MLPM Benchmark Report 2013

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Chapter 1: Introduction to MLPM

Conventional photovoltaic systems are designed for application in ideal circumstances. “Ideal” means that all panels are of the same type and have the same orientation and are not partially shaded by objects in the surroundings.

Typically such a PV system consists of solar modules connected in series and a power inverter which converts DC current to usable AC as shown in figure 1. This installation design is complex and requires special personnel due to lethal DC voltages.

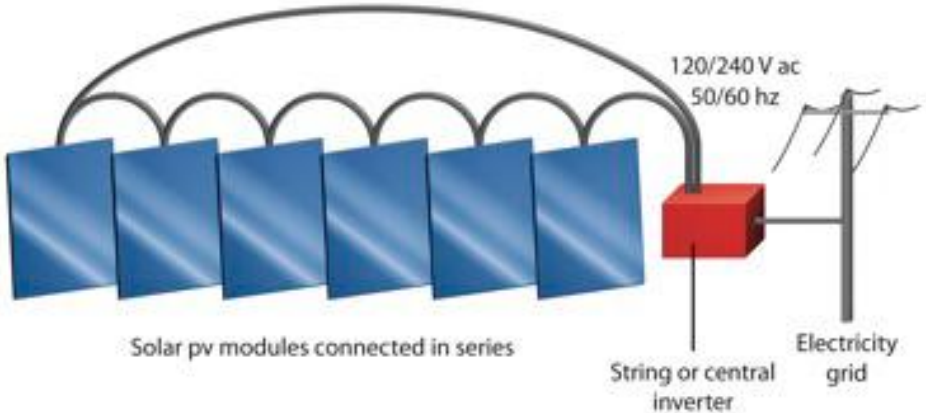


Figure 1: Standard PV system configuration[1]

Main disadvantages of the standard system design are:

- Mismatch losses. One of the basic principles of electrical engineering is that in a series connection only one current can flow. This basic principle imposes that in case a solar module performs worse than the rest of the modules, it will reduce the performance of the whole chain reducing the total energy yield. Due to the fact that the current produced in a PV module is proportional to the irradiation, an important problem occurs. Heterogeneous environmental conditions such as shadowing from horizon, obstacles casting shadows at the installation location, dirt or dust accumulating with time unevenly and manufacturing tolerance of power output can significantly reduce energy yield.

- Installation of the PV modules must be performed in the same orientation and inclination angle to assure as much as possible the same irradiation level of the PV modules. Additionally PV modules must be of the same power class and technology.

- The central inverter used in a conventional PV system is a single point of failure. In case the inverter fails the whole system shuts down.

[1] http://www.enecsys.com/technology/index.php

- Monitoring capabilities with conventional PV systems are limited and restricted to string voltage and current, making it difficult to identify faulty PV modules especially in large PV systems

- Safety issues have arisen in recent years because of the penetration of PV systems in the residential sector. Fires have been recorded which probably occurred from high DC voltage sparks.

Several approaches have been proposed to mitigate these disadvantages and to optimize the output of PV systems in non-ideal circumstances. A common feature of these approaches is that power optimization is brought down to the module level. In general we call these approaches Module Level Power Management (MLPM).

We distinguish two different architectures of MLPM:

- Power-Optimizers (DC/DC boost, buck, buck-boost)
- Micro-inverters (DC/AC)

Power optimizers are de-centralized DC/DC converters. They are typically installed to each PV module by the PV system installer. Alternatively, they can be embedded in the junction box by module manufacturers. They are designed to individually tune the Maximum Power Point Tracking (mppt) of a PV module and additionally adjust the output to match the "fixed" voltage of a string inverter.

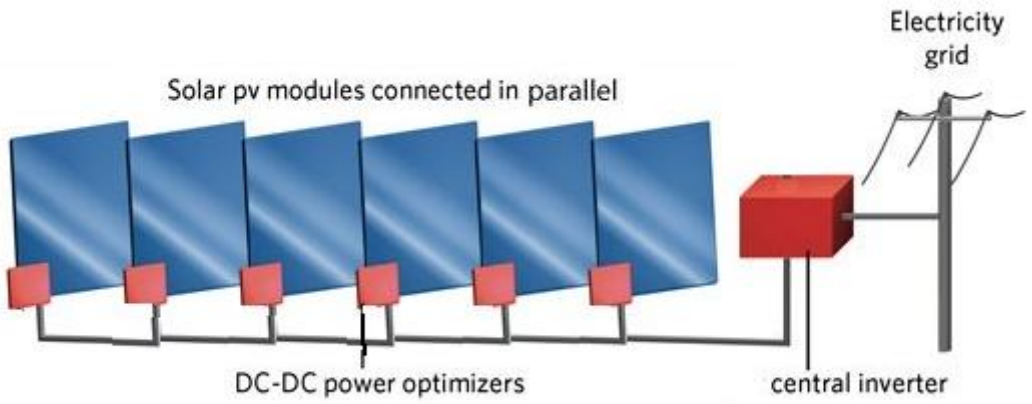


Figure 2: PV system configuration with power optimizers in parallel (boost)[2]

Power optimizers come in two configurations. The parallel arrangement is chosen in the solution from the company Femtogrid. The in series configuration by market leader SolarEdge.

[2]http://www.enecsys.com/technology/index.php

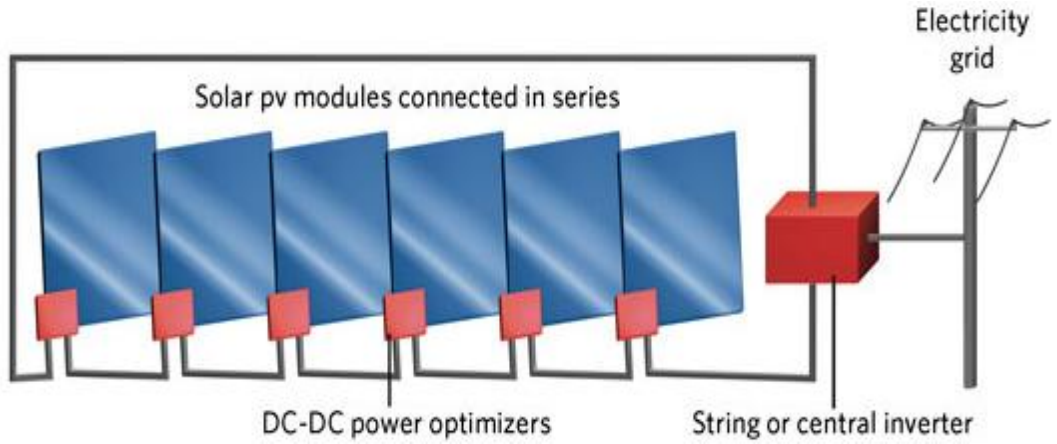


Figure 3: PV system configuration with power optimizers in series (buck and buck-boost)[3]

Micro-inverters are de-centralized power electronic converters installed to each or every other PV module. A micro-inverter essentially combines a power optimizer with a small inverter. Every micro-inverter contains a DC/DC and a DC/AC converter.

