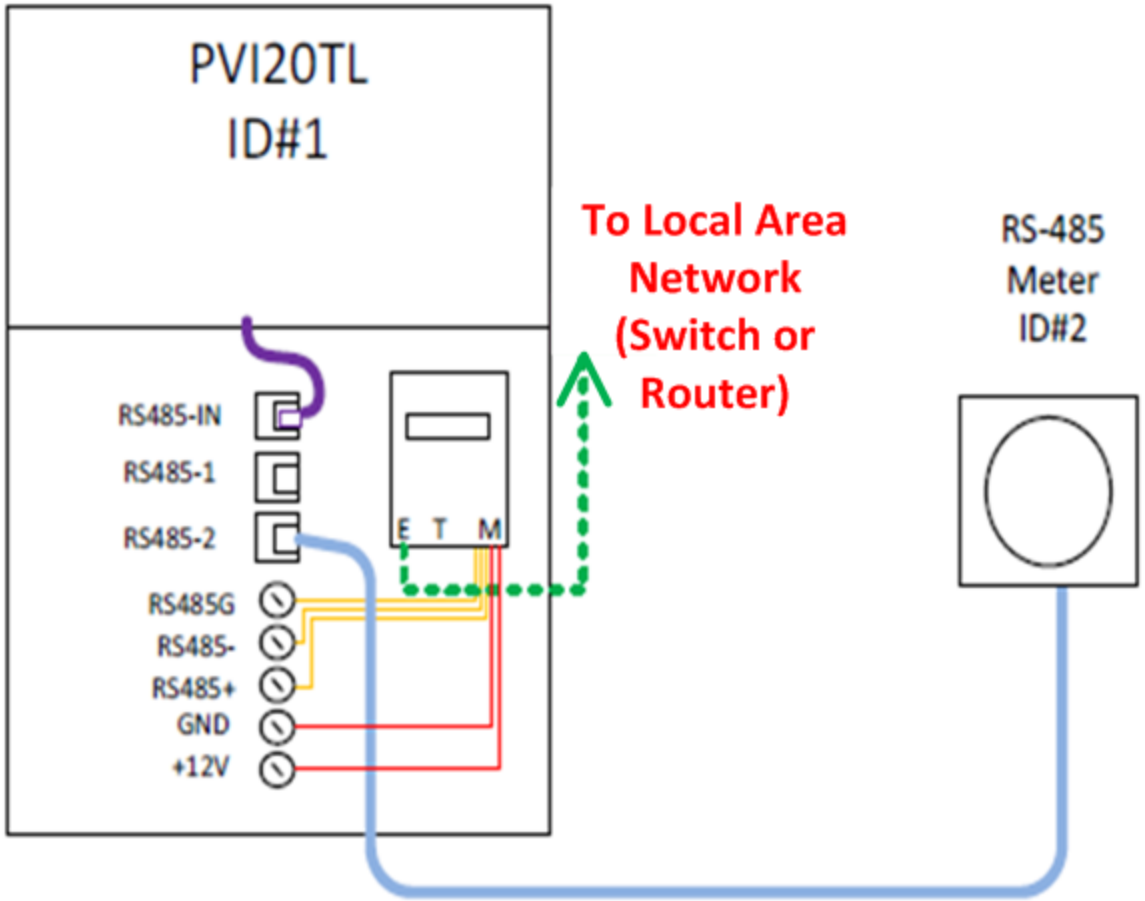


Revenue Grade Metering and Reporting

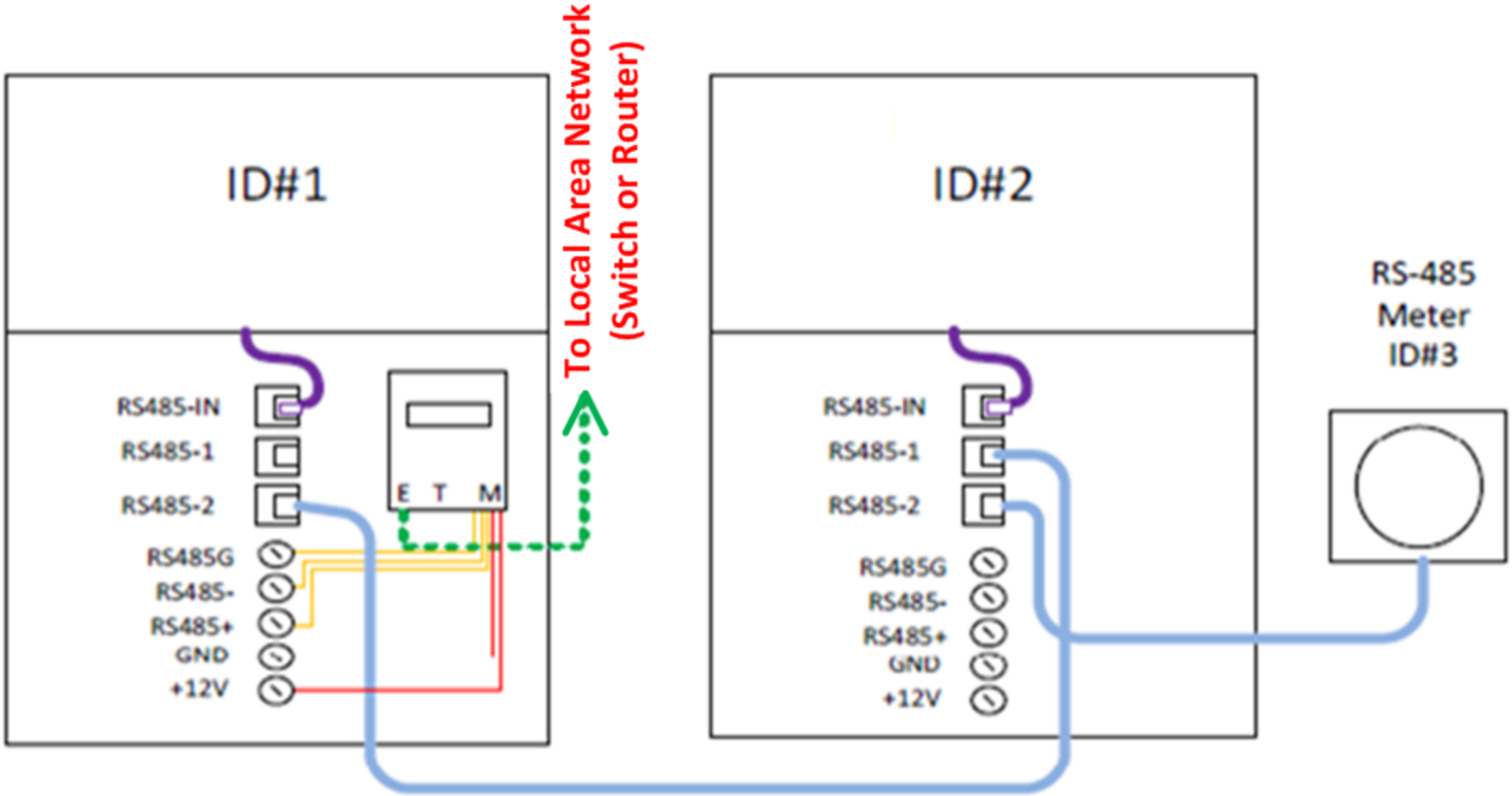
- Monitor the combined output of multiple inverters with revenue grade accuracy (1%)
- Agency Reporting Option through Solectria SolrenView Software
- Meter Kit with 100A CT's, meter kit, inline fusing, and voltage sensing leads. Can monitor:
  - 2 x PVI 14TL 208V
  - 4 x PVI 20TL 480V
- Options for 300A CT's and Larger
- Meter kit installed in downstream panel or CT cabinet (enclosure provided by customer)



Example 1: Single Inverter w/ RGM

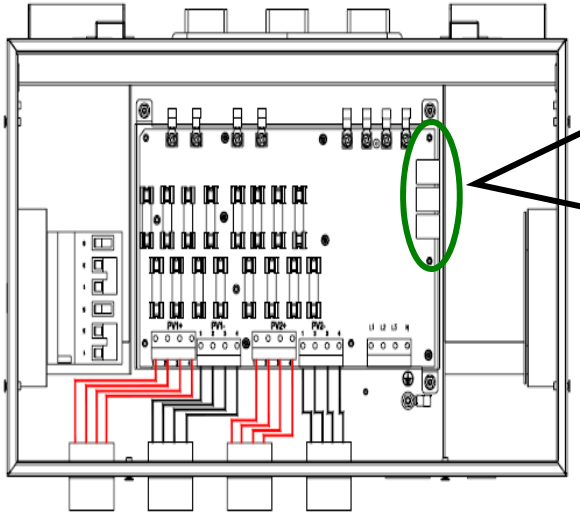


Example 2: Multiple Inverters w/ RGM

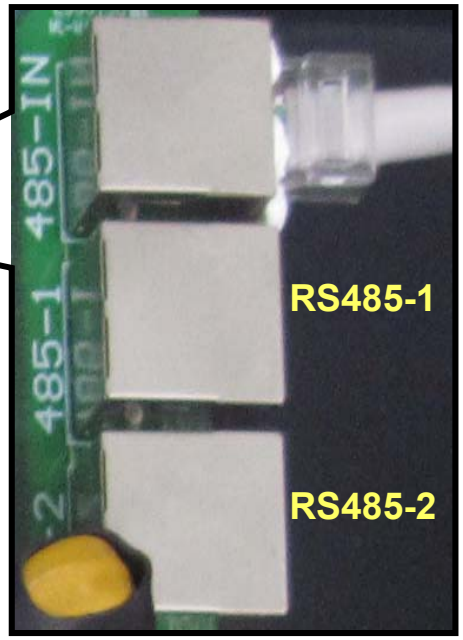


Third-Party Monitoring

- Utilizes the inverters standard RS-485 ports
- No SolrenView Board required
- Compatible with Third-Party Monitoring Software that utilizes Modbus RTU/RS-485
- Register Map Available



Inverter Wiring Box



Internal comm. connection

To third-party data logger/gateway card (or next inverter in daisy chain)

Open or to previous inverter in daisy chain

PVI 23TL & PVI 28TL

Introducing the PVI 23TL/28TL

SOLECTRIA
A YASKAWA COMPANY

Industry Buzz...

"Transformerless?" **Yes!**

For "Ungrounded/Floating Arrays?" **Yes!**

"3-Phase String?" **Yes!**

1000Vdc Arrays **Yes!**

Models

PVI 23TL – 23kWac (1000Vdc, 480Vac)

PVI 28TL – 28kWac (1000Vdc, 480Vac)

PVI 23TL/28TL Features

- Integrated Lockable DC/AC switch
- Compact, Light-Weight
- NEMA 4
- High Reliability
- Easy Installation & Maintenance
- Solectria or Third-Party Web Based Monitoring

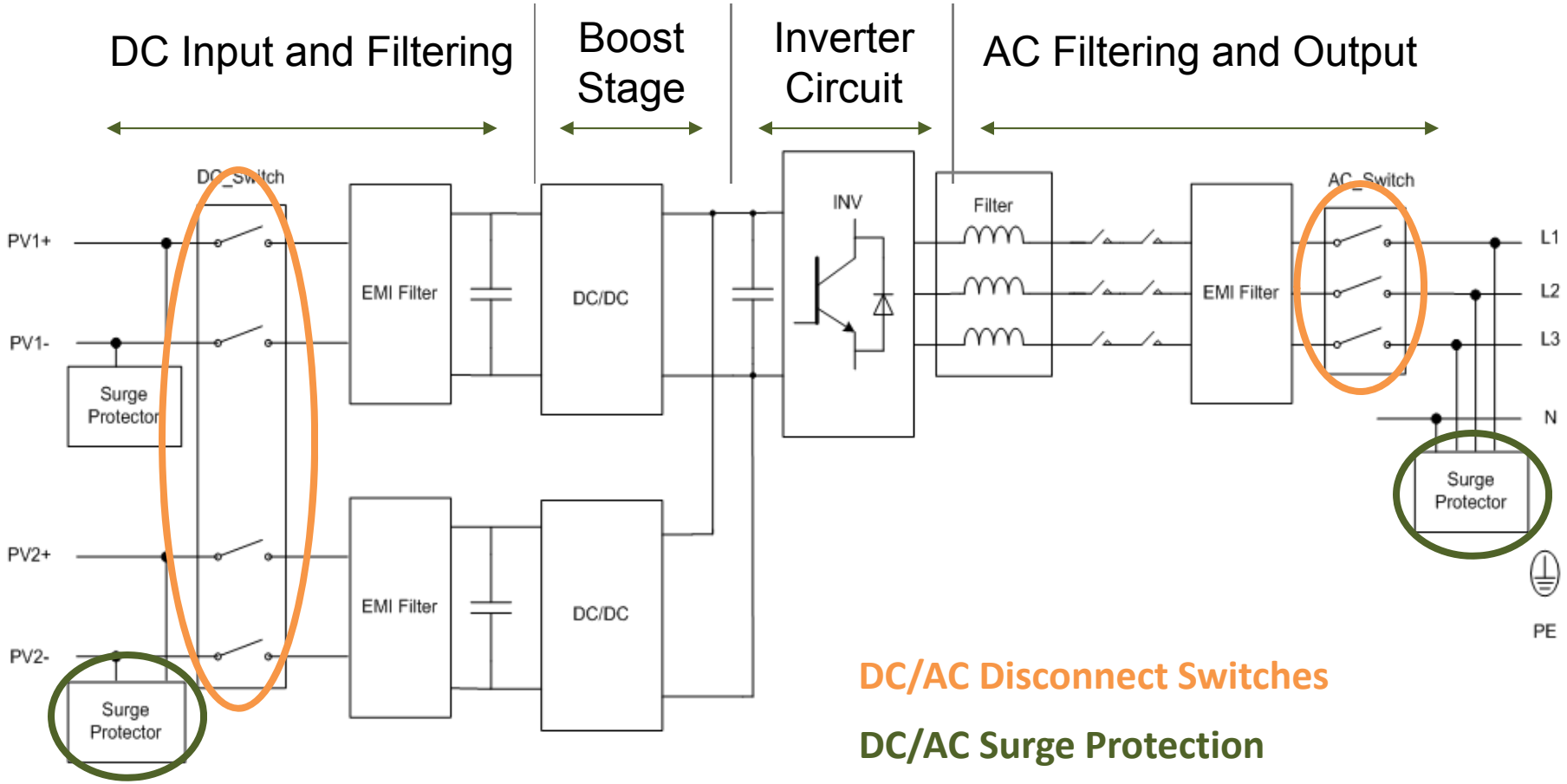
PVI 23TL/28TL Features

- High CEC and Peak Efficiencies
- Dual MPPT Zones for design flexibility and increased energy harvest
- 8 Fused Inputs (4 per MPPT channel), Fuse bypass possible
- Integrated fusing and DC/AC disconnect meets NEC 2011/2014 requirements

Applications

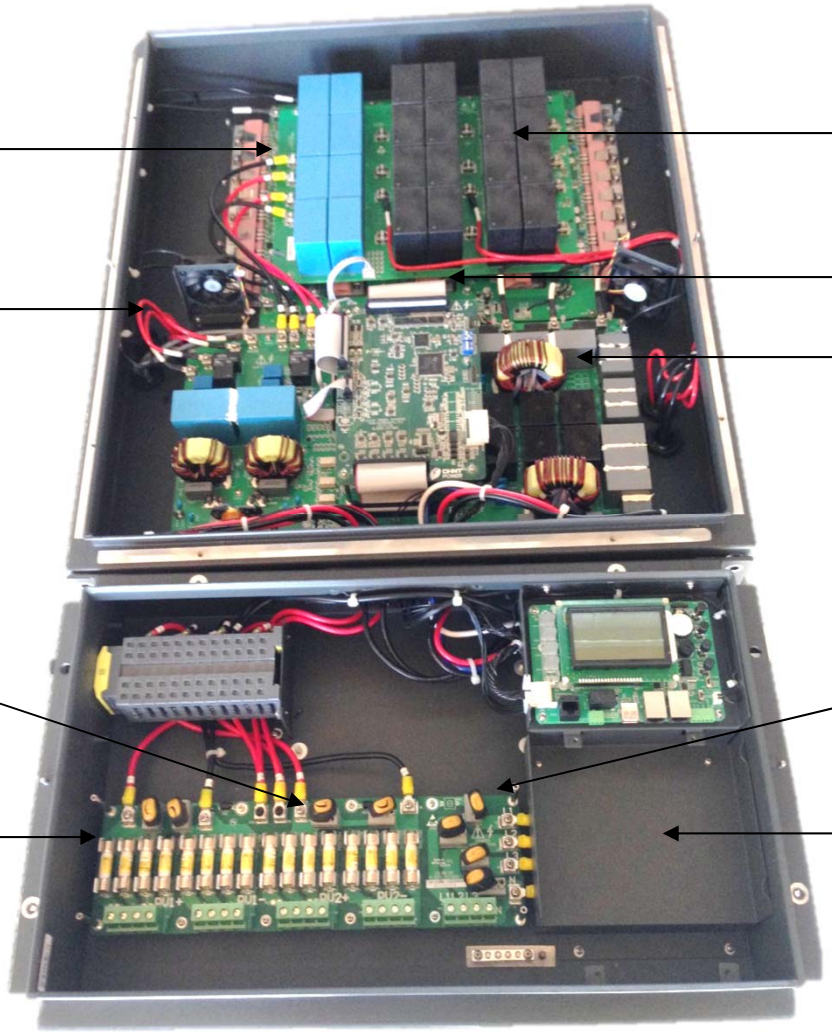
- Light Commercial Systems
- Systems with Multiple Tilt Angles/Orientations
- Complex Layouts
- Limited Space for Central Inverter
- Carports
- Weight Restricted Projects
- Utility Scale Trackers

