Solar PV Inverters for Residential Installations

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Introductions



Mid-Atlantic Renewable Energy Association

A non-profit organization, dedicated to educating and engaging the public and advocating for renewable energy production, energy efficiency and sustainable living.

www.themarea.org

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Grid-Tied Solar Electric—



About Inverters...

- Three Main Functions
 - Change the DC electricity (coming from solar) to AC electricity (to be same as electricity from utility company)
 - Shut down PV system in case of grid outage (safety requirement)
 - Maximize PV performance (make real time adjustments to generate as much power as possible)
- Technology Options
 - string (central), with MPPT for group (string) of modules
 - Microinverters, with MPPT for individual modules
 - DC optimizers w simplified inverter

Solar Current-Voltage (I-V) Curve



IV Curve per Cell Temperature



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Maximum Power Point Tracking

- When directly coupling to a PV module, the load determines the voltage at which the module will operate"
- ✤ V / I = R
- Maximum Power Point Tracking (MPPT)
 - Functionality built into inverter
 - Programmable electronics that vary the resistance to obtain the highest power

Central ("String") Inverter



One inverter for group of modules connected in electrically in series ("a string").

Performs MPPT for entire string as a group.

"String" Design

- For a central inverter to work properly, voltage needs to be within a certain window—not too high, not too low
- A string is a group of solar modules connected together electrically in series
- In series, voltages add (current stays same)
- An array consists of one or more strings

Modules in a String

In **series**, voltage increases while current stays the same



Modules wired electrically in Series

35 V + 35 V + 35 V = 105 V

Amperage (current) is unchanged

Parallel Strings in an Array

In **parallel**, current increases and voltage stays the same



Strings wired electrically parallel

Modules wired in **series**, each string: 105 V and 7 A

Strings wired in parallel, array: 105 V and 14 A

Voltage Additional Considerations

- Maximum Voltage
 - occurs at low temperature
 - too high, warranty void & possible inverter damage
- Minimum Voltage
 - occurs at *high* temperature (oddly enough)
 - cell temperatures are higher than ambient
 - not a safety issue, but necessary for inverter performance and MPPT

Sunny Boy 5000TL-US Inverter



	Technical data	Sunny Boy 5000TL-US			
		208 V AC	240 V AC		
	Input (DC)				
•	Max. DC power (@ $\cos \varphi = 1$)	5300 W			
	Max. DC voltage	600 V			
	MPP voltage range	175 - 480 V			
	Min. DC voltage / start voltage	125 / 150 V			
	Max. input current / per MPP tracker	30 A / 15 A			
	Number of MPP trackers / strings per				
	Output (AC)				
\Rightarrow	AC nominal power	4550 W	5000 W		
	Max. AC apparent power	4550 VA	5000 VA		
	Nominal AC voltage / adjustable	208 V / 💿	240 V / •		

53 pounds! (*transformerless*)

Microinverters



One microinverter per module. (In some cases per two modules.)

Performs MPPT for individual modules.

Microinverter Design

Compatibility with selected module

- Module power rating
- Number of module cells
- Voltage operating range
- Example manufacturers—
 - <u>Chilicon Power</u>
 - o <u>Enphase</u>

Chilicon 720 microinverter

INPUT DATA (DC)

Recommended input power (STC)	(190 - 420 W) x 2; (380 - 840	0 W) x 1
Maximum DC input voltage	120 V	
MPPT voltage tracking range	56 – 82 V (240V)	48.5 – 82 V (208V)
Operating range	47 – 82 V	
Min./Max. start voltage	44 – 96 V	
Max. DC input short circuit current	16 A	
Max. DC input current	13.5 A	



Microinverter Cabling

Branch Cable – connects a microinverter to the trunk cable



Trunk Cable – connects microinverters to one another and the grid



Chilicon CP-100 Gateway





- On-Site Array Configuration
- Power line communication,
 WiFi, Ethernet, and Zwave
- Auto-discovers and binds microinverters
- Production and Consumption Monitoring
- Automated Cloud Monitoring Registration
- Home Energy Audit Capable

Power Optimizers



One optimizer per module. Performs MPPT for individual module.

Simplifed Inverter does DC-to-AC for group of modules/optimizers.

Optimizer Design

- Modules compatible with optimizer (may be integrated)
- Optimizer compatible with simplified inverters (sometime proprietary)
- Example manufacturers
 - o <u>SolarEdge</u>
 - o <u>Tigo</u>

PV Game Changers in Recent Years

- Much, much lower module prices
 - Easier to cost justify, sites can be less perfect
- Increased solar module energy densities
 - More electricity generation from same PV area (300W solar modules common now)
- Performance management for groups of modules ("strings") and individual modules, rather than PV system as a whole
 - More shade tolerance
 - Solar modules don't need to match
 - Solar modules can be in different planes, with different orientation
 - Existing PV systems more easily expanded

So, less than "ideal" sites may now make sense!



U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018 (NREL)

PV "Rapid Shutdown"

- New rule added in NEC 2014
- Requires that PV systems be quickly de-energized when the AC service disconnect is open
- Can only be met through modulelevel control—this means microinverters or optimizers, not string inverters

civicsolar.com/article/nec-2017-modulelevel-rapid-shutdown

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	Home / Support / Solar articles / NEC 2017: Module-Level Rapid Shutdown	
	NEC 2017: Module-Level Rapid Shutdown	
	Note electricians and solar installers across the country are intimately familiar with the National Electric Code (NEC). Published every three years by the National Fire Protection Association (NFPA), the handbook aims to prevent electrical fires by fostering clarity and safety to national electrical standards. The first edition of the NEC was published in 1897 – a mere 20 years after the invention of the light bulb – and the NFPA has published the NEC since 1911. Today's handbooks are behemoths. The NEC currently enlists over 5,500 panel members that put in over 35,000 person-hours to compile the 1,000+ page report. When all is said and done, the NEC publishes concise safety guidelines for a laundry list of different electrical standards.	Published: 7 months ago Written by: Tom Schoder Support topic: NEC code Support keywords: NEC 2017 rapid shutdown MLPE Electric Code NFPA top 10 Share Image: Comparison of the post commentation of the post commenta

	String ("control") invertor		DC Power Optimizer &	
	Sunny (central) inverter	wicroinverter	Simplified Inverter	
Description	One inverter to support many modules. Performance is managed for individual groups of modules ("string") or entire array.	Individual inverter is connected to each solar module, or factory installed (AC module). Performance is managed for each solar module independently.	Individual DC Optimizer is connected to each solar module, or factory installed. Performance is managed for each solar module independently. Separate simplified inverter does DC-to-AC conversion for group of DC Optimizers.	
Location	Inverter is installed in vicinty of array, near service panel.	Inverters are installed with modules (more exposed to elements).	DC Optimizers are installed with modules (more exposed to elements). Simplified inverter located in more protected area.	
Operation	Solar modules must be closely matched, with same solar exposure and little or no shading. Any shading will affect performance of entire group.	Solar modules don't have to match or be in same plane or direction. Shading in one part of array, does not affect other areas.	Solar modules don't have to match or be in same plane or direction. Shading in one part of array, does not affect other areas.	
Expansion	Generally not suited for adding more modules later.	Can expand system, with few limitations.	Can expand system, within inverter specification.	
Monitoring	Optional	Necessary	Necessary	
Other	Special feature like SMA's Secure Power Supply provides some electricity during power outages.	Can make meeting electrical code requirements easier, depending on version enforced locally.	Can make meeting electrical code requirements easier, depending on version enforced locally.	



Thank you!



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