MLPM elements are a natural evolution in system design and architecture. They offer flexibility in design since now all inclination angles and orientations are suitable and not affecting each other. Different module classes and types can be connected in the same system for example upgrading of an existing system by adding more modules even if the power class of the existing modules has been discontinued. Installation is now easy and standardized because every MLPM device comes with its own wiring.

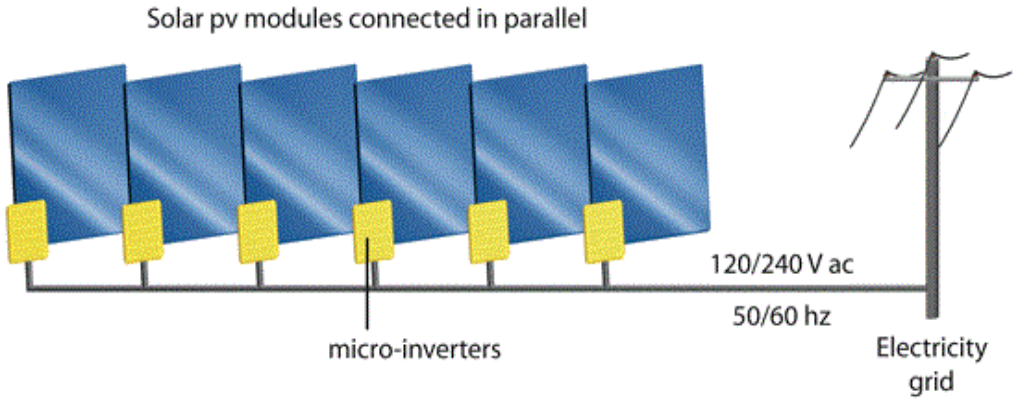


Figure 3: PV system configuration with micro-inverters

Additionally hazardous risks are being minimized due to the safety features introduced in MLPM. Spark detectors (mainly for DC/DC power optimizers) and DC shut down mechanisms from the module reduce

[3]http://www.enecsys.com/technology/index.php

accident rates of the lethal DC voltages. This feature of the MLPM devices adds value in terms of safety for the home owners-workers-firefighters. Another feature added with MLPM units is the wide monitoring capabilities. Until now monitoring was only possible at string level. Now power output of individual modules can be monitored and assessed. Faulty modules and components can be easily identified and corrected accordingly. This feature reduces the down time of the PV system and thus improves the annual energy yield. Figure 4 shows an example of PV monitoring on the panel side.

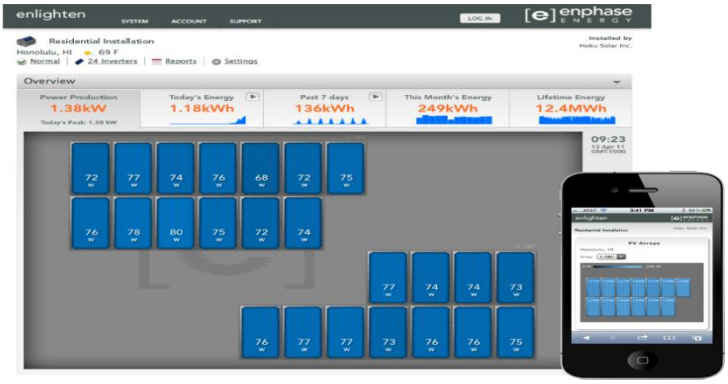


Figure 4: Screenshot from the enlighten software offered with Enphase micro-inverters

Chapter 2: Product development

String and central inverters are devices serving the solar PV industry for 3 decades. They have evolved in terms of performance, functionality and reliability. They represent the traditional PV system architecture and they have a big variety of applications and input ranges. Performance and quality of inverters especially from experienced manufacturers has been improved, however there are still remaining problems[4]. Improvement has been done also in the mppt section of the string and central inverters. New algorithms that work faster and more reliable have been introduced by many inverter manufactures[5]. Moreover, traditional inverters have high efficiencies up to 98% making them ideal for large ground mounted applications.

Three-phase string inverters for large ground mounted and roof commercial installations entered the market during 2010. These inverters help to maintain stability of the grid voltage and frequency because they are designed to meet the new "reactive power" and "Medium Voltage Directive" legislations that are introduced in Germany. Additionally utility providers request residential PV installations to have three phase grid feeding to prevent grid imbalances.[6]

Not only the architecture but also the main components of the traditional inverters are changing. Silicon-Carbide diodes are a promising solution to reduce size and cost of the expensive magnetic materials such as copper[7]. Additionally inverters with Si-C diodes have a higher current density making them ideal for high voltage operation thus reducing the BOS. Additionally GaN based power devices represent an excellent choice for improved device performance. GaN power devices reduce losses in all stages of power conversions. The first commercial 600V GaN devices have already been released to the market[8].

As inverter suppliers are under huge pressure to reduce costs there are some interesting examples on how the inverter manufacturers can save overall system costs with new developments:

- Increasing input voltage (Vdc): Longer strings can lead to less BOS costs like cables, fuses, switches etc
- Outdoor rated inverters: Manufacturers are increasing the supply of outdoor rated inverter which they don't need separate housing and thus save infrastructure costs
- Weight reduction: Work hours can be saved by lighter equipment. Installation and replacement are now easier without bulky inverters
- Using small string inverters rather than large central inverter: By offering more Mppt trackers and small three phase inverters, suppliers are targeting in reduction of lifetime system costs by increasing yield and downtime

[4] Evolution of inverters for Grid connected PV systems from 1989 to 2000, H. Haeberlin
[5] OptiTrac Global Peak SMA- www.sma.de
[6] The World Market for PV Micro-inverters and Power Optimizers 2012 IMS research
[7] Si-c make solar power systems more efficient, Michael Oneil, Cree Inc
[8] Latest in PV Inverter & Trends , Baumgartner- Vezzini

It is interesting to mention the improvements that are needed from the power optimizer and the micro-inverter devices in order for the devices to penetrate the market faster.

Power Optimizer:

- PV modules are designed to withstand harsh environmental condition for at least 25 years. Specific standards for testing reliability have been successfully implemented the past years. Like in every electronic device reliability starts at the design phase of the product. The selection of components is the other critical factor. The most frequently identified failure mechanism in power optimizers is the capacitor bank. For this reason many manufacturers disqualify electrolytic capacitors which are affected by high temperatures. Alternatives are thin film capacitors or Multilayer ceramic capacitors.