Inverter Topology

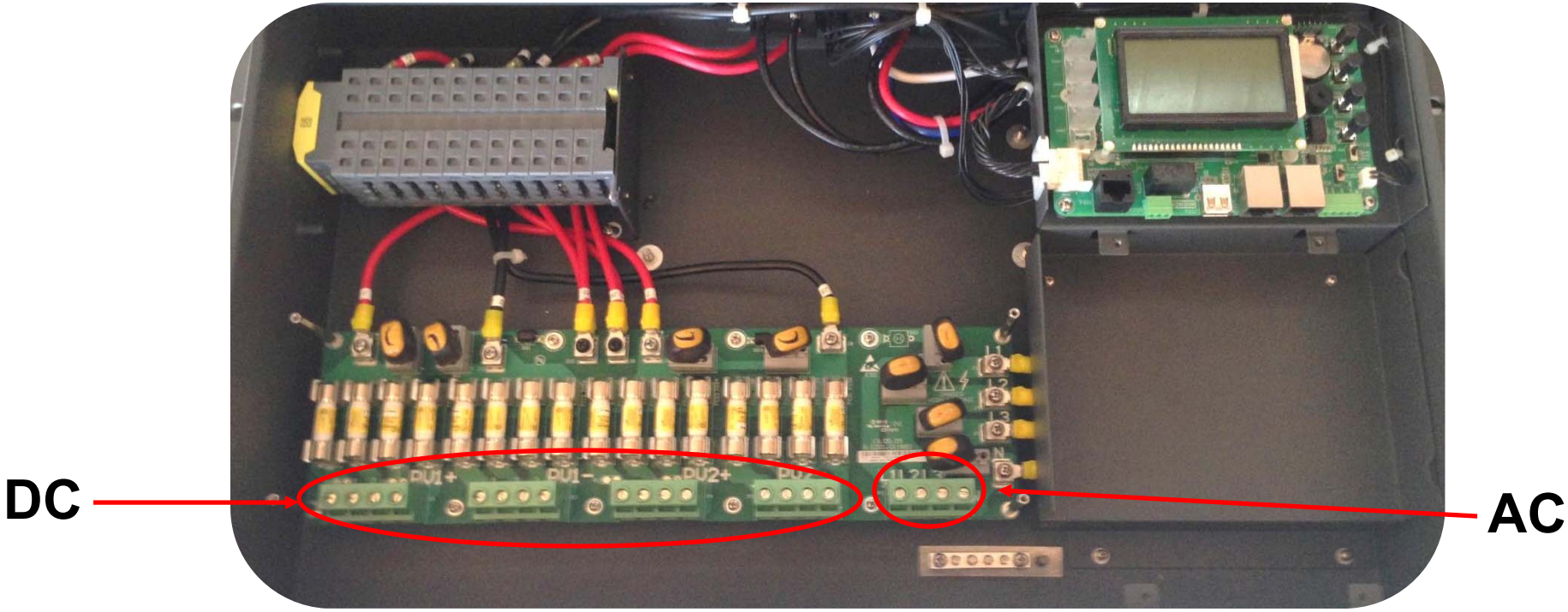


**DC +/- Fusing Not Shown*

Design


Boost Circuits
DC filter
DC string fuses and surge arrestors
DC/AC Switch
Inverter
Main control board
AC filter
AC fuses and surge arrester
SolrenView Web Monitoring Hardware

Wiring Box



DC and AC Wiring Connection Terminals

DC Fuse Pullers Not Shown

Electrical/Performance Benefits

- High CEC and Peak Efficiencies
  - 23TL- 98% CEC, 98.2% Peak
  - 28TL- 98% CEC, 98.2% Peak
- <2W Tare/Standby Losses
- Class III DC and AC Surge Protection (standard)
  - Optional Class II for AC/DC

Electrical/Performance Benefits

- Dual MPPT Zones

  PVI 23TL >>> 2 x 11.5kW MPPT Zones

  PVI 28TL >>> 2 x 14kW MPPT Zones

  - Design Flexibility – Strings of different tilt, orientation, length, module type per zone

  - Increased Performance – Reduced mismatch losses

Electrical/Performance Benefits

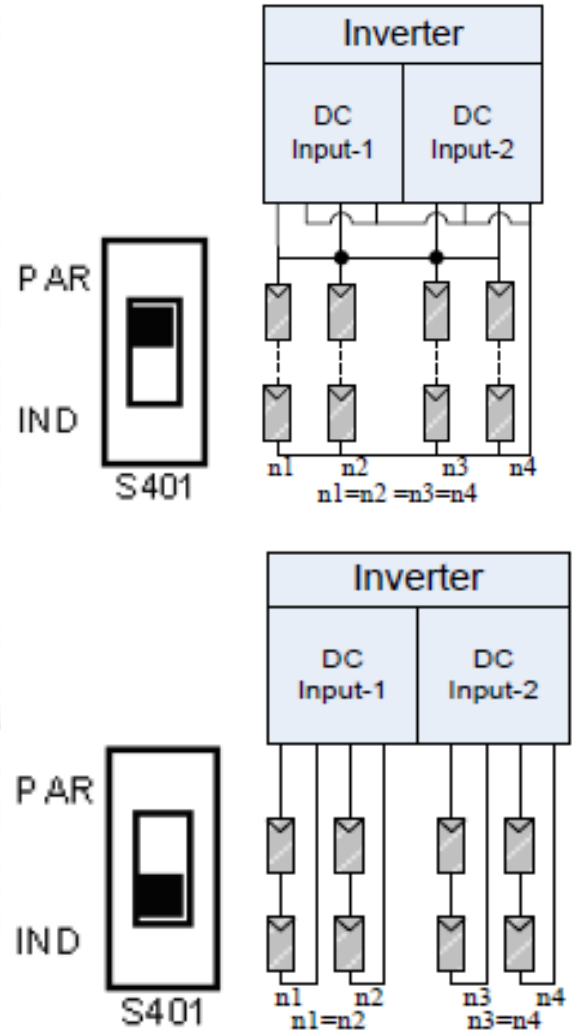
- Dual MPPT Zones

  PVI 23TL >>> 2 x 11.5kW MPPT Zones

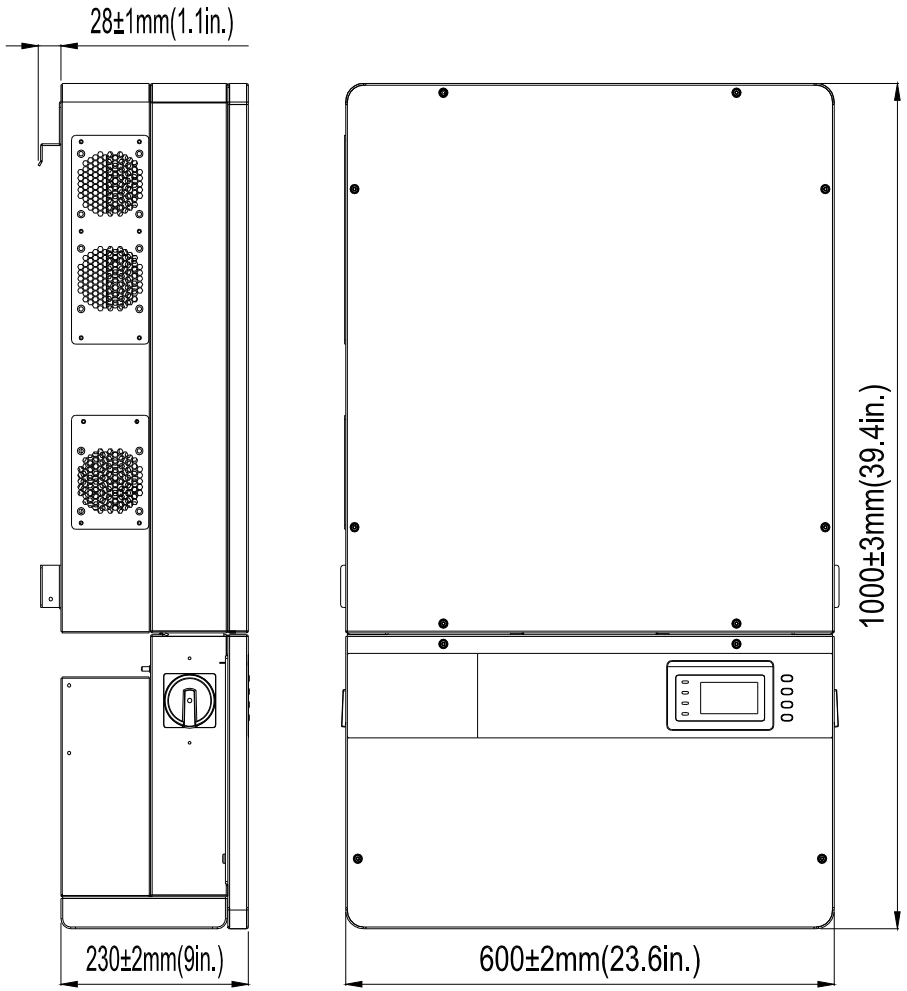
  PVI 28TL >>> 2 x 14kW MPPT Zones

  - ➢ Design Flexibility – Strings of different tilt, orientation, length, module type per zone

  - ➢ Increased Performance – Reduced mismatch losses



Compact and Lightweight



Weight: 122lbs

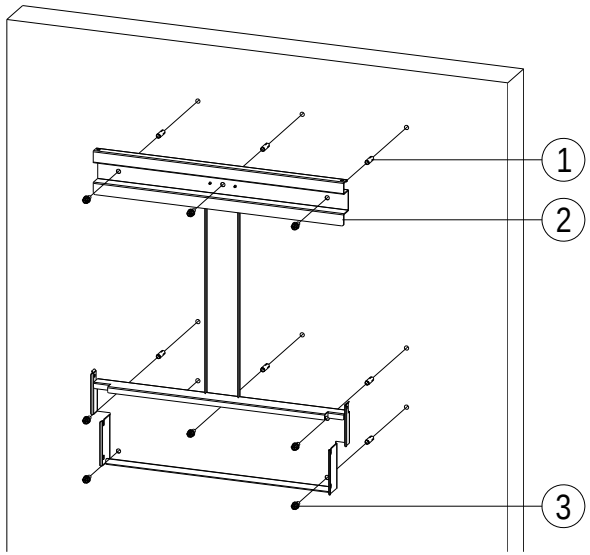
Can be lifted and mounted by two people!

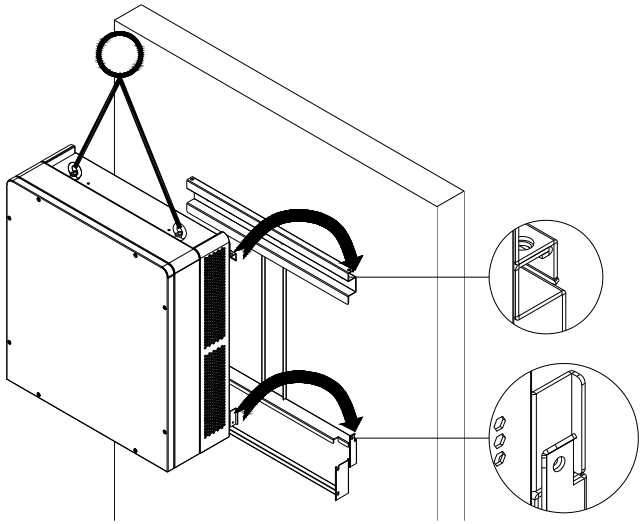
Mount to:

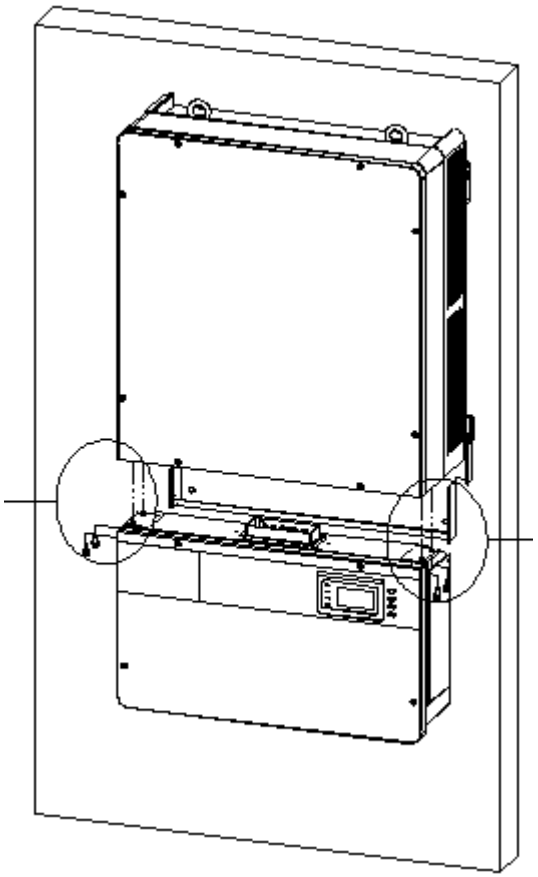
Exterior, Interior, or Parapet Walls, Racking Structure, Carport Frame

Save on inverter pad cost!

Easy to Install







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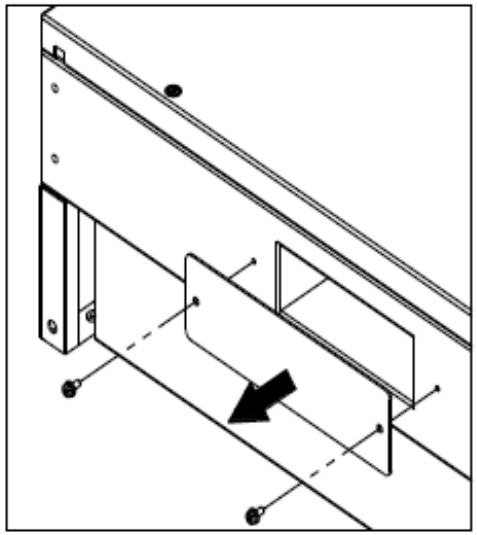
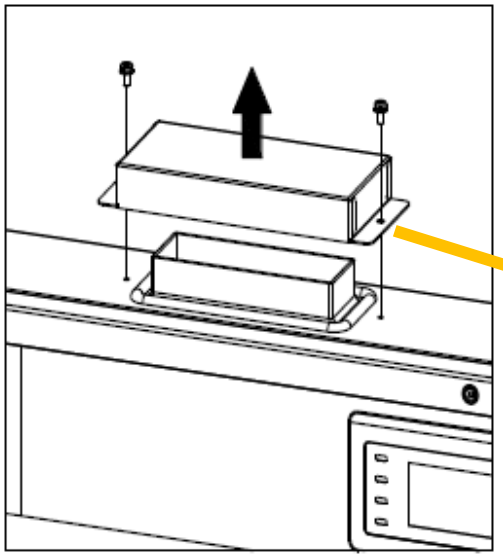
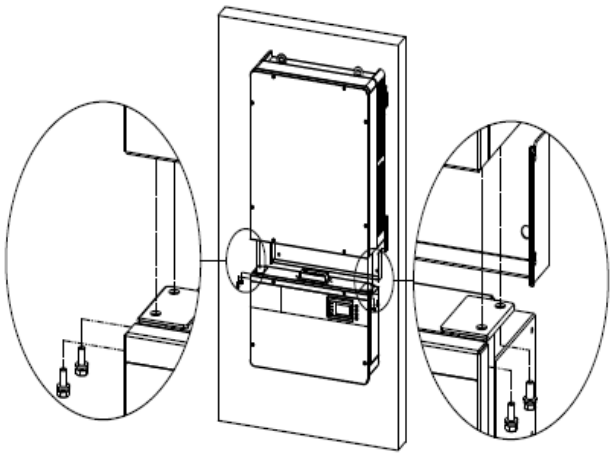
Easy to Install

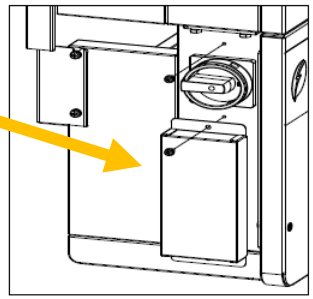




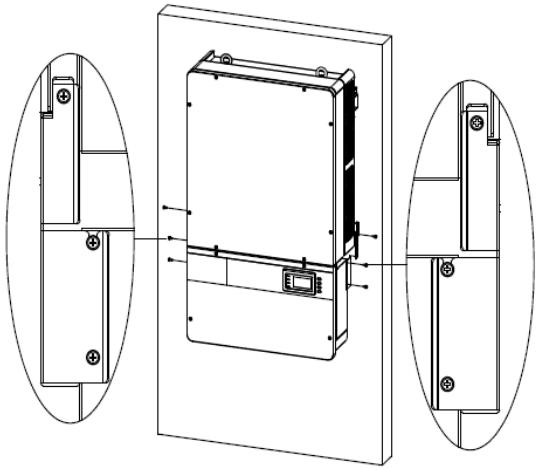
Secure the wiring box to the inverter



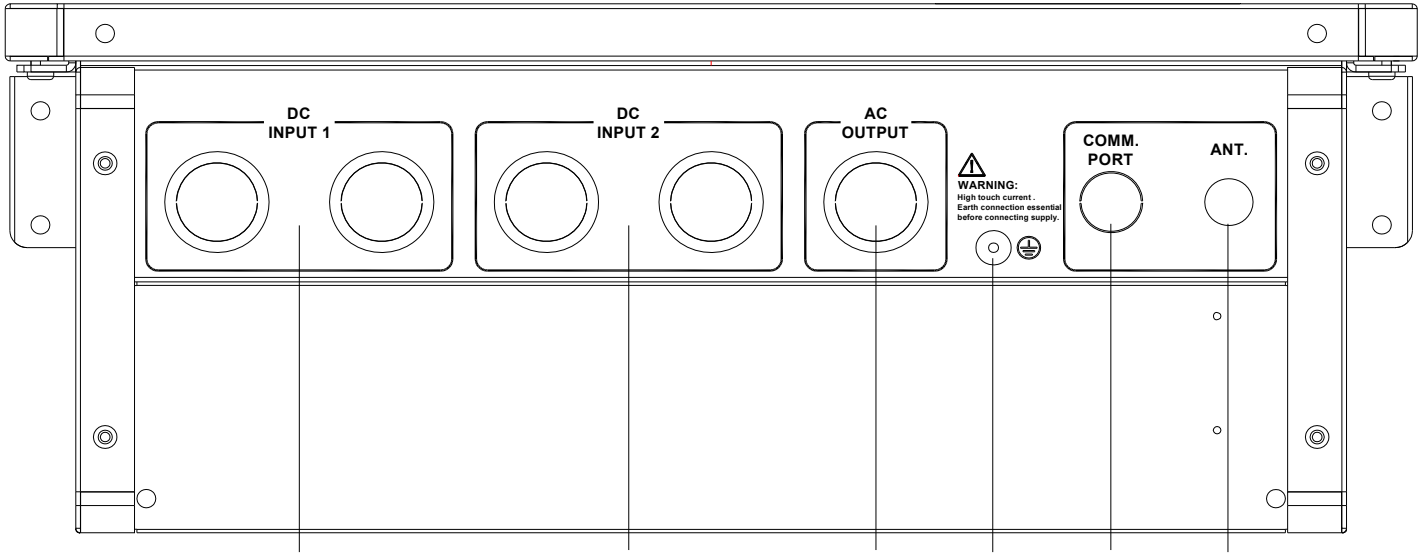
Save the cover



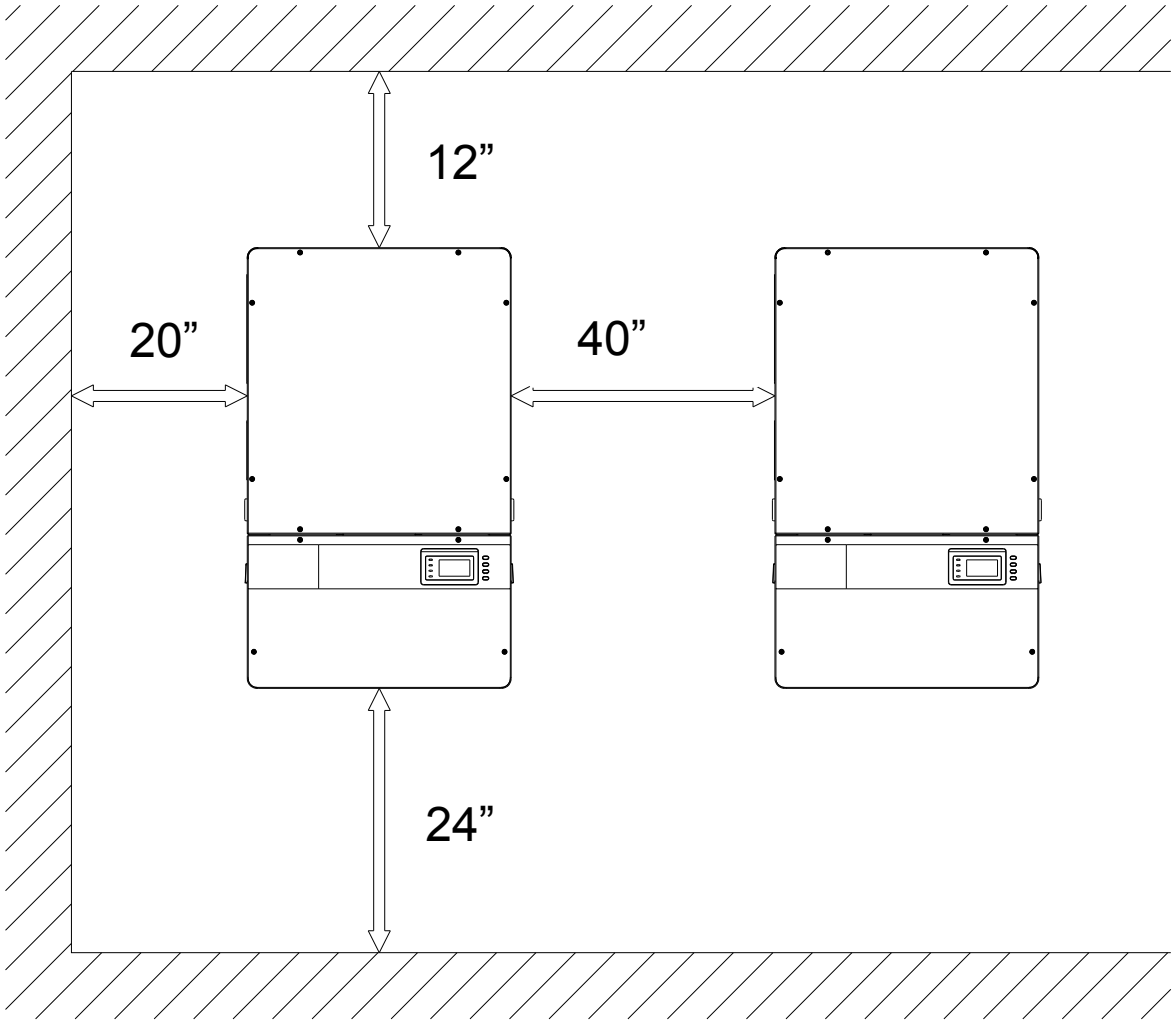
Secure the wiring box to the mounting bracket



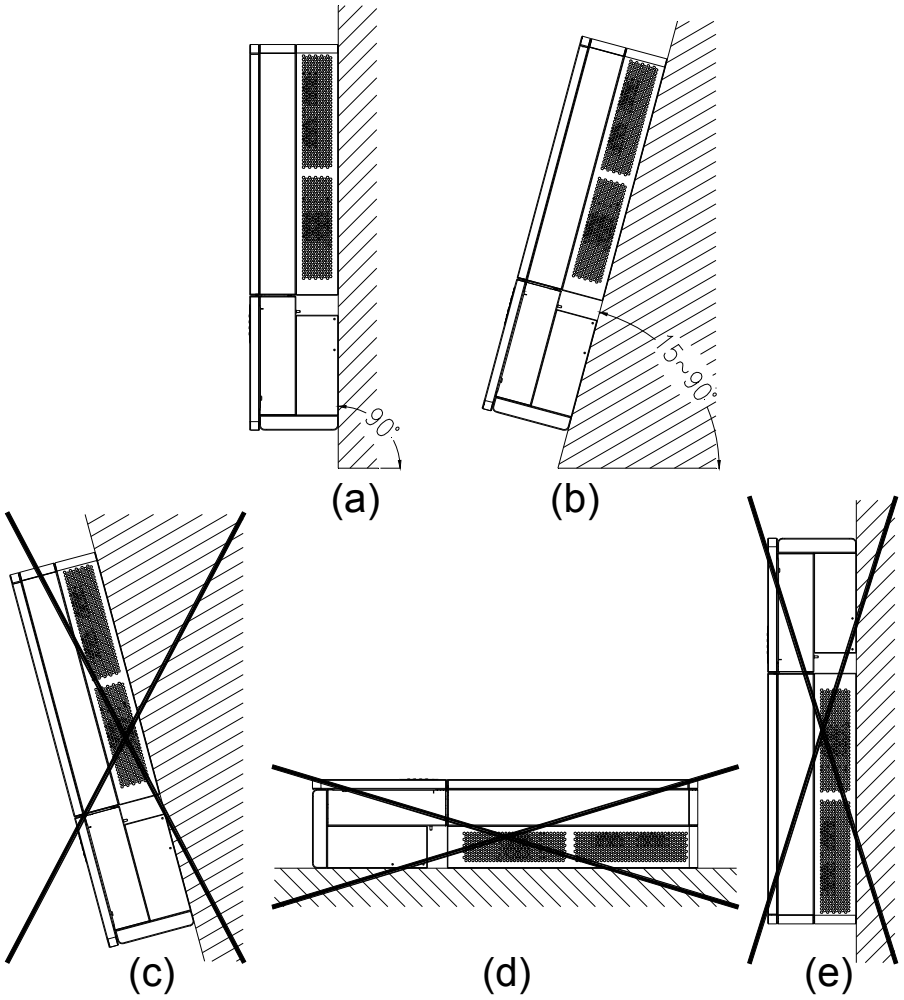
Knock Out Locations



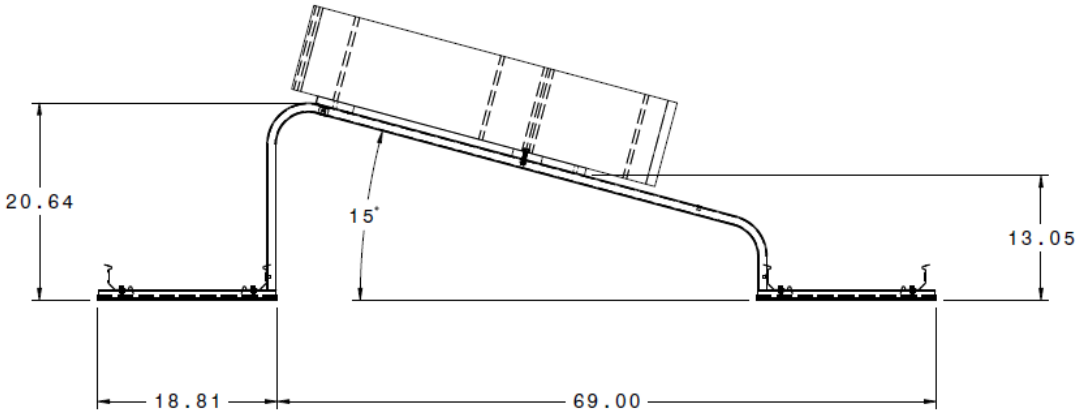
Clearance Requirements

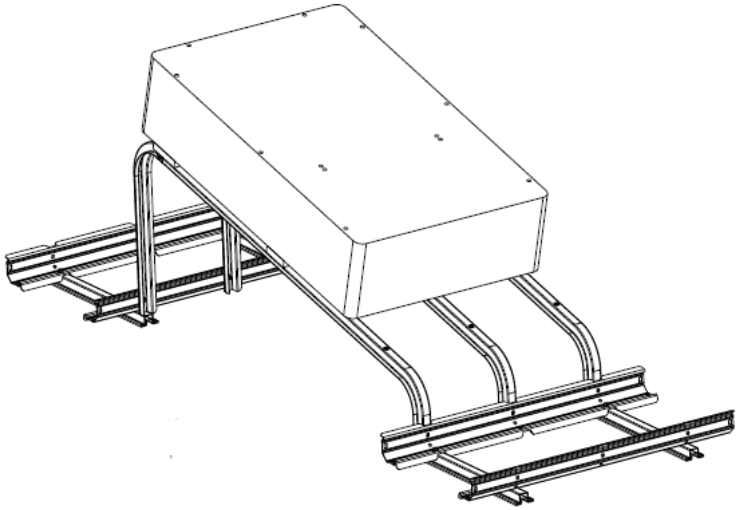


Mounting Considerations



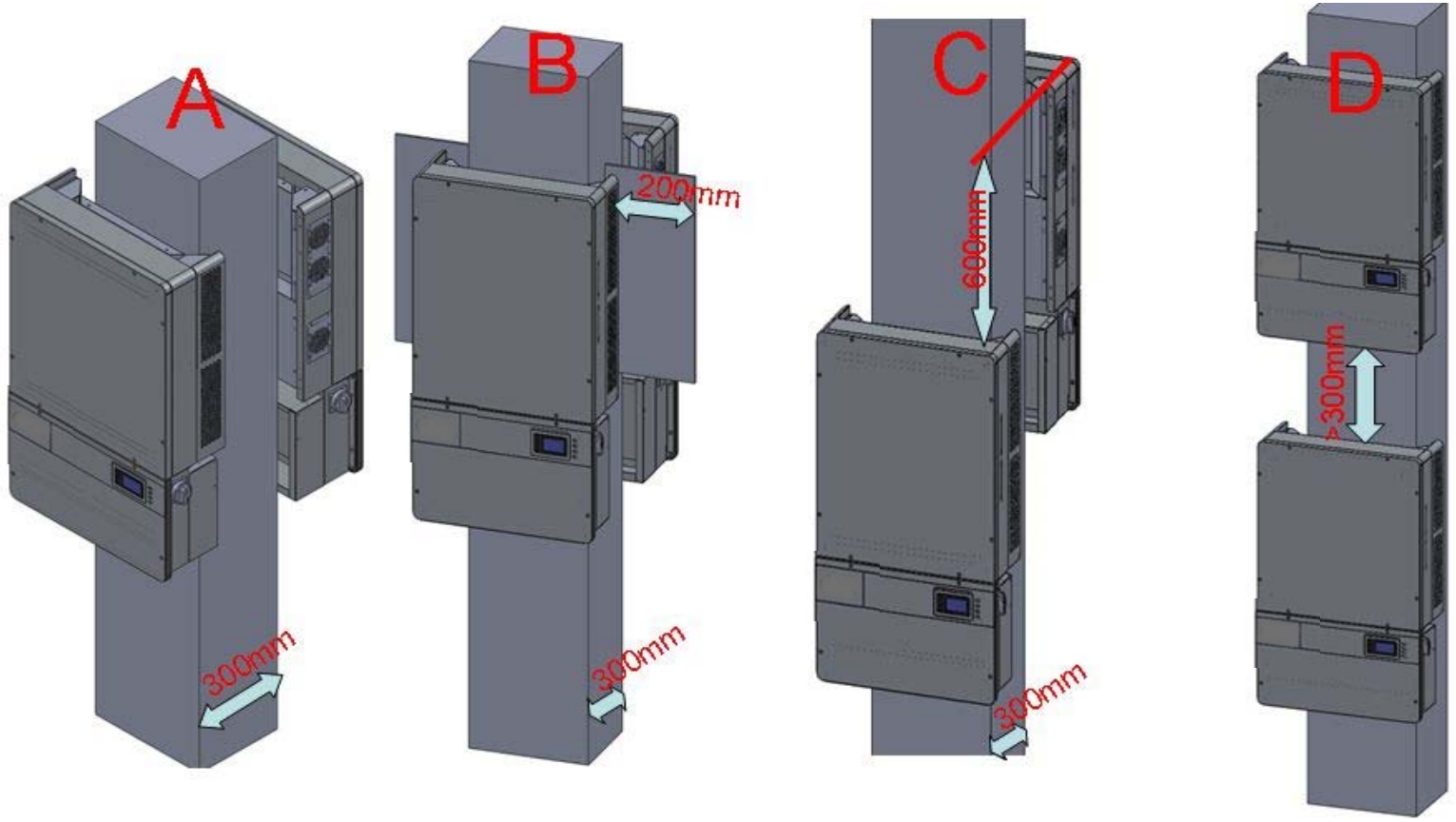
Mounting Considerations





Ballasted racking system for 15° tilt

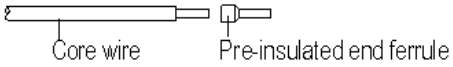
Mounting Considerations

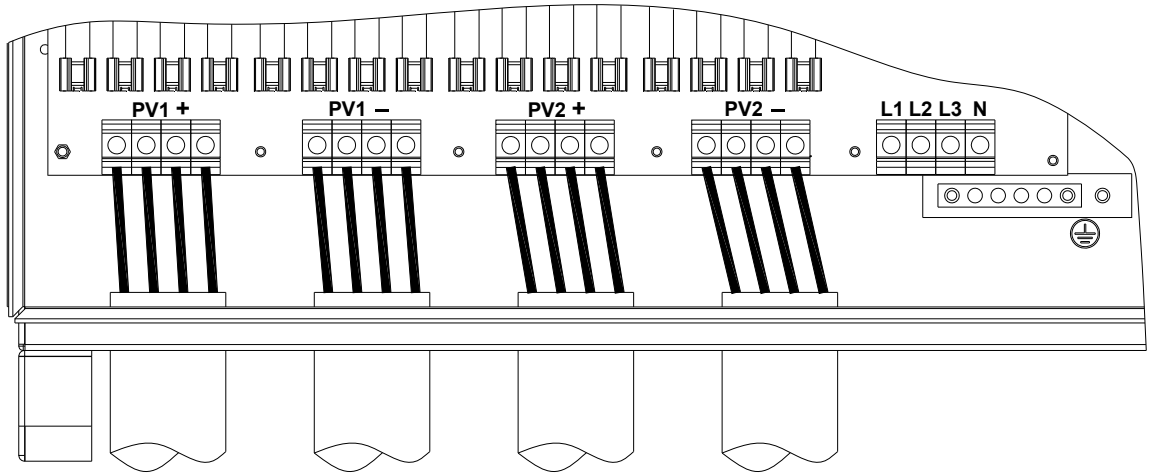


A- Air Intake temperature is 3-4 degrees greater than ambient.
B, C, & D-Inverters will not affect each other .