- The use of Application Specific Integrated Circuits (ASIC) helps to improve reliability as well, because the required number of components can be reduced.
- Power-optimizers must have a small and flexible size. Junction box embedded power optimizers have been developed in cooperation with module producers and are already in the market today.
- Another important success factor is the cost per watt. Because of the usage of the string inverter (even the simplified version of it without mppt), power optimizers will always add extra costs to the PV system. A more easy system design and more straightforward installation process partly compensates the cost of the power optimizer.
- Adaptation of power optimizers is popular in Europe. Probably this is based on the fact that power optimizers are still using a string inverter which is the common practice at the traditional European PV systems. The fact that power optimizers can be utilized at problematic modules only increases the penetration and adaptation of power optimizers.

Micro-inverter:

- The inverter in a PV system has been identified as the dominant failure mechanism. Usually inverters have to be replaced at least once during the lifetime of a PV system. Because of their mounting nature, micro-inverters need to be able to withstand harsh environmental conditions and deliver at least 25 years of fault free operation. The dominant wear-out failure mode is the electrolytic capacitor. This single component can reduce the lifetime and Mean Time Between Failures (MTBF) of the device. New capacitors which can withstand higher temperatures must be used for the micro-inverter industry. Companies already are using thin film capacitors which are known to be temperature tolerant.
- Efficiency of the micro-inverters is still lacking behind the string inverters which can reach up to 98%. The fact that string inverters are using transformer-less topologies boosts their efficiency and simplicity.
- Size of the micro-inverters must also be reduced in order to fit at the junction box without temperature problems. Micro-inverters that are small and reliable enough can be embedded in the junction box of the PV module. Modules with their micro-inverter embedded are commonly

referred to as “AC modules”. There are many development efforts towards these AC modules going on worldwide, but still there is no reliable solution.

- The cost of the micro-inverters is still high and the general approach of the industry is to add a premium price on top of the reference string inverter. In this way the micro-inverter will always be more expensive than the string inverter.
- Due to the fact that PV is becoming a significant percentage of some countries’ energy mix, grid stability and requirements change. For example in Germany the Low Voltage Directive introduced recently commands reactive power feeding requirements from the solar inverters. At this moment there is no micro-inverter with tunable power factor and thus installation of these devices is blocked in the German market for the moment.

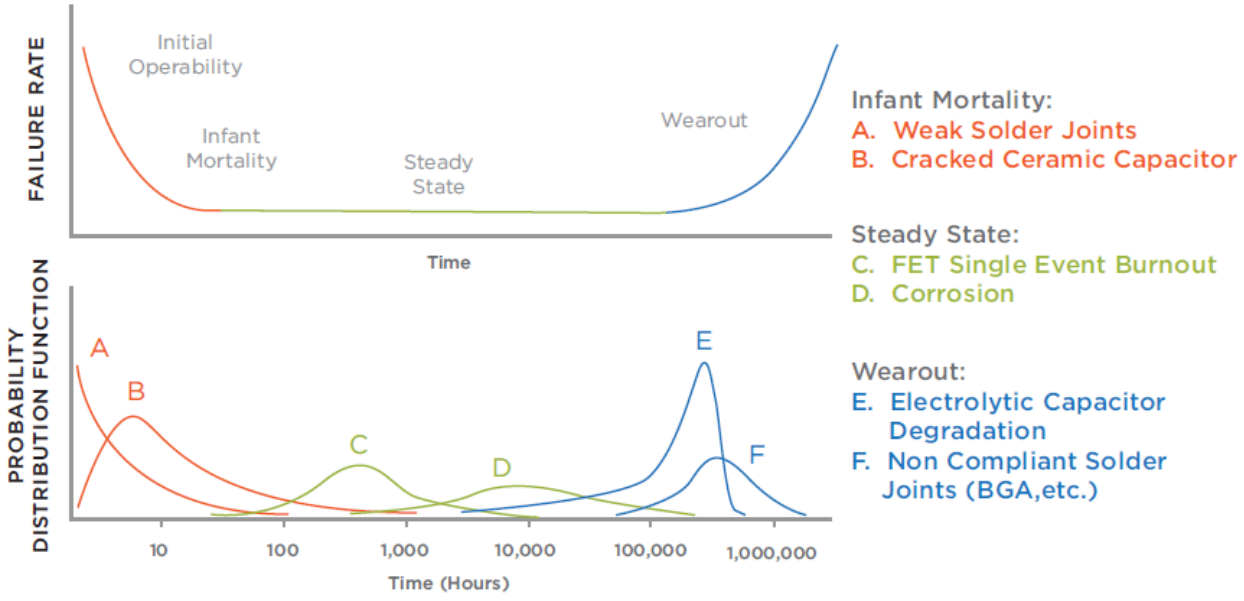


Figure 5: Failure modes of a micro-inverter[9]

In general the use of MLPM devices is based on a “spend more, get more“ philosophy which makes them ideal for problematic installation but not yet ideal for big roof commercial and ground mounted PV power plants. Simplified devices with low cost and high reliability will be the key developments that both the approaches must adopt. MLPM devices have started very dynamically and are claiming a part of the inverter market. Additional developments have to be made to increase penetration in market segments that are still dominated by more traditional solutions.

[9] Solarbridgetech.com

Chapter 3: MLPM Market

The PV market is highly associated with governmental subsidies and incentives. Currently the attractiveness of PV systems is determined by 4 major factors:

- Cost of PV equipment
- Governmental incentives
- Retail electricity price of the country
- Irradiation levels

Volumes and capacities are growing going hand in hand with remarkable price reductions worldwide. Subsidies are still leading the PV market even now that grid parity can be reached in many countries. 2011 was a mixed year for the inverter industry. Even if shipments grew by a third the revenues stayed on the levels of 2010[10]. 2012 was a year that started with a rush in many traditional markets because of the annually FIT reductions scheduled and the total shipments slightly rise from 2011 to 2012. 2013 was a harsh year for the industry having severe impacts in module and inverters shipments

It is estimated that the inverter accounts for up to 15% of the total PV installation cost and it is considered the second most expensive component of a PV system after the solar modules. However the inverter cost as a percentage of the total PV system cost is projected to increase. In an effort to follow the cost reduction of PV systems, many major inverter suppliers announced price discounts. Chinese suppliers continue to price competitively. For high power inverters bigger than 250kW western pricing was 43% higher than Chinese while lower power inverters are still cheaper by 40%. Chinese suppliers mostly ship their products in the local market which is rising. Huawei is developing low power inverters (<35kW) which could result in even cheaper inverter prices.

Another major change in the inverter industry is the new Low Voltage legislation recently introduced in Germany[11] (VDE-AR-N 4105). More than 80% of the installations in Germany are connected to the Low Voltage grid. With the penetration of PV in the energy mix, stability of the grid has become an important issue. In order to be able to provide reliability of the grid in the long term, inverters must execute functions contributing to ensuring grid stability in the future. The directive introduced in Germany will soon be adopted by other countries with increased solar activity to ensure grid stability.

The evolution of PV architecture with the introduction of MLPM devices will play an important role for the development of traditional inverters. The fact that MLPM technologies can work together with a traditional inverter, simplified inverter or even eliminate the need for a central inverter may and will change the inverter market. For this to happen a higher penetration rate in the traditional markets has to be achieved.

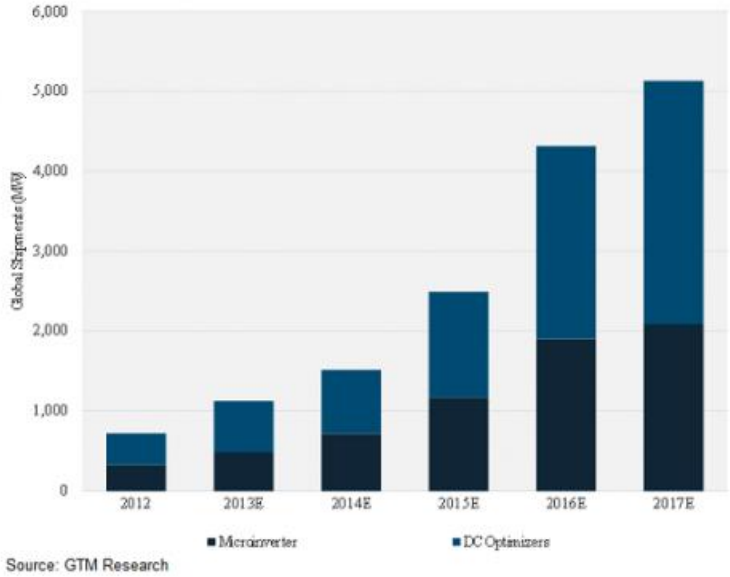
Possible target markets for micro-inverters and power optimizers are residential and small commercial installations. The fact that small installations have usually more expensive inverters per Wp will lead to

[10] iSuppli Topical Report : PV Microinverters and Optimizers: Can Moore's Law be Disruptive Again?
[11] http://www.vde.com/de/fnn/arbeitsgebiete/seiten/n4105.aspx

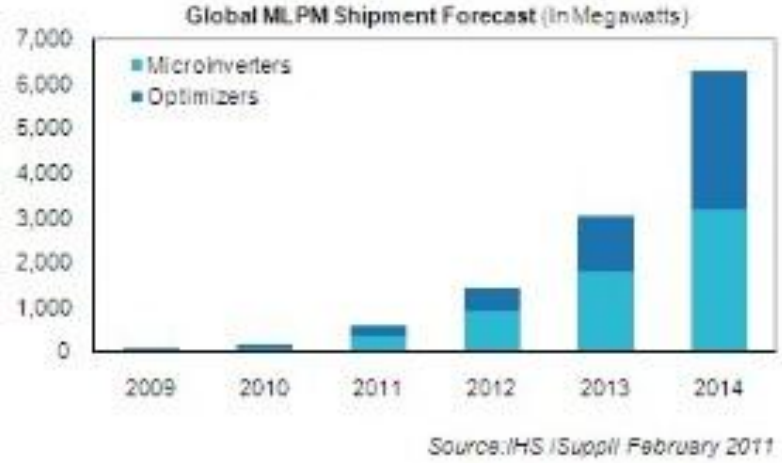
an easier closing of the price gap between string and micro-inverters. Additionally small installations are the ones affected by shadowing and thus MLPM solutions can increase yield by using panel-level mppt. Power optimizers will probably have a higher penetration than micro-inverters because of the similar topology with the traditional systems and the fact that power optimizers can be equipped at panels who are under shady conditions than in the whole array.

Some public figures from GTM Research and from IHS/ISupply (now: IMS Research) are shown below. More details are presented in commercially available reports from these companies.

FIGURE: Global MLPE Shipments (MW) by Technology, 2012-2017



Source: GTM Research



Source:IHS ISuppli February 2011

IHS predicts that MLPM shipments are expected to rise significantly after 2013 and peaking at 2016 at an astonishing 7GW and 1.2B€. revenues[12]. Penetration in traditional markets is never easy. MLPLM solutions must overcome two major obstacles: reliability and pricing.

Even now that they are still in an infancy stage, there is high acceptance especially from residential markets. For PO's this is mainly in the EMEA region, for micro-inverters mainly in the Americas region.

Another important market segment that has to be taken under consideration is the inverter replacement market. With central and string inverter average lifetimes of 10 years, many PV systems installed during the solar boom of 2007-2008 will soon need inverter replacement. This is an excellent opportunity for MLPM devices to increase their penetration.

[12] The World market for micro-inverters and power optimizers, 2013 edition IHS

Chapter 4: Micro-inverter companies

4.1 Heliox[13]

Heliox is a company specialized in switch mode power technology. Heliox designs and manufactures products and solutions for a broad range of markets, such as PSUs, Class D amplifiers, lamp drivers, chargers and AC inverters. The highly skilled R&D staff has many years of experience in a broad range of power supply architectures and converter topologies. Heliox is mainly engaged at audio, video, medical, industrial and e-mobility applications.

Heliox is entering the solar industry with a new design of a micro-inverter which is planned to hit the market in 2014.

The data sheet shown on the next page is preliminary.

[13] http://www.heliox.nl/

HELIOX SMI-250 - SOLAR MICRO INVERTER

INPUT CHARACTERISTICS

Parameter	Symbol	Min	Typ	Max	Units	Notes
DC Input						
Power	P_{DC}			250	W	
Voltage	V_{DC}	15		50	V	Start at 25V
Voltage MPPT Range	$V_{DC\text{-}MPPT}$	16		48	V	
Current	I_{DC}	0,1		9	A	

OUTPUT CHARACTERISTICS

Parameter	Symbol	Min	Typ	Max	Units	Notes
AC Output						
Power	P_{AC}			240	W	
Voltage Range	V_{AC}	198	230	253	V_{RMS}	
Current	I_{AC}			1,05	A_{RMS}	
Frequency	f_{AC}	48	50	50,5	Hz	
Power Factor	PF	0,95	0,995			
Total Harmonic Distortion	THD			5	%	
Dielectric withstand			1500		V_{RMS}	Primary to secondary

EFFICIENCY CHARACTERISTICS

Parameter	Symbol	Min	Typ	Max	Units	Notes
Efficiency						
Euro Efficiency	η_{EURO}		94,5		%	@31V_{DC}
CEC Efficiency	η_{CEC}		95,5		%	
Peak Efficiency	η_{PK}		96,0		%	
Night Time Power Consumption			35		mW	230 V_{AC}