DC Wiring

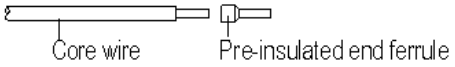
- Prepare cable ends with ferrules

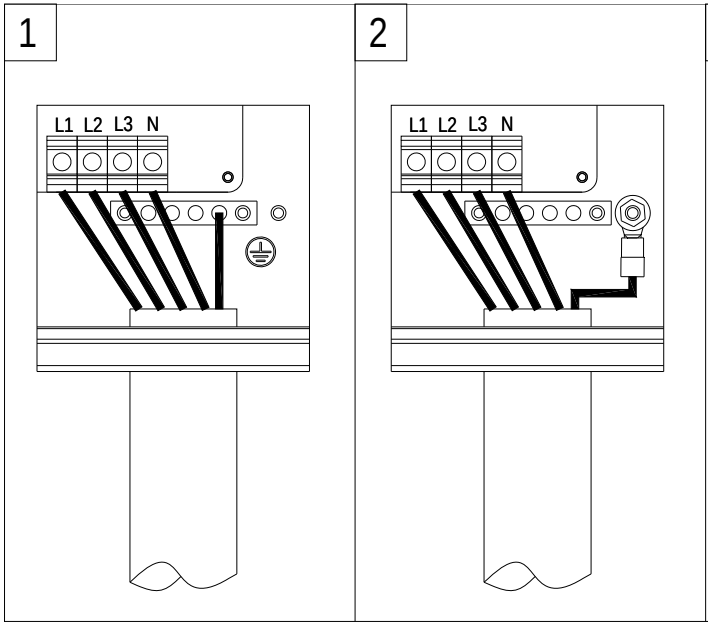




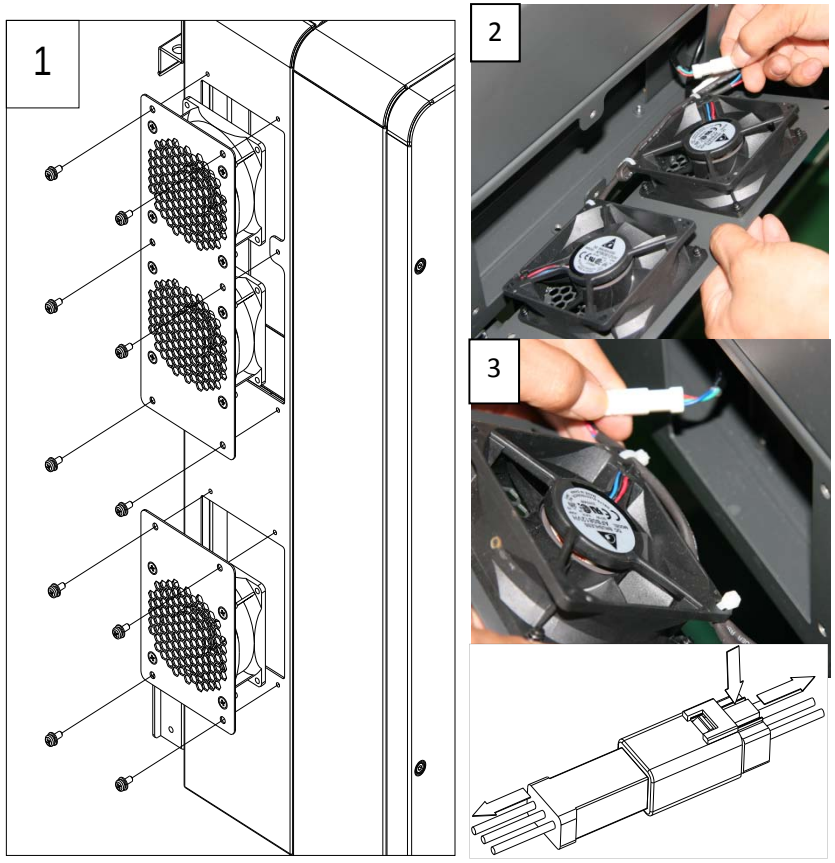
AC Wiring

- Prepare cable ends with ferrules

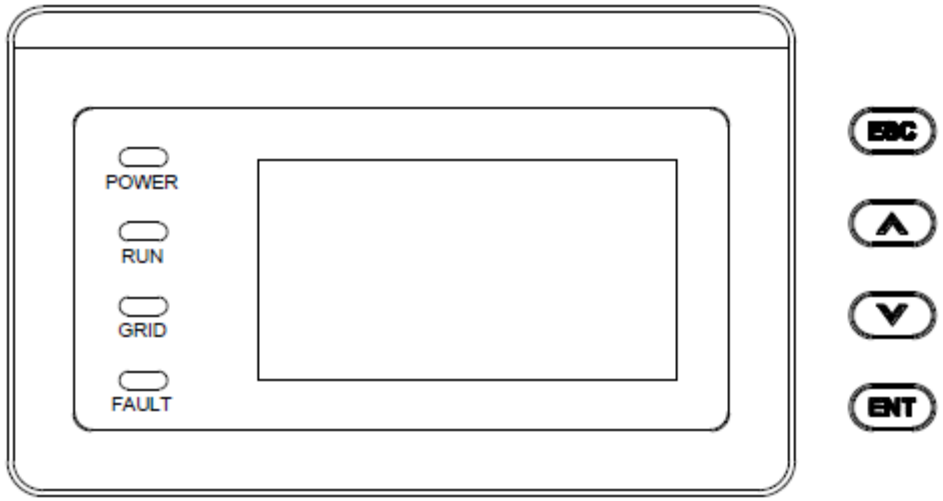




Fan Servicing



LED Trouble Shooting



LED fault status	Solutions
Neither the “Power” LED nor the LCD screen lights up.	1. Turn off the external AC breaker 2. Switch the DC switch to “OFF” position 3. Check the PV input voltage and polarity
The “GRID” LED is blinking.	1. Turn off the external AC breaker 2. Switch the DC switch to “OFF” position 3. Check whether the grid voltage is normal and whether the cable connection of AC side is correct and secure
The “RUN” LED lights off or “FAULT” LED lights up.	Call Solectria Renewable’s Customer Service

Engineered to Maximize Uptime

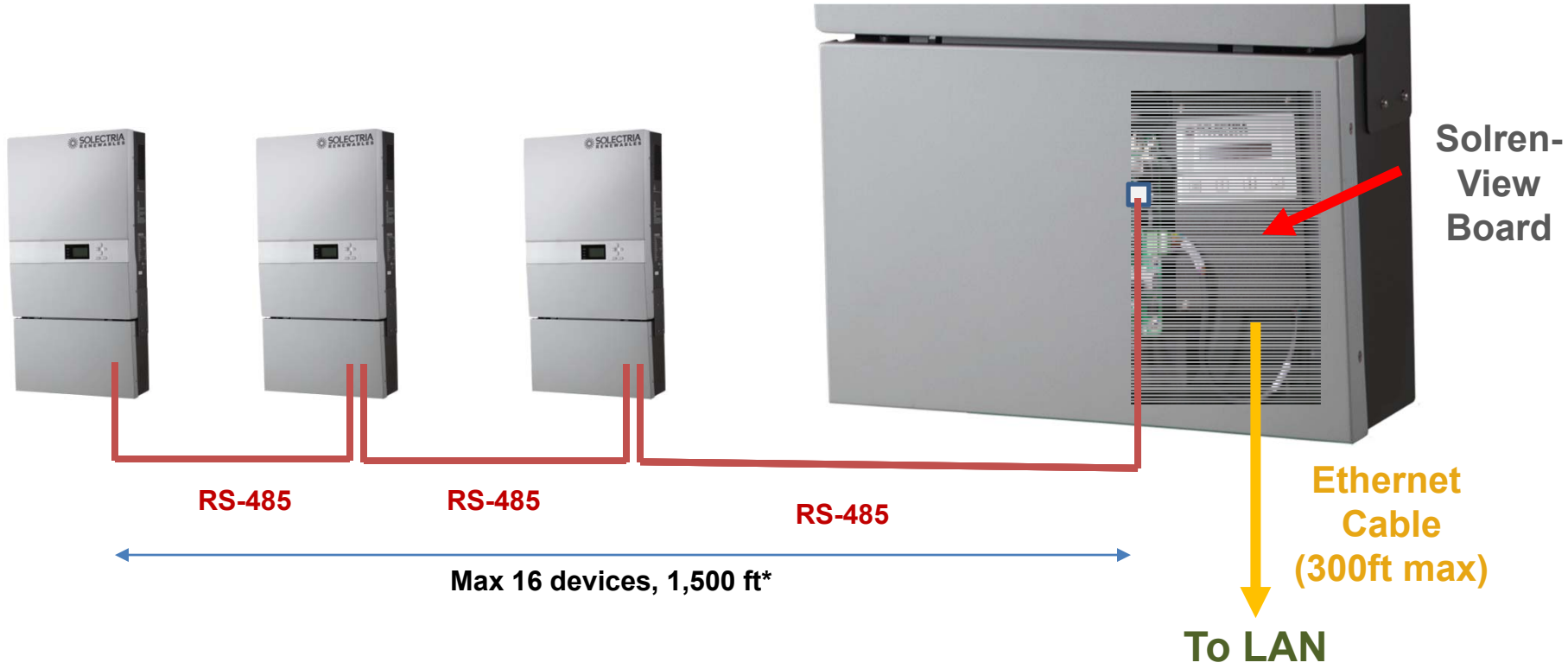
Choice of swapping entire inverter or only top section for service.

Replacement unit is provided for field swap of down unit.

Standard 10 year warranty (15 and 20 year options available)

Configuration 1: Daisy Chaining via Modbus RTU/RS-485

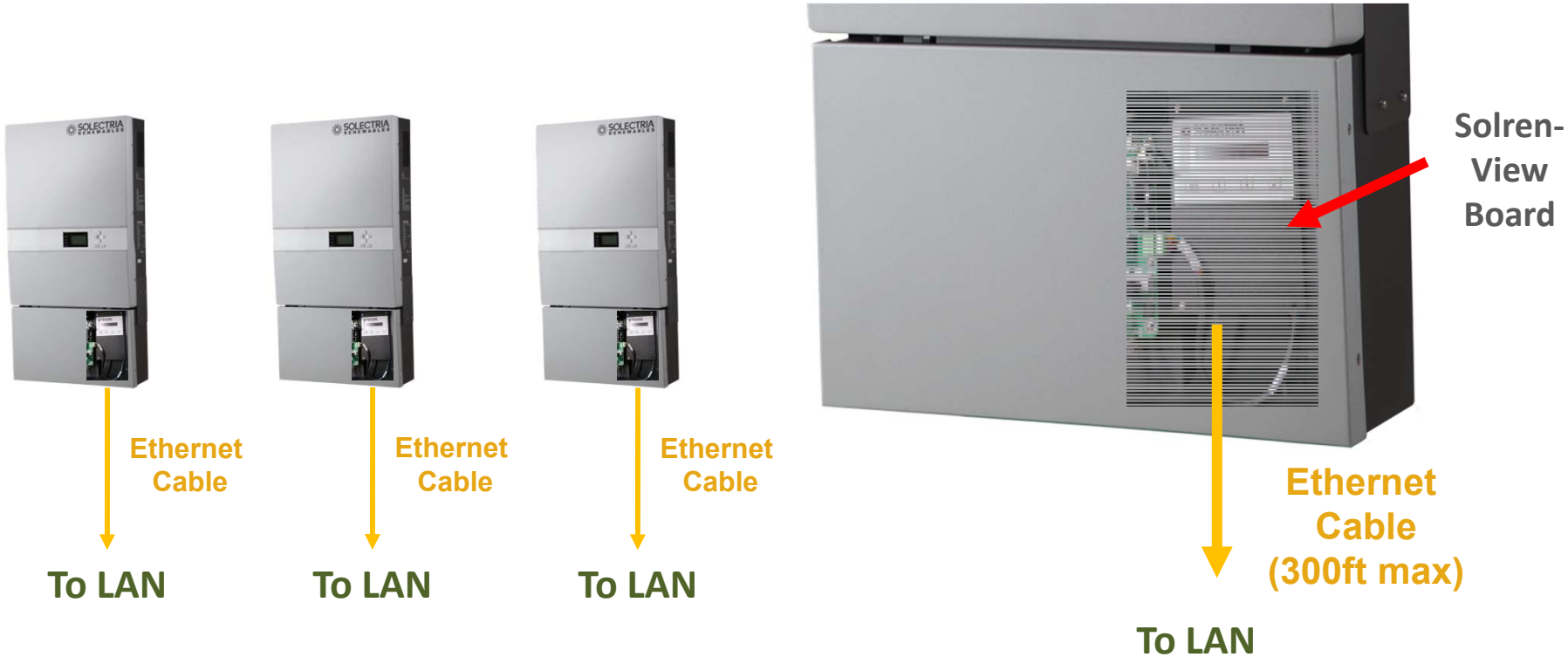
- Requires at least one PVI TL with SolrenView Board.
- All inverters are displayed on same SolrenView site



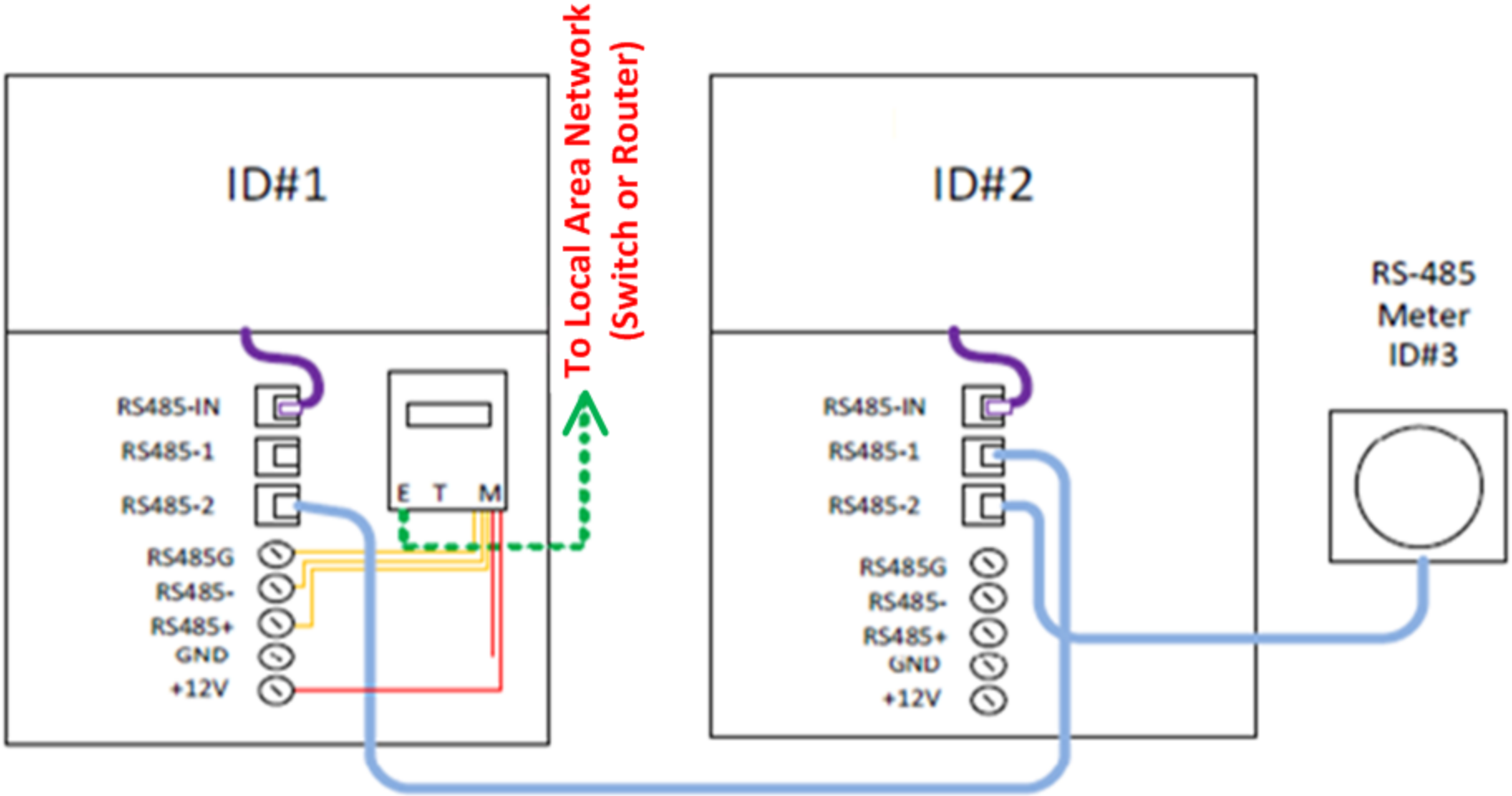
*Longer network length possible in low noise environment or with isolator/repeaters

Configuration 2: Ethernet Connection to Each Inverter

- Designer/Installer may choose to make direct Ethernet connection directly to each inverter
- Requires SolrenView board in each inverter
- All inverters are displayed on the same SolrenView Site