MECHANICAL CHARACTERISTICS

Parameter	Symbol	Typ	Units	Notes
Weight		1,65	kg	
Dimensions		264 x 245 x 34	mm	L x W x H, incl. mounting plate, excl. connectors

ENVIRONMENTAL CHARACTERISTICS

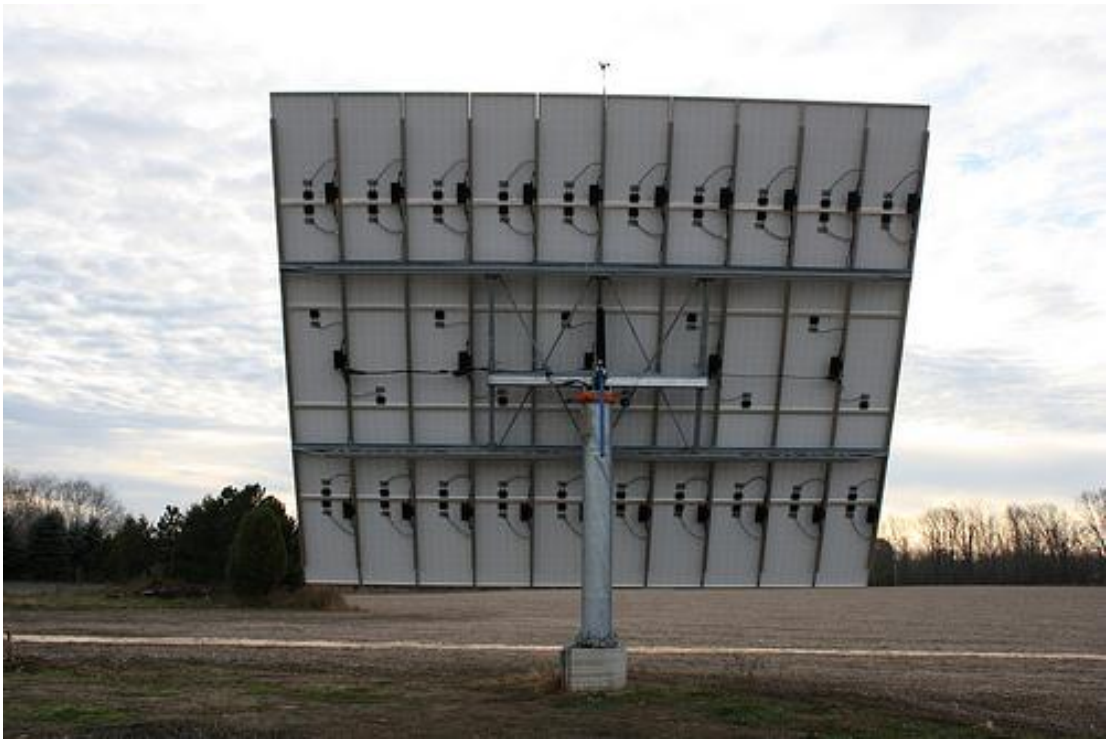
Parameter	Symbol	Min	Typ	Max	Units	Notes
Operating Temperature						
Ambient Air		-40		75	°C	No Power Derating
Cooling			Natural Convection			
Enclosure Environmental Rating			IP-67			
Conduced EMI Compliance			EN61000			
Safety Compliance			EN62109			part 1 & 2
Additional requirements			IEC61215			
			EN50438			
Warranty (limited)			25		year	

4.2 Enphase[14]

Recognized as the market leader in the micro-inverter segment, Enphase recently went public in an effort to gather funds to develop further the micro-inverter system. With increased net revenues by 136% from 2011 to 2012 Enphase shows that it can hold its position in the global market. With a wide portfolio consisting of various micro-inverters, sophisticated software and installation accessories Enphase is leading the niche market it helped create.

After the raising of $50million from the public offering (IPO) Enphase is targeting to use the money for further expansion in the European region and Asia. New offices opened in China are not so much focused on sales but in opening doors to module manufacturers in order to start partnerships.

The Enphase product portfolio consist of 4 micro-inverters: the M250 (last generation), M215, M190-210 and D380 which is a micro-inverter connected with 2 solar modules.



[14] www.enphase.com

M215 — MICROINVERTER TECHNICAL DATA

Input Data (DC)	M215-60-2LL-S22/S23 and M215-60-2LL-S22-NA/S23-NA (Ontario)
Recommended input power (STC)	190 - 260W
Maximum input DC voltage	45V
Peak power tracking voltage	22V - 36V
Operating range	16V - 36V
Min./Max. start voltage	22V/45V
Max. DC short circuit current	15A
Max. input current	10.5A

Output Data (AC)	@208 Vac	@240 Vac
Maximum output power	215W	215W
Nominal output current	1.0A (arms at nominal duration)	0.9A (arms at nominal duration)
Nominal voltage/range	208V/183-229V	240V/211-264V
Extended voltage/range	208V/179-232V	240V/206-269V
Nominal frequency/range	60.0/59.3-60.5 Hz	60.0/59.3-60.5 Hz
Extended frequency range	60.0/59.2-60.6 Hz	60.0/59.2-60.6 Hz
Power Factor	>0.95	>0.95
Maximum units per 20A branch circuit	25 (three phase)	17 (single phase)
Maximum output fault current	1.05 Arms, over 3 cycles; 25.2 Apeak, 1.74ms duration	

Efficiency	
CEC weighted efficiency	96.0%
Peak inverter efficiency	96.3%
Static MPPT efficiency (weighted, reference EN50530)	99.6%
Dynamic MPPT efficiency (fast irradiation changes, reference EN50530)	99.3%
Night time power consumption	46mW

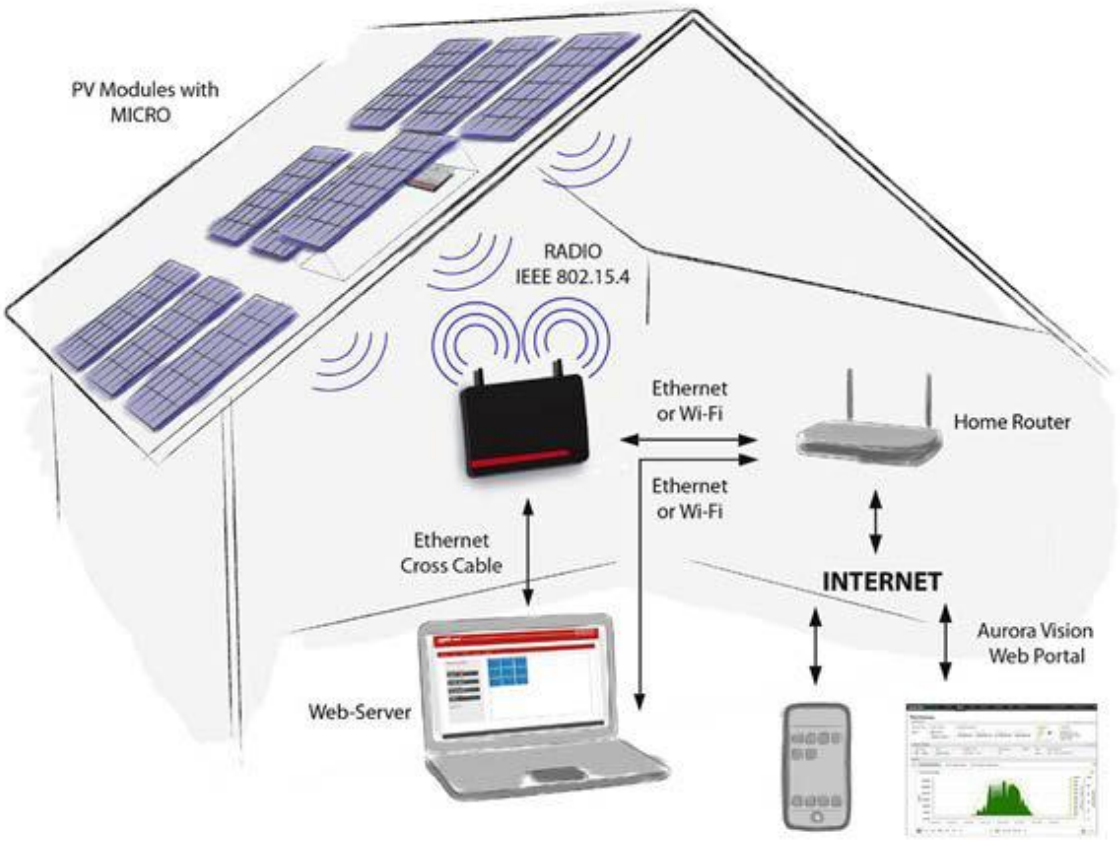
Mechanical Data	
Ambient temperature range	-40°C to + 65°C
Operating temperature range (internal)	-40°C to + 85°C
Dimensions (WxHxD)	17.3 cm x 16.4 cm x 2.5 cm (6.8" x 6.45" x 1.0")*
Weight	1.6 kg (3.5 lbs)
Cooling	Natural convection - No fans
Enclosure environmental rating	Outdoor - NEMA 6

* without mounting bracket

Features	
Compatibility	Pairs with most 60-cell PV modules
Communication	Power line
Warranty	25-year limited warranty
Monitoring	Free lifetime monitoring via Enlighten software
Compliance	UL1741/IEEE1547, FCC Part 15 Class B CAN/CSA-C22.2 NO. 0-M91, 0.4-04, and 107.1-01

4.3 Power-One (member of the ABB group)[15]

In July 2013 ABB completed the full acquisition of Power-One. Power One has recently establish itself as the second largest provider of solar inverters globally. It is divided in two strategic business units, Renewable Energy Solutions and Power Solutions. As part of its strategy for geographic diversification Power One has entered into the North American and Asia Pacific markets and have established new factories in North America and China, as well as product development laboratories, and continue to build regional sales and service teams. Power One will continue to strategically invest in sales and marketing, R&D and global service team as they believe these are key drivers of their business. They are focused on reducing lead times, improving deliveries to customer request dates, and reducing freight and other transportation costs by localizing the supply chain. The new products from Power One at the range of 250-300Wp are electrolytic capacitor free. This means increased tolerance in heat and thus higher lifetime expectation.