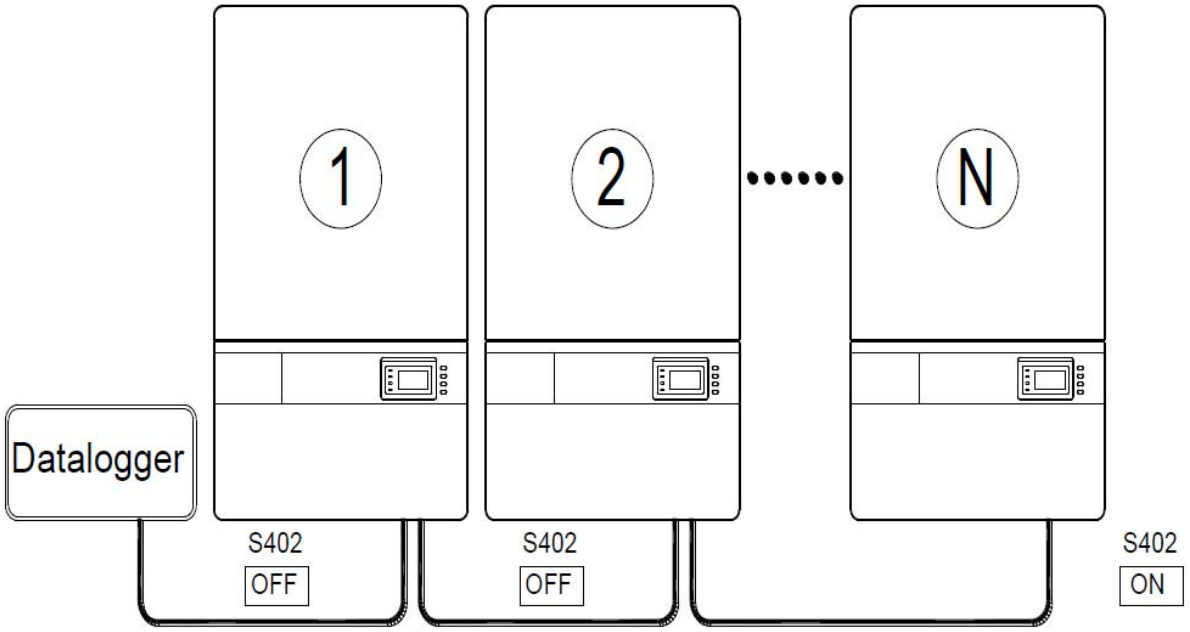


Example 2: Multiple Inverters w/ RGM



RS-485 Termination Resistor

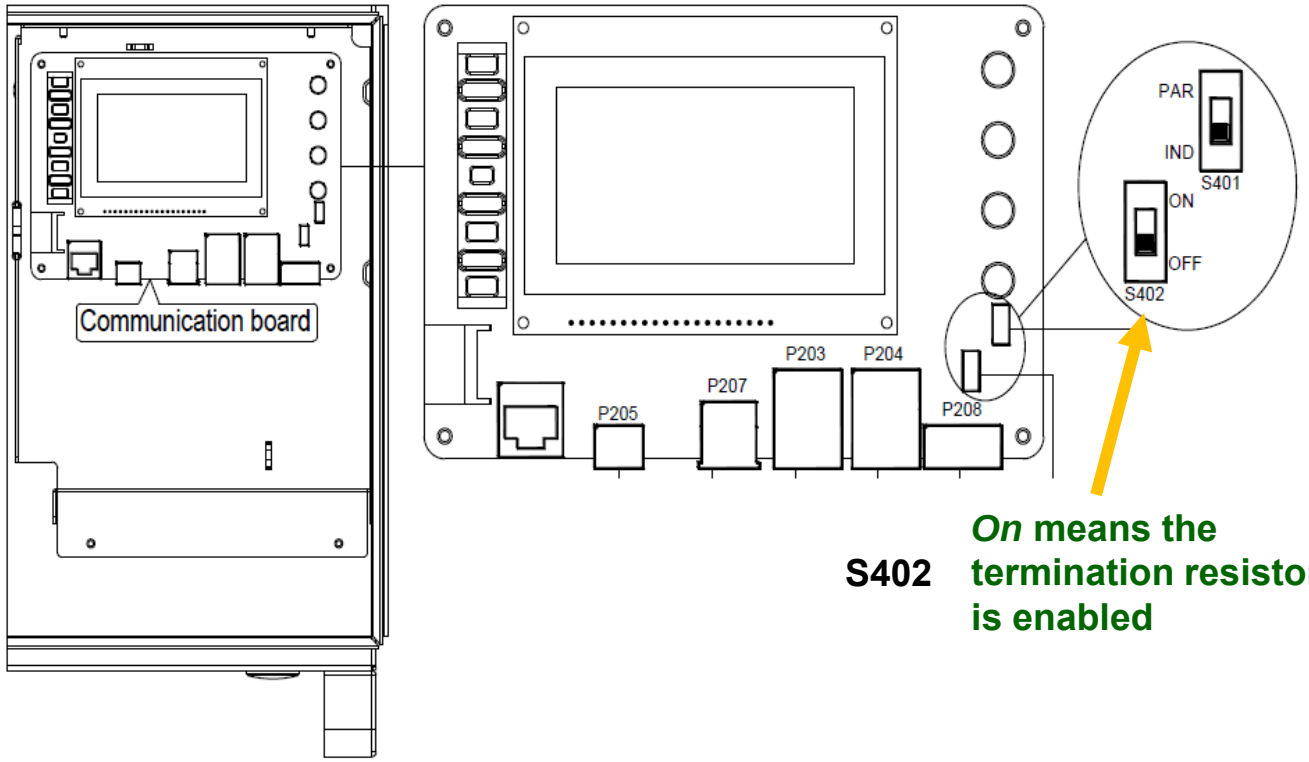
- **The inverter furthest away from the gateway needs its termination resistor set.**



- The termination resistor helps maintain data signal quality and prevents *Ghost Data*

RS-485 Termination Resistor

- **The inverter furthest away from the gateway needs the termination resistor enabled.**



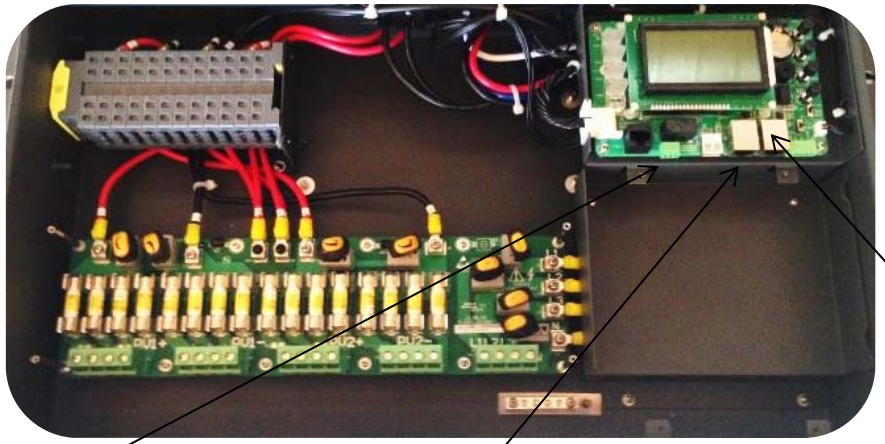
S402 ***On*** **means the termination resistor is enabled**

- The termination resistor helps maintain data signal quality and prevents *Ghost Data*

Third-Party Monitoring

- Utilizes the inverters standard RS-485 ports
- No SolrenView Board required
- Compatible with Third-Party Monitoring Software that utilizes Modbus RTU/RS-485
- Register Map Available

Inverter Wiring Box



Internal comm. connection

RS485-1

To third-party data logger/gateway card (or next inverter in daisy chain)

RS485-2

Open or to previous inverter in daisy chain

PVI 50-100KW

Competitive Comparison Chart – 50-85kW

SOLECTRIA A YASKAWA COMPANY

	SOLECTRIA RENEWABLES	SOLECTRIA RENEWABLES	ADVANCED ENERGY	Fronius	Fronius	SOLECTRIA RENEWABLES	SOLECTRIA RENEWABLES	ADVANCED ENERGY
Model	**PVI 50KW**	**PVI 60KW**	**AE 50TX (PVP 50)**	**Fronius CL 55.5 Delta**	**Fronius CL 60.0**	**PVI 75KW/75KW-PE**	**PVI 85KW/85KW-PE**	**AE 75TX (PVP 75)**
Electrical								
MPP tracking range	300-500	300-500	295-595	230-500	230-500	300-500	300-500	295-595
Low voltage MPP range	285-500	285-500	n/a	n/a	n/a	285-500	285-500	n/a
Available grid voltages	208, 240, 480, 600	208, 240, 480, 600	208, 480, 600	208, 240	277	208, 240, 480, 600	208, 240, 480, 600	208, 480, 600
Number of DC inputs	8	8	5	0	0	8	8	9
Transformer Isolation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Delta/Wye Compatible	Yes	Yes	No	Yes	Yes	Yes	Yes	No
Nighttime tare loss (W)	0.49-2.85W (depends on VAC)	0.49-2.85W (depends on VAC)	33W	11.6W	12.2W	0.49-2.85W (depends on VAC)	0.49-2.85W (depends on VAC)	42W
CEC Efficiency	96.0% (208) 96.0% (480)	96.0% (208) 96.0% (480)	96.0% (208) 96.0% (480)	94.5% (208) 95.0% (240)	95.5%	96.0% (208/240); 96.5% (208 PE) 97.0% (480/600); 97.5% (480 PE)	96.0% (208/240); 96.5% (208 PE) 96.5% (480/600); 97.0% (480 PE)	95.5% (208) 95.5% (480)
Mechanical								
Dimensions (HxWxD - inches)	76 x 54 x 29.25	76 x 54 x 29.25	73.5 x 48.75 x 34.5	76.6 x 43.5 x 31.4	76.6 x 43.5 x 31.4	76 x 54 x 29.25	76 x 54 x 29.25	91.5 x 60 x 35
Weight (lbs)	1545	1545	1600	783	783	1765	1765	2750
Enclosure rating	NEMA 3R	NEMA 3R	NEMA 4	NEMA 3R	NEMA 3R	NEMA 3R	NEMA 3R	NEMA 4
Cooling method	Fan	Fan	Fan	Fan	Fan	Fan	Fan	Fan
Temp range full power	-40°F to 122°F	-40°F to 122°F	-22°F to 122°F	-13°F to 122°F	-13°F to 122°F	-40°F to 122°F	-40°F to 122°F	-22°F to 122°F
AC/DC Disconnects	External	External	External	Internal	Internal	External	External	External
Communications								
Standard communication	RS-485	RS-485	RS-485	RS-485	Yes	RS-485	RS-485	RS-485
Ethernet port hardware	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cellular option, installed	Yes	Yes	No	No	No	Yes	Yes	No
Integrated Subarray monitoring optional	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Certifications								
UL1741 / IEEE1547	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CSA 22.2 #107.1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
FCC Part 15 Class A	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Additional								
Subcombiner options	Yes (fuses or breakers)	Yes (fuses or breakers)	Fuses only	Fuses only	Fuses only	Yes (fuses or breakers)	Yes (fuses or breakers)	Fuses only
Stainless enclosure option	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Third party compatibility	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Competitive Comparison Chart – 100kW

SOLECTRIA A YASKAWA COMPANY

	SOLECTRIA RENEWABLES	power-one	ADVANCED ENERGY	KACO	Schneider Electric	SUNGROW
Model	**PVI 100KW/100KW-PE**	**PVI-CENTRAL-100**	**AE 100TX (PVP 100)**	**XP-100-U**	**GT100**	**SG100KU/KC**
Electrical						
MPP tracking range	300-500	330-600	295-595	300-600	300-480	300-600
Low voltage MPP range	285-500	n/a	n/a	n/a	n/a	n/a
Available grid voltages	208, 240, 480, 600	208, 480	208,480,600	208, 480	208, 480	480
Number of DC inputs	8	6	9	4	4	4
Transformer Isolation	Yes	Yes	Yes	Yes	Yes	Yes
Delta/Wye Compatible	Yes	Yes	No	No	No	Yes
Nighttime tare loss (W)	0.49-2.85W (depends on VAC)	<30W	42W	<60.4W	<100W	<30W
CEC Efficiency	96.0% (208/240); 96.5% (208 PE) 96.5% (480/600); 97.0% (480 PE)	95.0% (208) 95.0% (480)	95.5% (208) 96.0% (480)	N/A 96.0% (480)	95.0% (208) 96.0% (480)	N/A 96.5% (480)
Mechanical						
Dimensions (HxWxD - inches)	76 x 54 x 29.25	50 x 66 x 33.5	91.5 x 60 x 35	73 x 68 x 37	73.3 x 67 x 46.1	77 x 40 x 30
Weight (lbs)	1765	1873	3000	2425	3000	1984
Enclosure rating	NEMA 3R	NEMA 1	NEMA 4	NEMA 3R	NEMA 3R	NEMA 3R
Cooling method	Fan	Fan	Fan	Fan	Fan	Fan
Temp range full power	-40°F to 122°F	14°F to 122°F	-22°F to 122°F	-5°F to 122°F	-5°F to 122°F	-13°F to 131°F
AC/DC Disconnects	External	Internal	External	Internal	Internal	Internal
Communications						
Standard communication	RS-485	RS-485 (2)	RS-485	RS-232, RS-485 Ethernet	RS-232, RS-485 Ethernet	RS-485 Ethernet
Ethernet port hardware	Yes	No	Yes	Yes	Yes	Yes
Cellular option, installed	Yes	Yes	No	No	No	data not available
Integrated Subarray monitoring optional	Yes	No	Yes	No	Yes	data not available
Certifications						
UL1741 / IEEE1547	Yes	Yes	Yes	Yes	Yes	Yes
CSA 22.2 #107.1	Yes	Yes	Yes	Yes	Yes	Yes
FCC Part 15 Class A	Yes	Data not available	Yes	Yes	Yes	No
Additional						
Subcombiner options	Yes (fused or breakers)	Fuses only	Fuses only	Fuses only	Fuses only	data not available
Stainless enclosure option	Yes	No	Yes	Yes	No	data not available
Third party compatibility	Yes	Yes	Yes	Yes	Yes	Yes

PVI 50-100KW interior explained

PVI 50-100KW Integrated Inverter

SOLECTRIA
A YASKAWA COMPANY

AC DISCONNECT (NEMA3R)

LED INDICATORS

LCD DISPLAY/ SOLRENVIEW GATEWAY

RAINPROOF MAIN ENCLOSURE

INSIDE:
TRANSFORMER, FILTERS, OFF-LINING CONTACTOR

LIFTING EYES

DC DISCONNECT (NEMA3R)

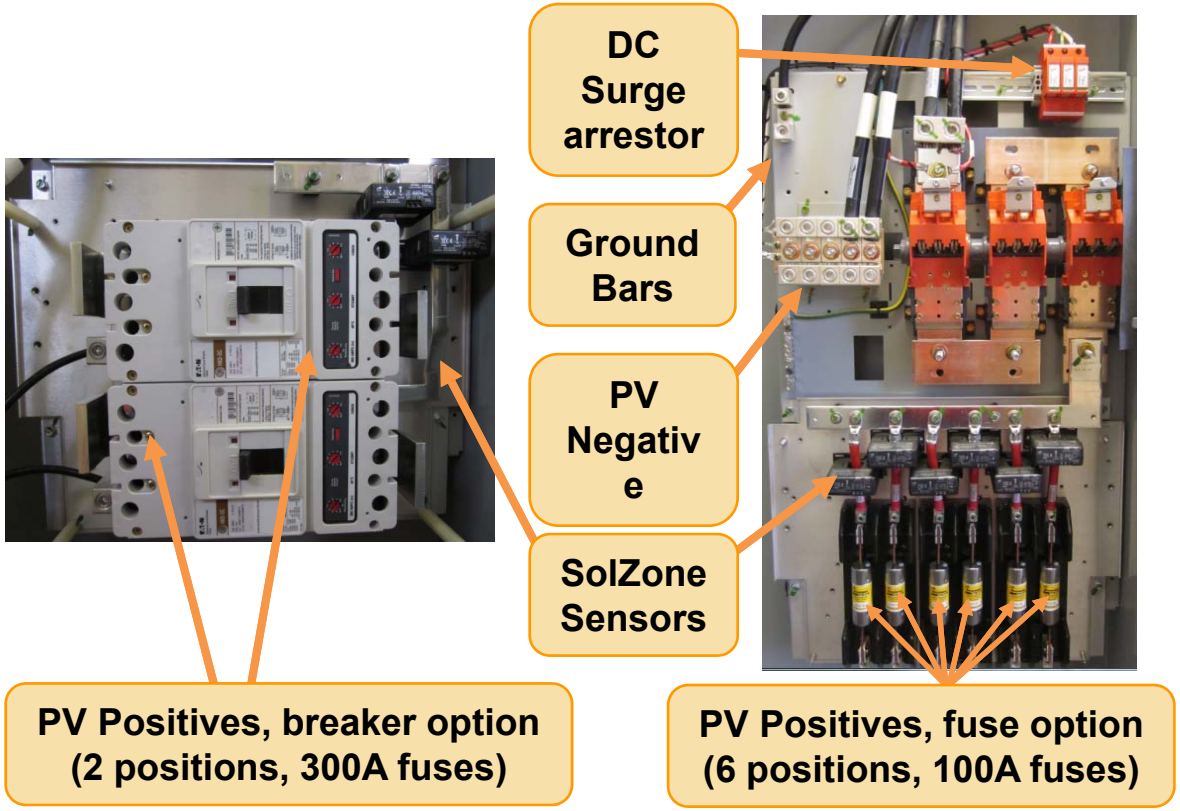
MOUNTING FEET

Forward Facing Disconnects

PVI 50-100KW Electrical Connections & Subcombiner Options

NOTES:

- Do not bond PV negative outside of the inverter
- Do not switch the negative array conductor



AC Disconnect Connection

- Connection dedicated AC overcurrent protection device to inverter AC disconnect
- AC Fusing optional

SGI 225-500PE

Reliable & High Efficiency Design

- Sealed electronics enclosure
- Full power testing
  - 4-12 hours at 100%+
  - “burned in” before leaving factory
- Over 20 years experience
- Premium efficiency transformer and filters
- Low loss IGBTs
- Lowest night-time losses
- Thermostat controlled automatic blower
- 97.5% CEC efficient SMARTGRID inverters
  - Highest CEC tranformer-based inverter in the industry!

SGI 225-300 vs. competition

SOLECTRIA A YASKAWA COMPANY

	SOLECTRIA RENEWABLES	ADVANCED ENERGY	Satcon	SMA	power-one
Model	**SGI 225, 250, 266, 300**	**Solaron 333 (TRANSFORMERLESS)**	**PowerGate 375**	**Sunny Central 250**	**PVI Central 300**
Electrical					
MPP tracking range	300-600	330-600	320-600	330-600	320-600
Low voltage MPP range	285-600	n/a	n/a	n/a	n/a
Start up voltage	380	425	320	380	320
Available grid voltages	480 / 600	480	208 / 480	480	480
Number of DC inputs	6-24	4	15-24	4-6	5
Redundant cores	Yes	No	No	No	Yes
Transformer Isolation	Yes	No	Yes	Yes	Yes
Nighttime tare loss (W)	28	60.0	123	79.0	90
CEC Efficiency	97.5	97.5	95.5	97.0	97.0
Mechanical					
Dimensions (HxWxD)	109 x 79 x 37	81 x 74 x 35	155 x 93 x 39	110 x 80 x 33	116 x 76 x 49
Footprint	109 x 36	81 x 35	155 x 39	110 x 33	116 x 49
One piece	Yes	Yes	No	No	Yes
Weight	5650	2045	5800	4189	5750
Enclosure rating	NEMA 3R	NEMA 3R	NEMA 3R	NEMA 3R	NEMA 3R
Cooling method	Blower	Blower	Blower	Blower	Blower
Temp range full power	-40 to +50	-20 to +50	-20 to +50	-25 to +45	-25 to +50
Disconnects	AC & DC	No	AC & DC	Optional	DC only
Communications					
Standard communication	RS-485	RS-485	RS-485	RS-485	RS-485
Ethernet port hardware	Yes	Yes	Yes	Option	Yes
Cellular option, installed	Yes	Yes	No	Yes	Yes
Subarray monitoring optional	Yes	No	Yes	No	No
Mechanical					
UL1741 / IEEE1547	Yes	Yes	Yes	Yes	Yes
CSA 22.2 #107.1	Yes	Yes	Yes	No	Yes
FCC Part 15 Class A	Yes	No (Exempt from FCC requirements per 47 CFR 15.103(b))	Yes	Yes	Yes

SGI 225-300 vs. competition cont.