[15] http://www.power-one.com/

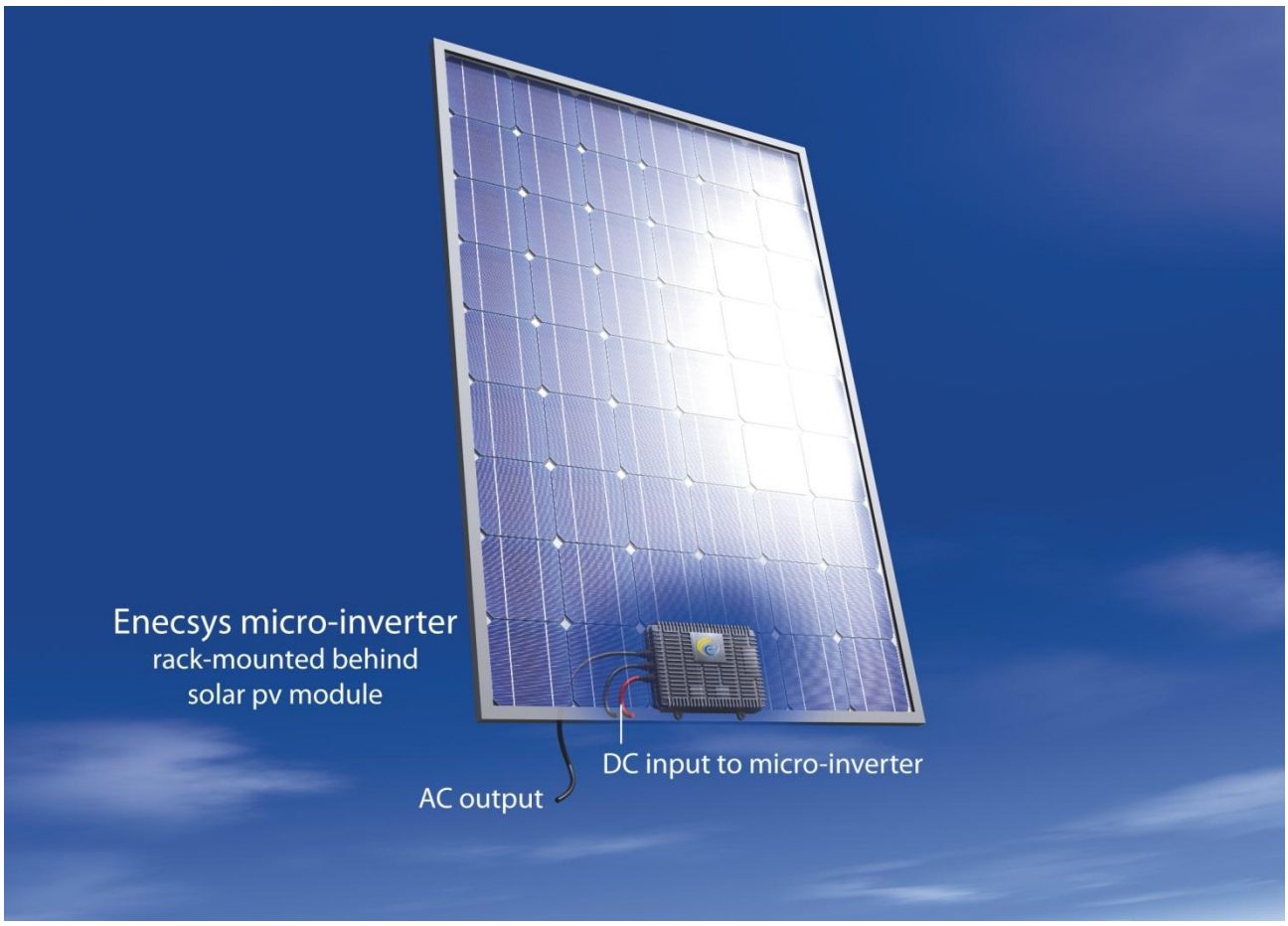
TECHNICAL DATA	VALUES	MICRO-0.25-I-OUTD-US-208/240		MICRO-0.3-I-OUTD-US-208/240	
Nominal Output Power	W	250		300*	
Rated Grid AC Voltage	V	208	240	208	240
Maximum Output Power	W	250		300	
Input Side (DC)					
Maximum DC Input Power	Wp	265		320	
Absolute Maximum Voltage (Vmax)	V	65		65	
Start- Up Voltage (Vstart)	V	25		25	
Full Power MPPT Voltage Range	V	25-60		30-60	
Operating Voltage Range	V	12-60		12-60	
Maximum Current (Idcmax)	A	10.5		10.5	
DC Connection Type		Tool Free PV connector WM/MC4			
Output Side (AC)					
Grid Connection Type		1Ø/2W	Split-Ø/3W	1Ø/2W	Split-Ø/3W
Adjustable Voltage Range (Vmin-Vmax)	V	183-228	211-264	183-228	211-264
Grid Frequency	Hz	60		60	
Adjustable Grid Frequency Range	Hz	57-60.5		57-60.5	
Maximum Current (Iacmax)	A	1.3	1.3	1.5	1.5
Power Factor		> 0.95		> 0.95	
Maximum Number of Inverters per String		13	15	11	12
Grid Wiring Termination Type		12AWG Drop Cable from Inverter to 10AWG AC Trunk Cable			
Protection Devices					
Input					
Reverse Polarity Protection		Yes Polarized PV Connectors (WM/MC4)			
Output					
Anti-Islanding Protection		Meets UL 1741/IEEE1547 requirements		Meets UL 1741/IEEE1547 requirements	
Over-Voltage Protection Type		Varistor		Varistor	
Efficiency					
Maximum Efficiency	%	96.5		96.5	
CEC Efficiency	%	96		96	
Operating Performance					
Stand-by Consumption	mW	< 50		< 50	
Communication					
Monitoring System		Wireless and Web-Based Monitoring through AURORA CDD			
Environmental					
Ambient Air Operating Temperature Range	°F (°C)	-40 to 167 (-40 to 75) with derating above 149 (65)		-40 to 167 (-40 to 75) with derating above 149 (65)	
Ambient Air Storage Temperature Range	°F (°C)	-40 to 176 (-40 to +80)		-40 to 176 (-40 to +80)	
Relative Humidity	% RH	0-100 condensing		0-100 condensing	
Acoustic Noise Emission Level	db (A) @1m	< 30		< 30	
Maximum Operating Altitude without Derating	ft(m)	6560 (2000)		6560 (2000)	
Mechanical Specifications					
Enclosure rating		NEMA 4X		NEMA 4X	
Cooling		Natural Convection		Natural Convection	
Dimensions (H x W x D)	in (mm)	10.5 x 9.7 x 1.37 (266 x 246 x 35)			
Weight	lb/(kg)	< 3.5 (1.65)		< 3.5 (1.65)	
Mounting System		Panel Mounted		Panel Mounted	
Safety					
Isolation Level		HF Transformer		HF Transformer	
Safety and EMC Standard		UL1741, EN61000-6-2, EN61000-6-3, FCC Part 15 Class B		UL1741, EN61000-6-2, EN61000-6-3, FCC Part 15 Class B	
Safety Approval		cCSAus		cCSAus	
Warranty					
Standard Warranty	years	10		10	
Available Models					
Standard		MICRO-0.25-I-OUTD-US-208/240		MICRO-0.3-I-OUTD-US-208/240	

* With derating below 200V for 208VAC operation

4.4 Enecsys[16]

Founded in 2003 in UK from a Cambridge University patent, Enecsys fast became one of the leaders in the micro-inverter niche market. Headquarters are situated in Cambridge UK but the company has sales and support offices in USA, Taiwan and Germany. Having secure investment of $14 million on 2009 plus $41 million on 2011 the group is dedicated in evolving the micro-inverter concept further. By using thin film capacitors Enecsys believes that will solve the reliability and lifetime problem that many micro-inverter companies are experiencing. Additionally having support from Cambridge University in terms or new topologies and research brings Enecsys in a beneficial position.

Enecsys has products for 60 and 72 crystalline silicon technology solar cell modules. Moreover, the micro-inverter can be connected with 1 or 2 solar modules depending on the model.



[16] http://www.enecsys.com/

Technical Specification	SMI-S240W-60-(see "ordering information" for region code)
Input Data (DC)	
Nominal Input Power	240W
Recommended Input Power (STC)	260W
Maximum DC Voltage	44V
Minimum DC Voltage	20V
MPPT Voltage Range	23V - 35V
Maximum Input Current	12A
Output Data (AC)	
Maximum AC Output Power	225W
Nominal AC Output Current	0.98A
Nominal Output Voltage	230V
Nominal Frequency	50Hz
Power Factor	> 0.95
Total Harmonic Distortion	< 5%
Efficiency	
Euro Efficiency	91.5%*1
Peak Efficiency	94.8%
Maximum Night Power Consumption	< 30mW
Mechanical Data	
Operating Temperature Range	-40°C to 85°C
Enclosure Rating	IP66
Dimensions (LxHxW)	262mm x 160mm x 35mm*2
Weight	1.8kg
Cooling	Natural Convection
Features & Compliance	
Safety Class Compliance	CE, pr EN 62109-1, AS/NZS 3100
EMC (Emission & Immunity) Compliance	EN61000-6-3, EN61000-6-1
Grid Connection Compliance	G83/ 1-1, VDE 0126-1, VDE 4105, IEC 61727, IEC 62116, AS 4777, RD 1699*3
Communication	Zigbee IEEE 802.15.4
Connector	MC4 compatible
PV Compatiblity	Compatible with most 60 cell modules
Warranty	20 Years (at full ambient temperature range)
Technology	Thin film capacitors
Isolation	Galvanic

4.5 SolarBridge Technologies[17]

SolarBridge was founded in 2004 to commercialize power electronics technologies created at the University of Illinois. Recognizing the need for more efficient and reliable inverter technologies in the solar industry, company founders began developing an innovative microinverter system for residential and commercial photovoltaic (PV) systems in 2008. In 2009, the company moved its headquarters to Austin, Texas. Led by a highly experienced management team, SolarBridge is enabling its partners to offer complete AC modules to the market with its fully integrated microinverter solution.