	SOLECTRIA RENEWABLES	ADVANCED ENERGY	Satcon	SMA	power-one
Model	**SGI 225, 250, 266, 300**	**Solaron 333 (TRANSFORMERLESS)**	**PowerGate 375**	**Sunny Central 250**	**PVI Central 300**
Additional					
Subcombiner options	Yes	No	Yes	4-6	6
Revenue grade meter option	Yes	Yes	Yes	No	Yes
Stainless enclosure option	Yes	Yes	No	No	No
Install/wiring labor	Minimum	Average	Maximum	Maximum	Average
Third party compatibility	Yes	Yes	Yes	Yes	Yes
GFDI breaker	Breaker	Fused	Fused	Breaker	Fused
AC OCPD	Breaker	Fused	Breaker	Breaker	Fused
Contactors (AC & DC)	Yes	Yes	Yes	Disconnect optional	AC contactor
Uptime Guarantee Option	Yes	Yes	Yes	No	No

SGI 500 vs. competition

SOLECTRIA A YASKAWA COMPANY

Model	SOLECTRIA RENEWABLES SGI 500	SOLECTRIA RENEWABLES SGI 500XT (EXTERNAL TRANSFORMER)	ADVANCED ENERGY AE 500TX	ADVANCED ENERGY AE 500NX-HE (TRANSFORMERLESS)	SMA Sunny Central 500
Electrical					
MPP tracking range	300-600 VDC	300-500 VDC	310-595 VDC	330-600 VDC	330-600 VDC
Start up voltage	380 VDC		330 VDC	425 VDC	380 VDC
Available grid voltages	480, 600 VAC	208 VAC	480 VAC	480 VAC	480 VAC
Number of DC inputs	8-32	8-32	20	2 x 10	6-9
Redundant Power Stages	Yes	Yes	No	No	No
Transformer Isolation	Yes	Yes	Yes	No	Yes
Nighttime tare loss	32 W	41 W	< 80 W	< 100 W	80 W
Susceptibility to unbalanced array voltages	No	No	No	Yes	No
Compatible with Delta or Wye Transformer	Yes	Yes	No	No	Yes
Simplicity-fewer points of failure	Yes	Yes	No	No	No
Standard IGBT's	Yes	Yes	Yes	No	Yes
Can be substituted into existing PV plant design	Yes	Yes	Yes	No	Yes
DC contactor in array needed	No	No	No	Yes	No
GFDI breaker	Yes	Yes	Yes	No	Yes
Built-in AC OCPD	Breaker	Breaker	None	None	None
Built-in DC OCPD	Fuses or Breaker	Fuses or Breaker	Breakers only	Fuses only	Fuses only
CEC Efficiency	97.5%	98.0%	97.0%	98.0%	97.0%
Mechanical					
Dimensions (H x W x D)	79 x 109 x 37 in.	82 x 109 x 41 in.	99 x 120 x 49 in.	83 x 128 x 38 in.	80 x 140 x 37 in.
One piece	Yes	Yes	Yes	Yes	No
Weight	6980 lbs.	3410 lbs.	8750 lbs.	4100 lbs.	7165 lbs.
Enclosure rating	Type 3R	Type 3R	Type 4	Type 3R	Type 3R
Cooling method	Blower	Blower	Blower	Liquid	Blower
Redundant cooling system	Yes	Yes	Yes	No	No
Temp range full power	-40°F to +122°F	-40°F to +122°F	-22°F to +122°F	-4°F to +122°F	-13°F to +113°F
Disconnects	AC/DC standard	AC/DC standard	AC/DC standard	Optional	Optional

SGI 500 vs. competition cont.

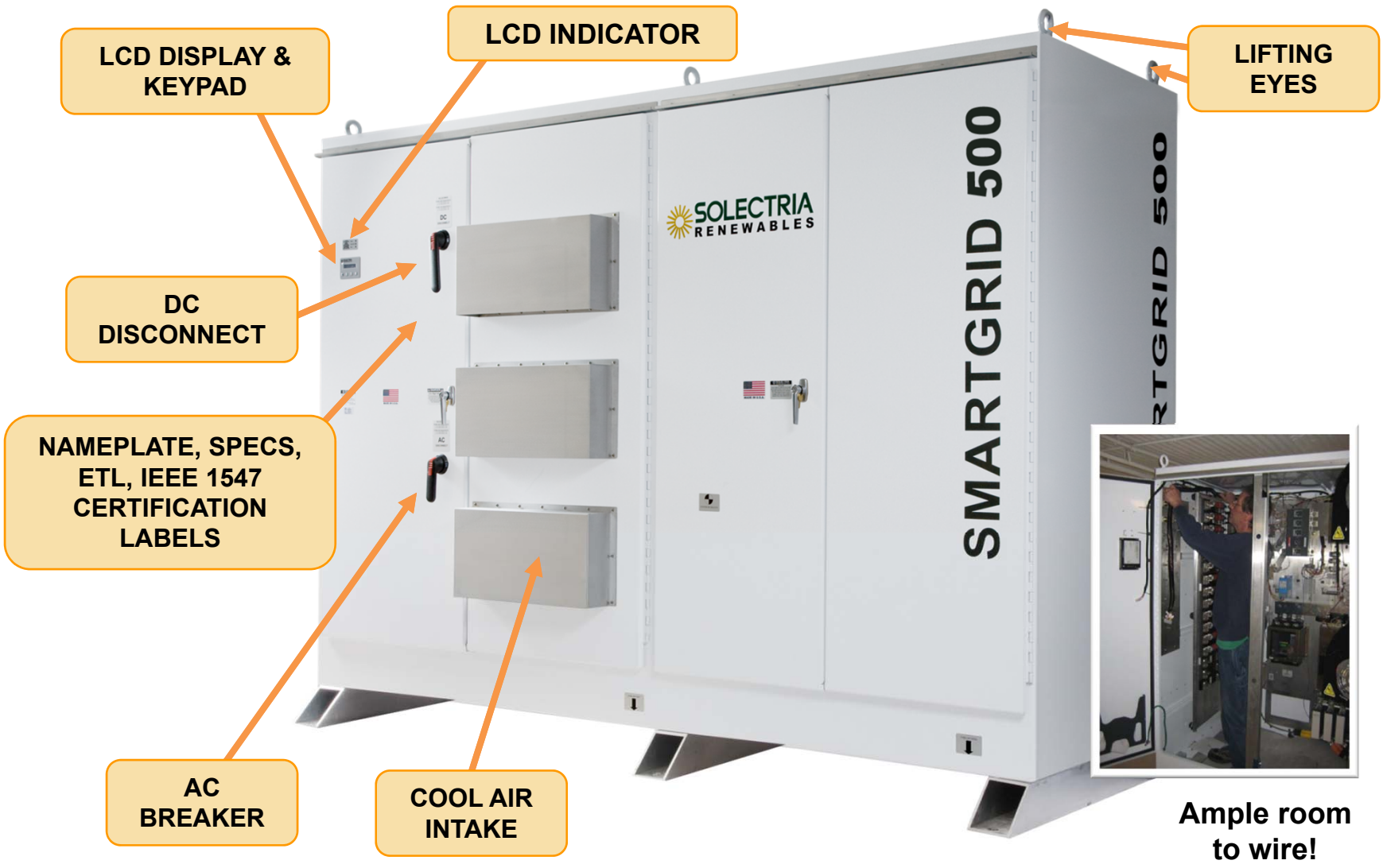
Model	SGI 500	SGI 500XT (EXTERNAL TRANSFORMER)	AE 500TX	AE 500NX-HE (TRANSFORMERLESS)	Sunny Central 500
Communications					
Third party compatibility	Yes	Yes	Yes	Yes	Yes
Standard communication	RS-485	RS-485	RS-485	RS-485	RS-485
Ethernet port hardware	Yes	Yes	Yes	Yes	Yes
Cellular option, installed	Yes	Yes	Yes (If purchased with SEEDs monitoring equipment)	Yes (If purchased with SEEDs monitoring equipment)	Yes
Subarray monitoring optional	Yes	Yes	Yes	Yes	No
Compliance					
UL1741 / IEEE1547	Yes	Yes	Yes	Yes	Yes
CSA 22.2 #107.1	Yes	Yes	Yes	Yes	Yes
Additional					
Subcombiner options	Yes	Yes	Yes	Yes	Yes
Revenue grade meter option	Yes	Yes	Yes	Yes	Yes
Stainless enclosure option	Yes	Yes	No (Exempt from FCC requirements per 47 CFR 15.103(b))	No (Exempt from FCC requirements per 47 CFR 15.103(b))	No
Install/wiring labor	Yes		Yes	Yes	Yes

SGI Inverter Models and Efficiency Chart

Inverter Model	Peak Efficiency	CEC Efficiency
SGI 225 – 480VAC	98.0%	97.5%
SGI 250 – 480VAC	98.0%	97.5%
SGI 266 – 480VAC	98.0%	97.5%
SGI 300 – 480VAC	97.9%	97.5%
SGI 500 – 480VAC	97.9%	97.0%
SGI 500PE – 480VAC	98.3%	97.5%

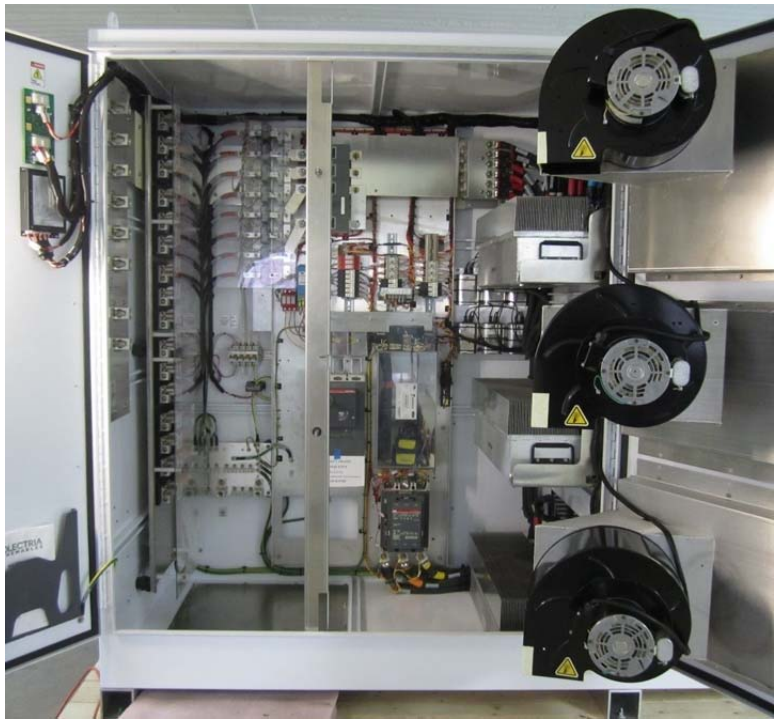
SGI 225/250/266/300/500

SOLECTRIA
A YASKAWA COMPANY



Ample room to wire!

SGI Inverter Components



- Redundant cores – contains all electronics
- Transformer / Magnetics Enclosure
- Premium-efficient components
- Web-based Monitoring (SolZone & Agency Reporting options)

Redundant/Modular Inverter Core

- DMGI 960 cores
- Redundant/module cores:
  - 2 inverter cores
    - SGI 225/250/266/300
  - 3 inverter cores
    - SGI 500
- Tested (“burnt in”) at factory before shipping
  - Tested at above nameplate capacity
- Run paralleled input & output, ramping up power as c

competition which maxes 1 out

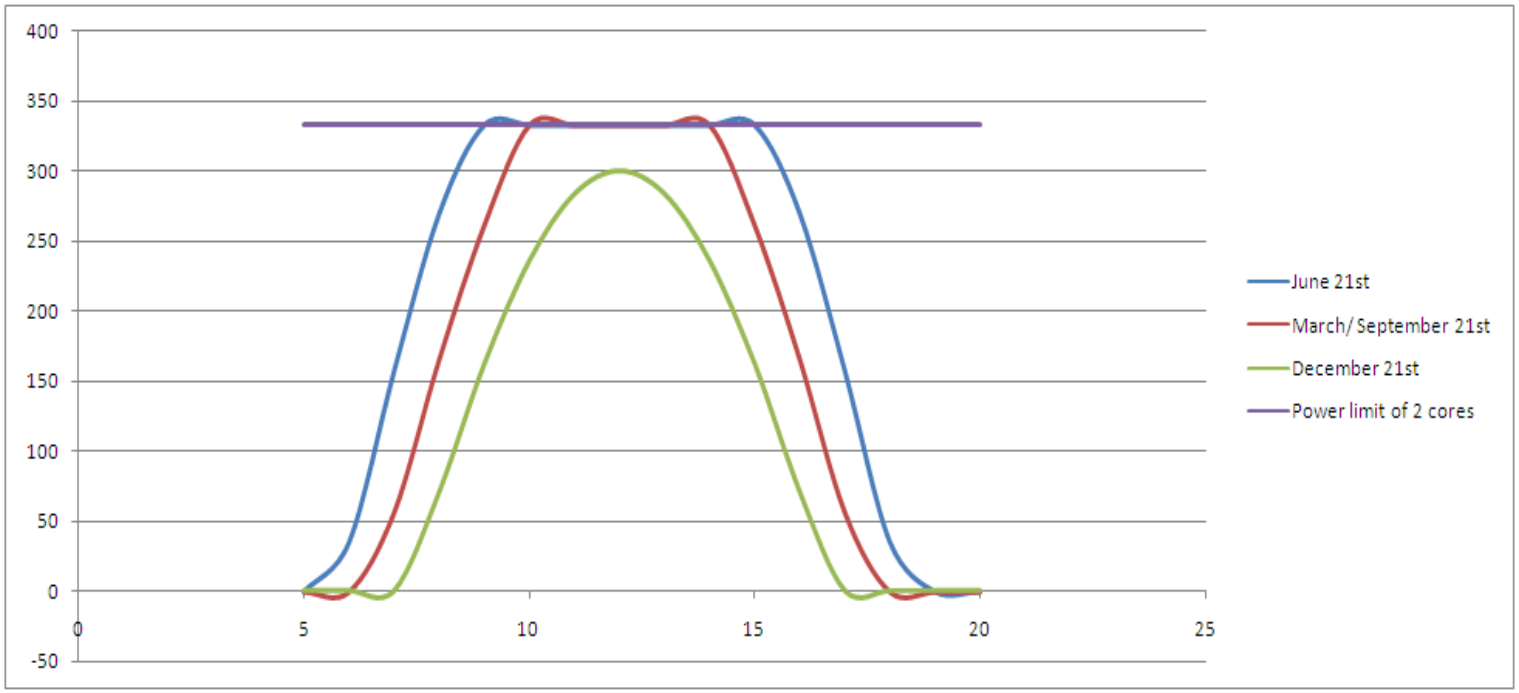
Smart Inverter

SOLECTRIA
A YASKAWA COMPANY

Features: (sites >10MW)

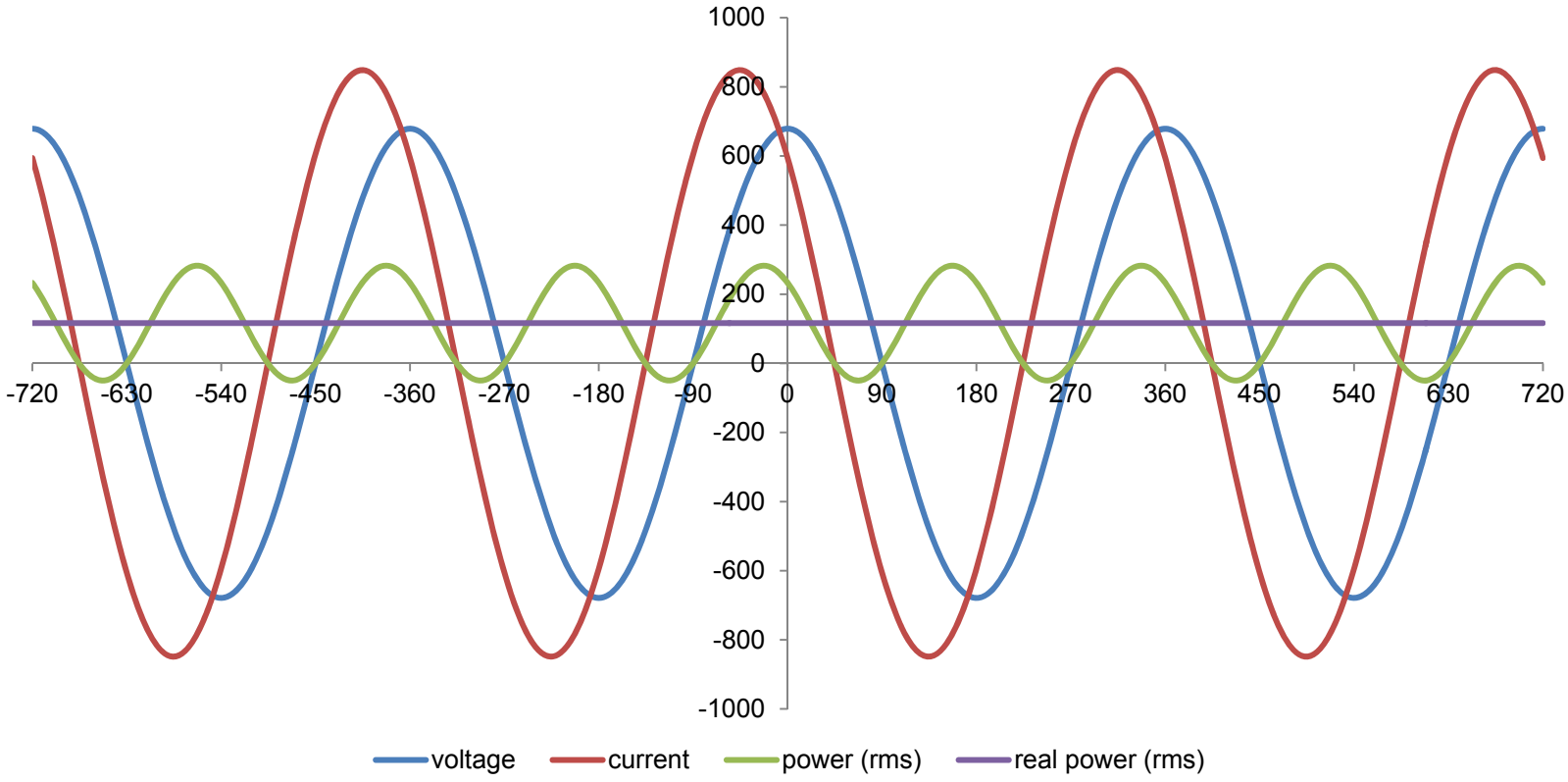
- VAR support (Power factor control, AC voltage control, VAR control mode)
- Low voltage ride-through (LVRT)
- Frequency ride-through
- Power curtailment
- Reactive power control
- Controlled ramp rate

SGI will function with a core down



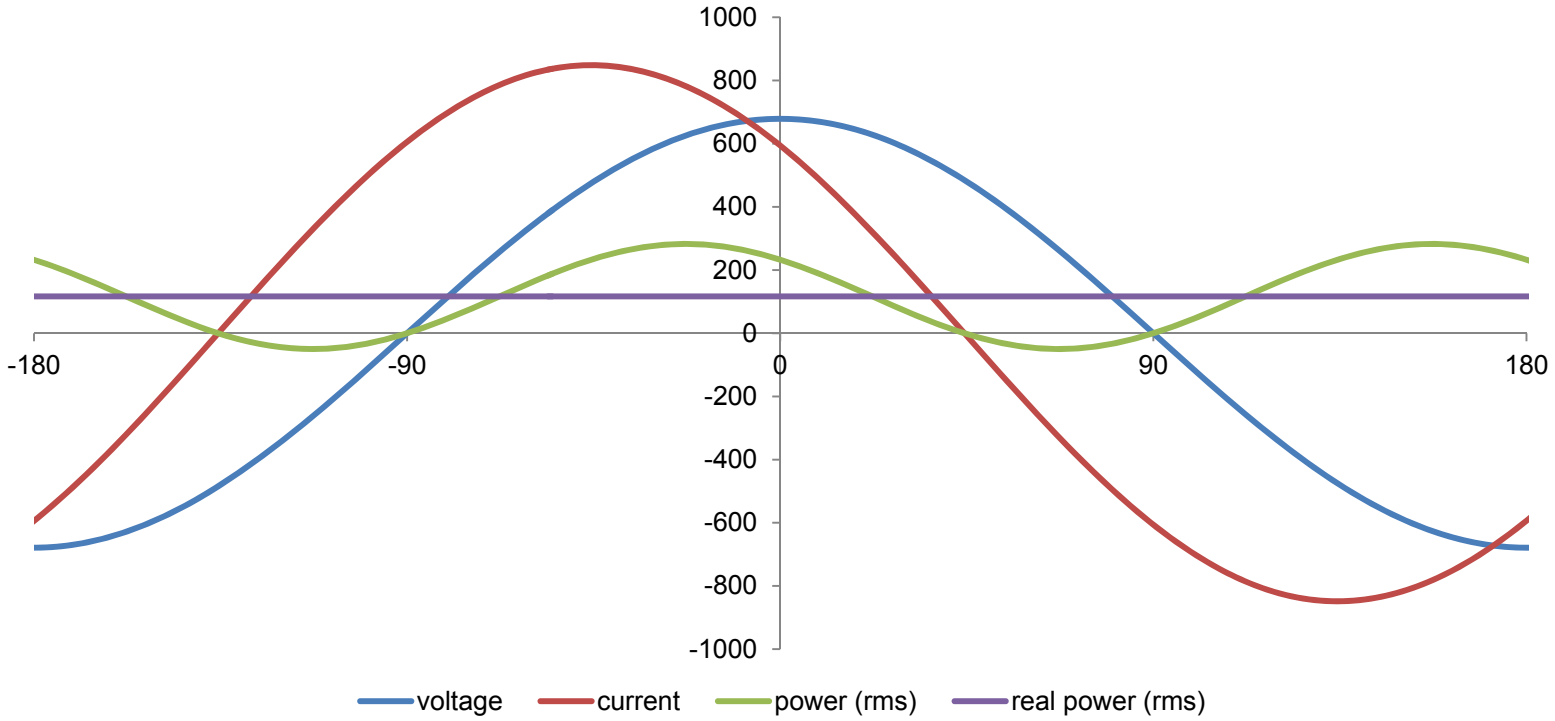
In the wintertime, 2 cores are sufficient to convert 100% of the available power

VAR support (remote utility option)



- PPA owned (“in front of the fence”)
  - UL1741 enforces a PF > 0.95

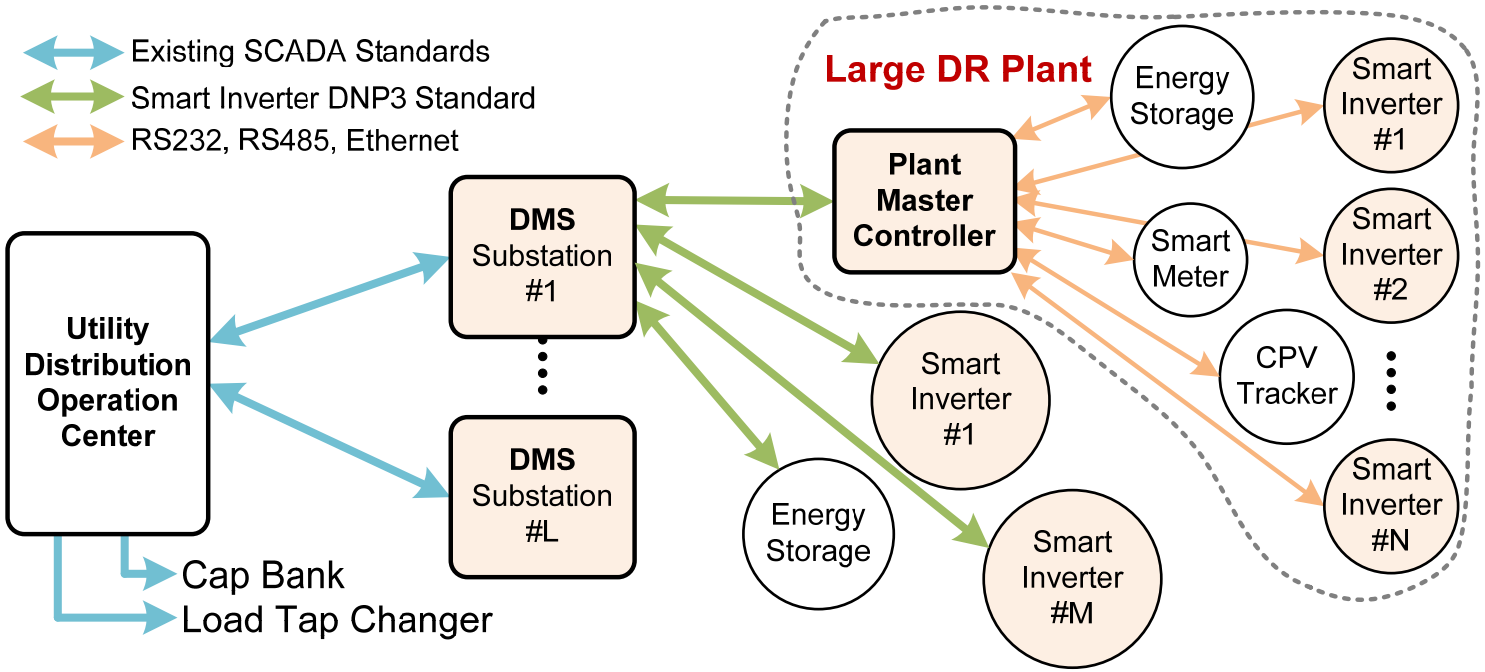
Leading or lagging power factor



- Utility owned (“behind the fence”)
  - IEEE 1547.4 enables VAR support on systems > 250kW
- VARs absorbed by the inverter, in order to adjust power factor on secondary side of distribution transformer

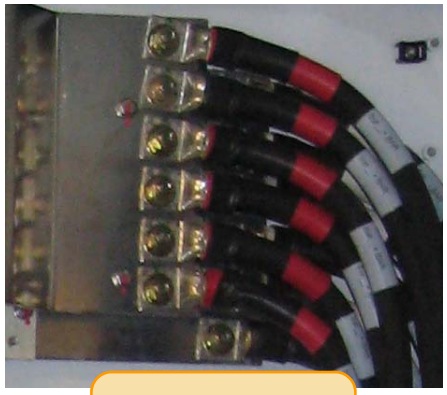
Power System Engineering Services

Plant master controller (SCADA)

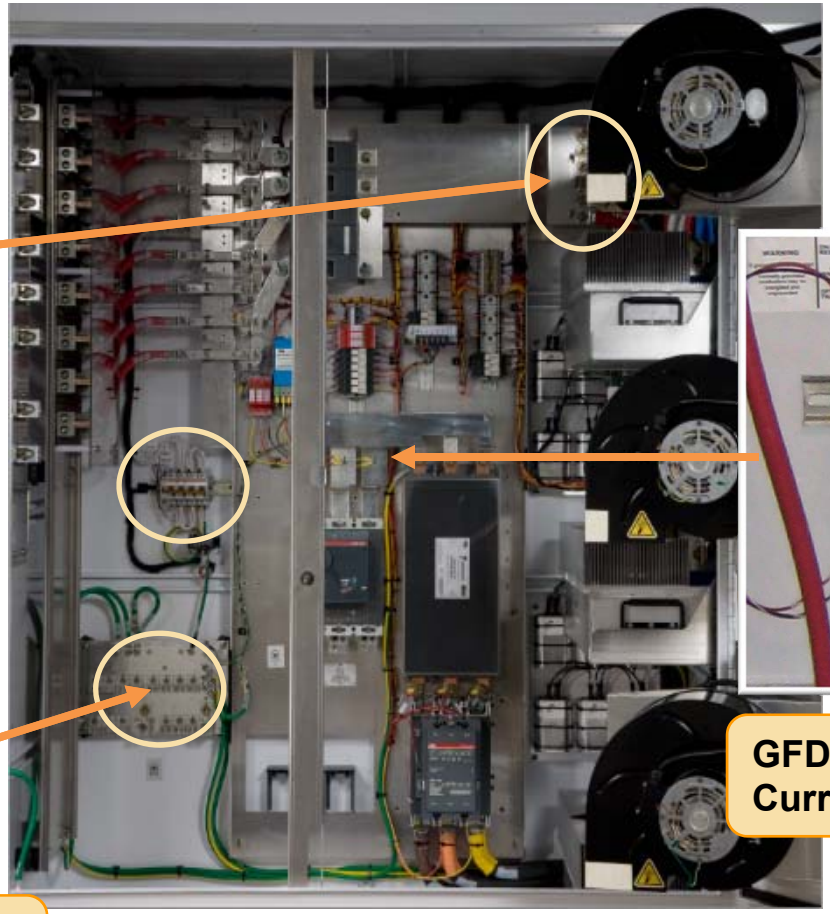


Plant testing / Certification

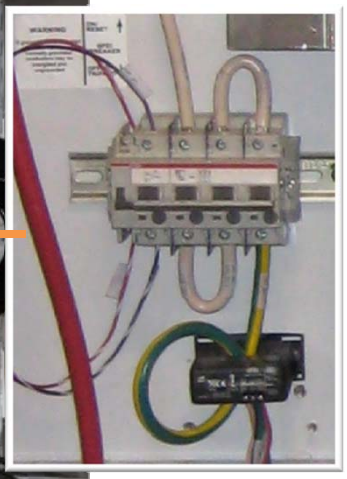
SGI Advanced DC Features



DC bus bar structure

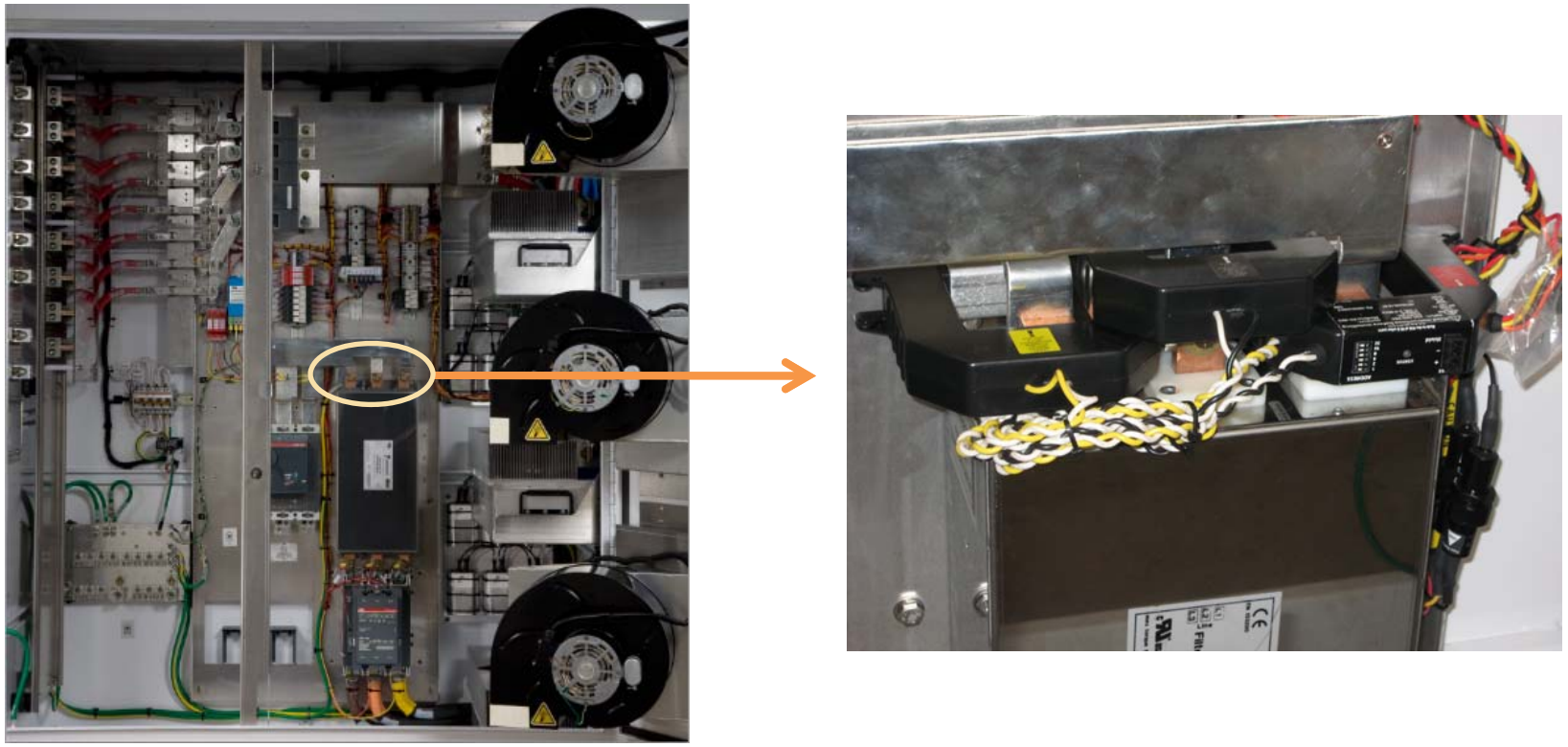


Large AC and DC ground bar for EGCs and GEC



GFDI Breaker and Current reporting

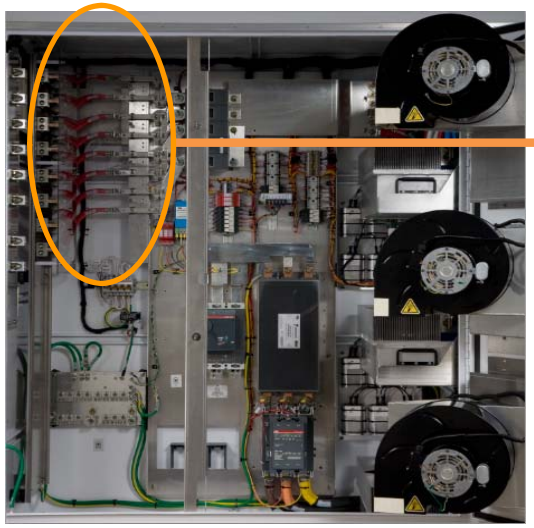
Revenue grade meter (option)



Only one wire connection is to be made for agency reporting (Ethernet)

SGI 225/250/266/300/500 Subcombiners & CT's

Inside (left side)



Current Transducers (CT's)

8 Breaker Option (7, 400A; 1, 350A)

16 Fuse Option (4, 150A; 4, 125A; 8, 175A)

SGI DC Disconnect Connection

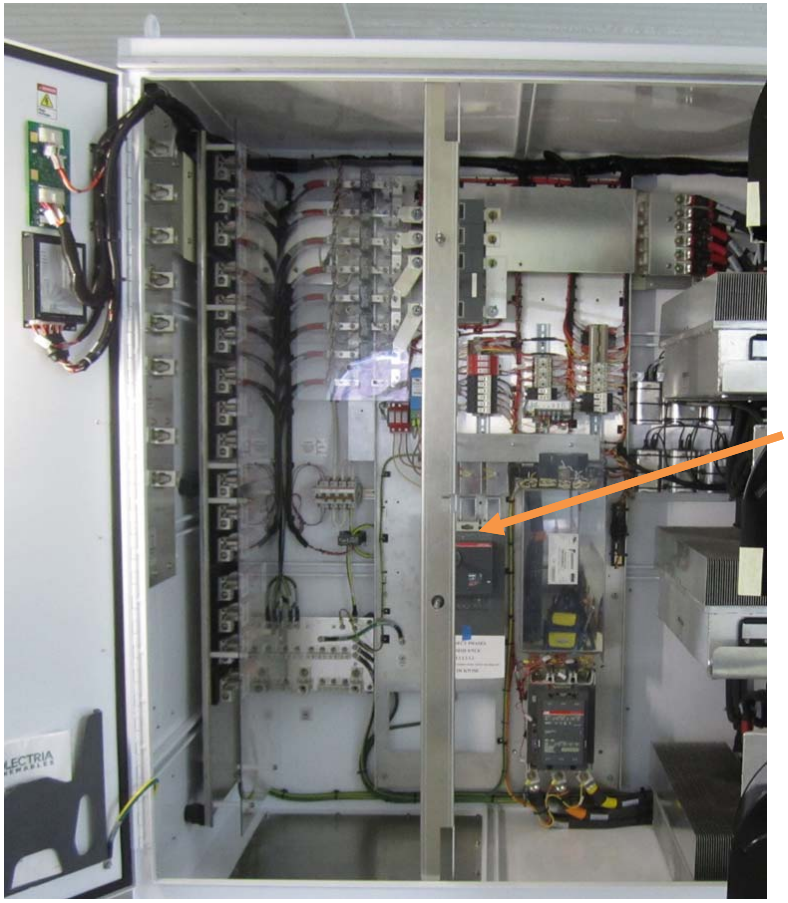
SGI 225/250/266/300	Positions	Fuse Range
Fuses	6	225 A, 250 A, 300 A, 350 A, 400 A
	12	110 A, 125 A, 150 A, 175 A, 200 A
	24	70 A, 80 A, 90 A, 100 A
Breakers	6	225 A, 250 A, 300 A, 350 A, 400 A
	12	110 A, 125 A, 150 A, 175 A, 200 A
SGI 500/500PE/500XT		
Fuses	8	225 A, 250 A, 300 A, 350 A, 400 A
	16	110 A, 125 A, 150 A, 175 A, 200 A
	32	70 A, 80 A, 90 A, 100 A
Breakers	8	225 A, 250 A, 300 A, 350 A, 400 A
	16	110 A, 125 A, 150 A, 175 A, 200 A

Current Transducers (CT's)

8 Breaker Option (7, 400A; 1, 350A)

16 Fuse Option (4, 150A; 4, 125A; 8, 175A)

AC Disconnect Connection



AC BREAKER OPTIONS

SGI Advanced AC Features

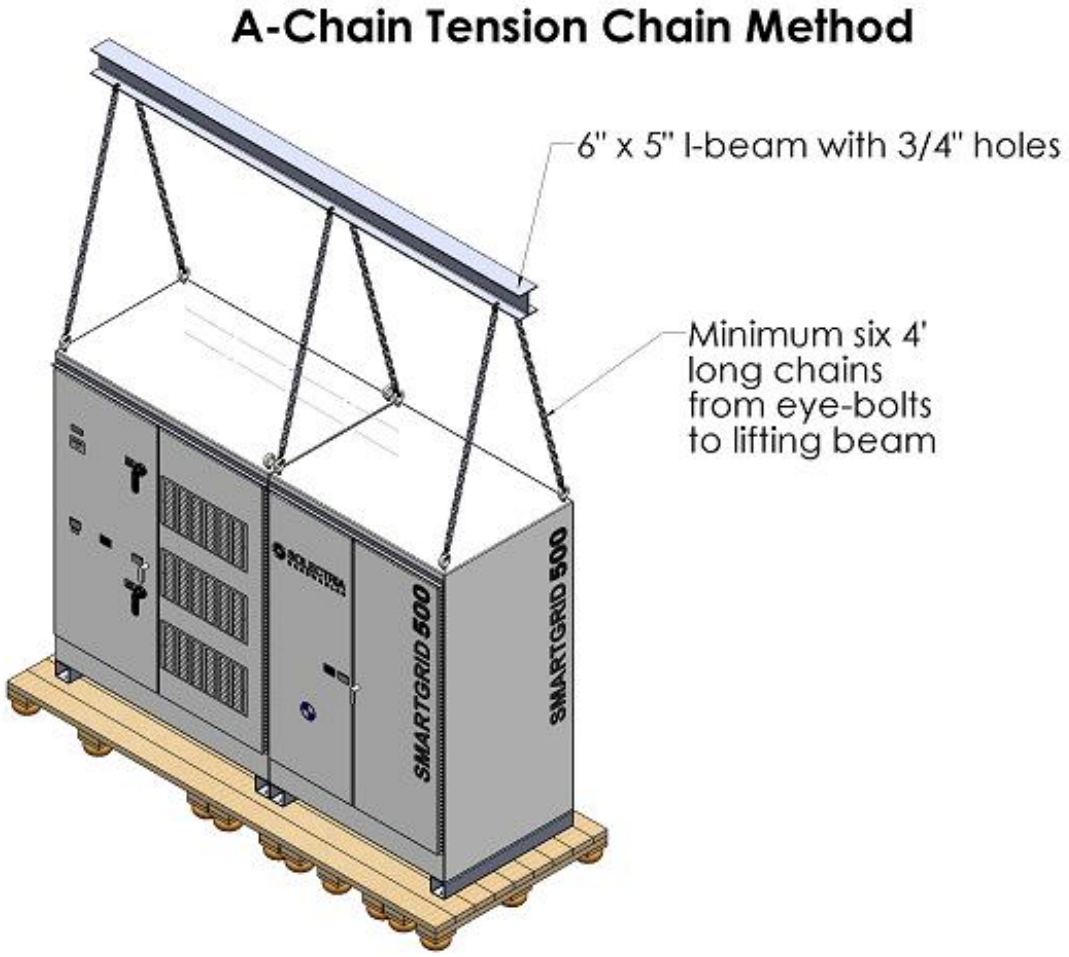
Heavy Duty circuit breaker

Optional integrated revenue-grade meter

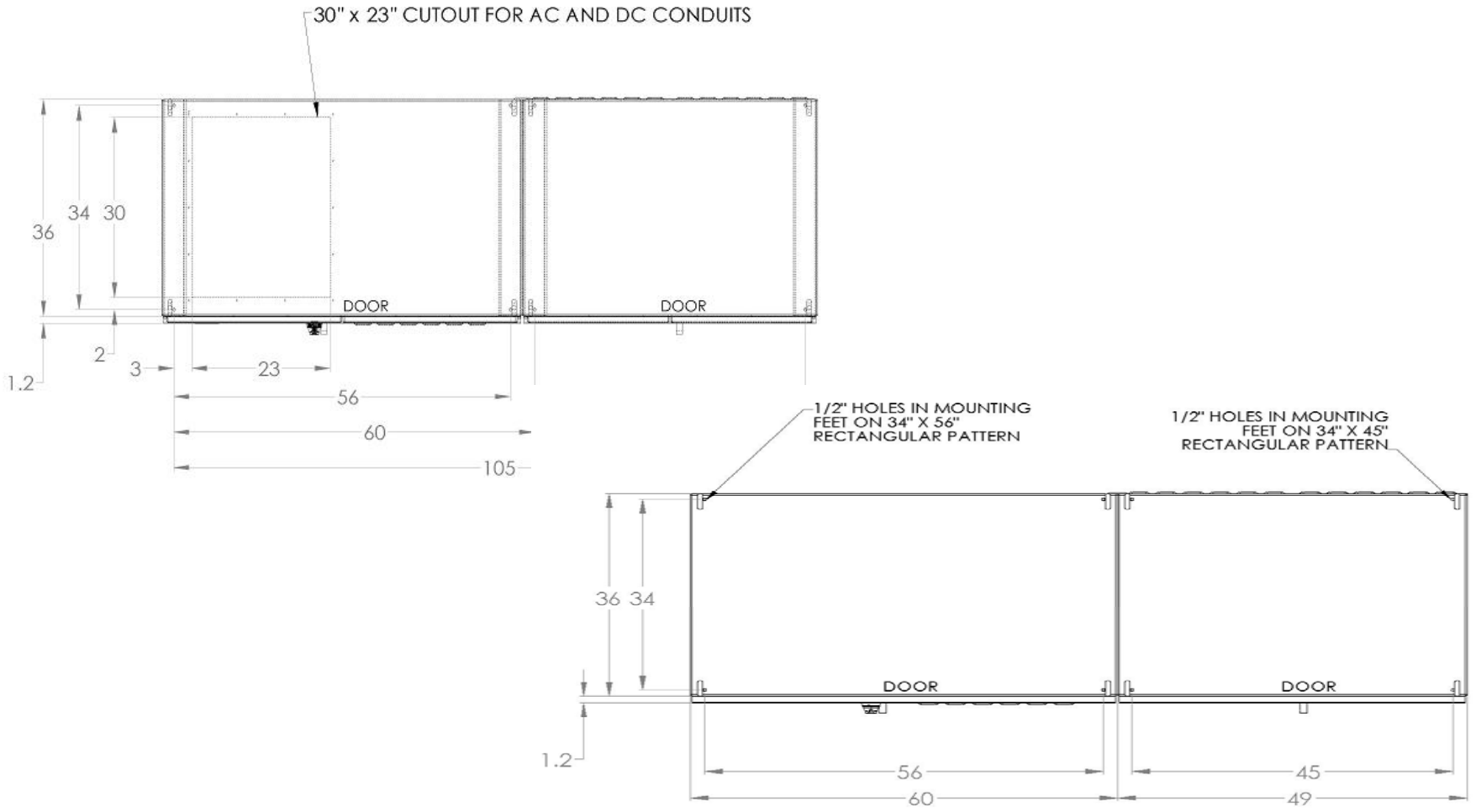
EMI Filter

Contactor

SGI Lifting Diagram



SGI Mounting Diagrams



Installation

Quick Installation = Low Installed Cost

PV Array

Grid-Tied PV Inverter

Electric Utility Grid

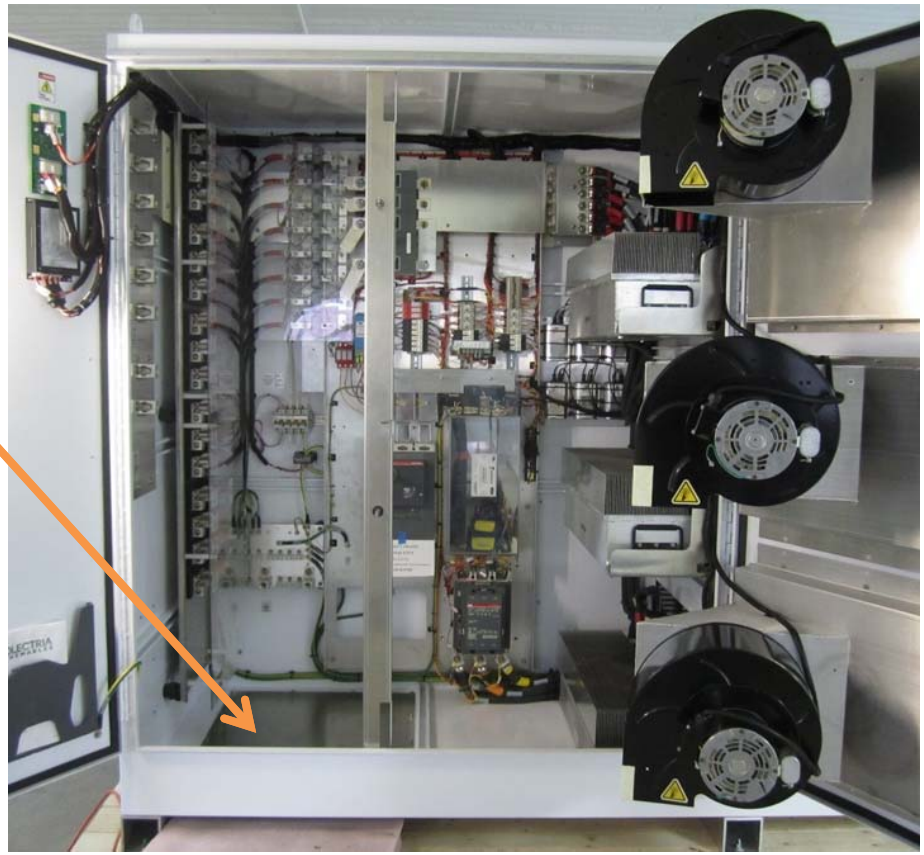
SGI Installation

ACCEPTABLE:

- Conduit Entry (removable plate)
- Conduit enters/exits in same place

UNACCEPTABLE

- Drilling top of Inverter
- DO NOT DRILL INVERTER



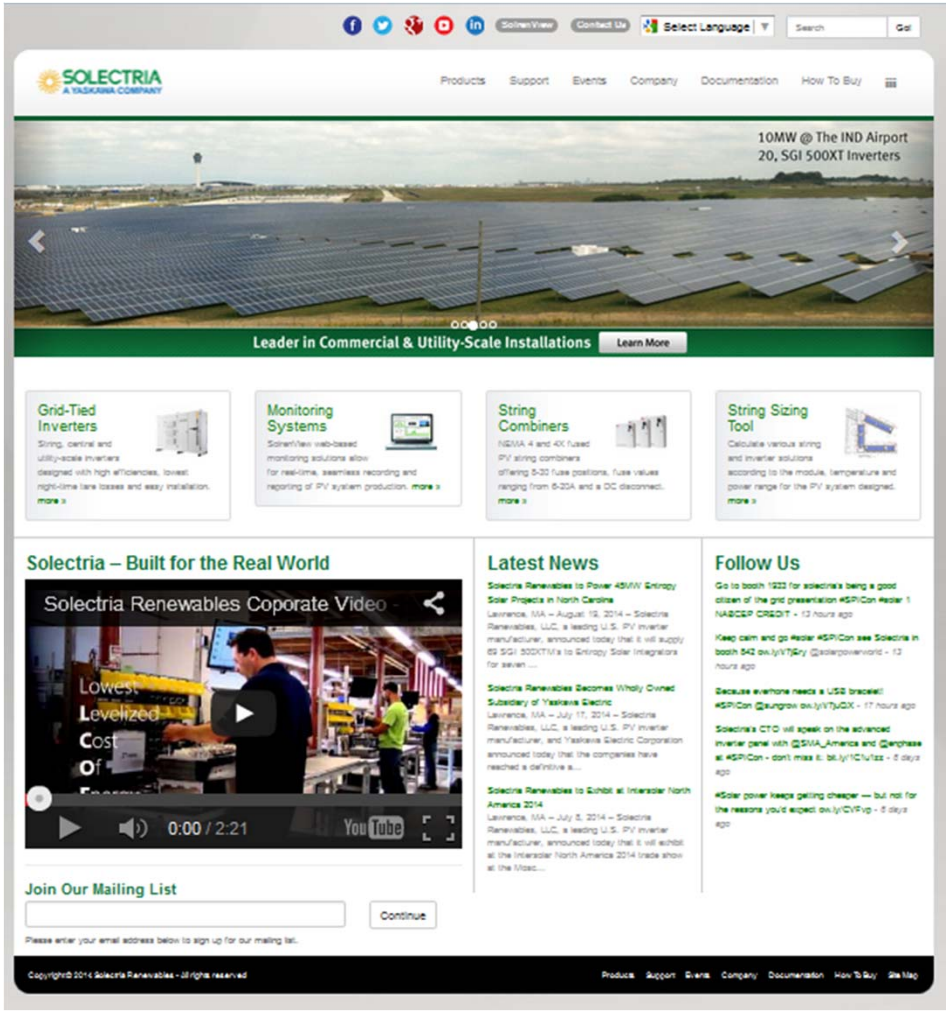
Resources

Resources

#1 Technical Resource is Solectria Applications Engineers

- Design/Application Questions
- String Sizing Review
- Single Line Review
- Code Questions

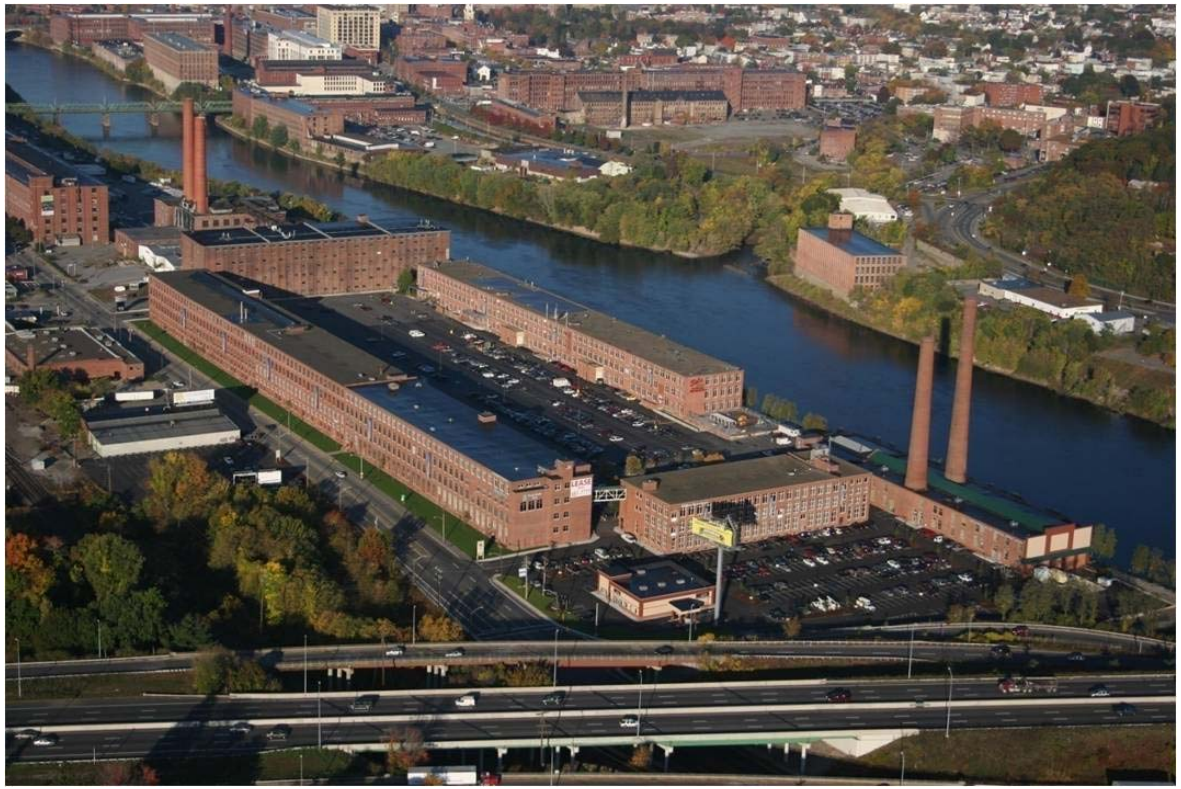
- Solectria Website www.solectria.com
  - Spec Sheets
  - Installation Manuals
  - PVsyst Files
  - String Sizing Tool
  - Customer Interface Drawings
- Other Resources
  - SolarPro
  - HomePower



Thank You

Questions??

Thank you!



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