SolarBridge has launched a second generation of micro-inverters called Pantheon II. It has increased power than the previous model and a much smaller size. Below the data sheet for the second generation model can be seen.

[17] www.solarbridgetech.com

SPECIFICATIONS

INPUT (DC) DATA	P250LV-208/240	P250HV-208/240
Recommended STC Module Input Power Rating	235 W–280 W	235 W–280 W
Maximum Continuous Input Power	250 W	250 W
Maximum Input Voltage	48 V	64 V
MPPT Voltage Range	18 V–37 V	25 V–50 V
Maximum Power Voltage Range	25 V–37 V	33.5 V–46 V
Maximum DC Short Circuit Current	15 A	15 A
Maximum Input Current	10 A	7.5 A

OUTPUT (AC) DATA		
Maximum Continuous Output Power		238 W
Nominal Output Current	@240 VAC	0.99 A
	@208 VAC	1.14 A
Adjustable Operating Voltage Range	@240 VAC	211 V–264 V
	@208 VAC	183 V–229 V
Operating Frequency Range		59.3 Hz–60.5 Hz
Adjustable Frequency Range		57 Hz–62.5 Hz
Power Factor		> 0.99
Total Harmonic Distortion		IEEE 1547 Compliant

MECHANICAL DATA	
Ambient Temp Range	-40° C to +65° C
Operating Temp Range (Case)	-40° C to +85° C
Nighttime Power Consumption (Tare)	< 150 mW
Dimensions (W x H x D)	27.23 cm x 10.13 cm x 3.53 cm (10.72 in. x 3.99 in. x 1.39 in.)
Weight	1.6 kg (3.6 lbs.)
Weight With Cables	2.3 kg (5.0 lbs.)
Cooling	Natural Convection; No Fans
Enclosure Environmental Rating	Outdoor: Tested to UL 1703
AC Connector Type	Square Style, Double Locking

FEATURES		
Maximum Units Per 20A Branch	@240 VAC	16 (Single Phase)
	@208 VAC	24 (Three Phase)
Communication		Power Line Carrier
Warranty		25 Years
Compliance		FCC Part 15 Class B
		UL 1741 / CSA 107.1

EFFICIENCY	
Peak Inverter Efficiency	95.7%
CEC Weighted Efficiency	95%
Power Point Tracking Effectiveness	> 99.5%

4.6 Sparq Systems Inc[18]

Founded in 2011 in Kingston Canada, SPARQ Systems Inc. is the Canadian leader in developing advanced photovoltaic microinverter products and systems. SPARQ is focused initially on solar PV system applications under 300KW serving the residential and small commercial segment of the PV market. An initial investment of $500K has been given for the development and operation of Sparq.

The company has launched a microinverter solution with two products of different power range.

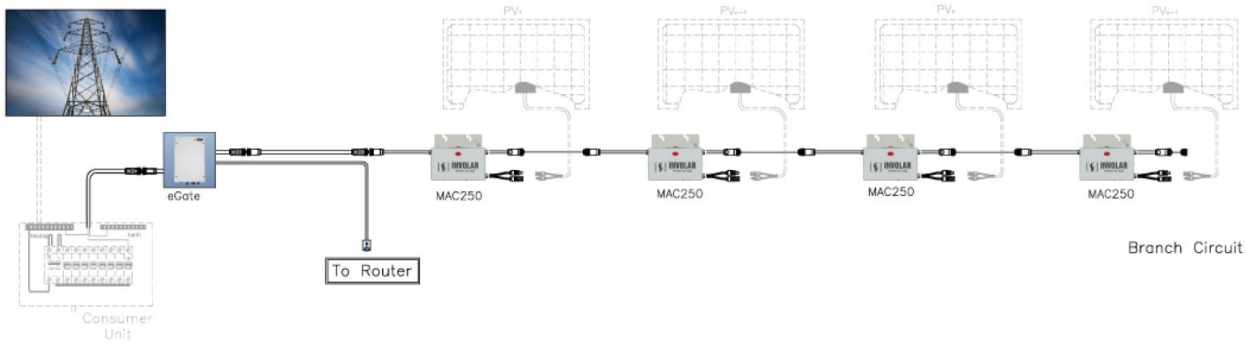
[18] http://www.sparqsys.com/

Model	S215NA3250 / S215NA3250T	S215NA2240 / S215NA2240T
Input Data (DC)		
Maximum power drawn from PV	230W	230W
Maximum input DC voltage	65V	50V
Maximum input DC current	10A	12A
Maximum power tracking voltage range	32V-50V	22V-40V
Minimum start-up voltage	33V	23V
Output Data (AC)		
Maximum output power	215W	215W
Nominal output voltage	240V	240V
Output voltage range	211V-264V	211V-264V
Maximum output current	0.9A	0.9A
Nominal output frequency	60Hz	60Hz
Output frequency range	59.3-60.5 Hz	59.3-60.5 Hz
Power factor	> 0.99	> 0.99
Output current THD	< 2%	< 2%
Maximum units per branch - S215NA3250 / S215NA2240 - S215NA3250T / S215NA2240T	 13 Determined by bus cable gauge	 13 Determined by bus cable gauge
Efficiency		
Peak efficiency	95%	94.5%
CEC efficiency	93.6%	93.1%
Nighttime power consumption	25mW	25mW
Mechanical Data		
Operating temperature range	-40°C to +65°C	-40°C to +65°C
Enclosure rating	NEMA 6 - outdoor	NEMA 6 - outdoor
Dimensions (L X W X H)	7.5" X 5" X 1.2"	7.5" X 5" X 1.2"
Weight - S215NA3250 / S215NA2240 - S215NA3250T / S215NA2240T	 4.3 lbs 3.2 lbs	 4.3 lbs 3.2 lbs
Cooling	Natural convection	Natural convection
Features		
Communication	Power line	Power line
Warranty	25 years	25 years

4.7 INVOLAR[19]

Founded in 2008 in China Involar started developing micro-inverter concepts in the end of 2009. Focused initially in string inverters INVOLAR has established strategic partnerships with several of the largest domestic solar photovoltaic module manufacturers, fundamentally ensuring sales of micro-inverters from the very beginning. With financial and field aid from the Shanghai Municipal People's Government and the Zhangjiang Hi-Tech Group, INVOLAR is leading the first Chinese domestic photovoltaic micro-inverter model project for a full exploration of the Chinese domestic micro-inverter market.

One product has been released till now, the MAC250. The data sheet can be seen below.

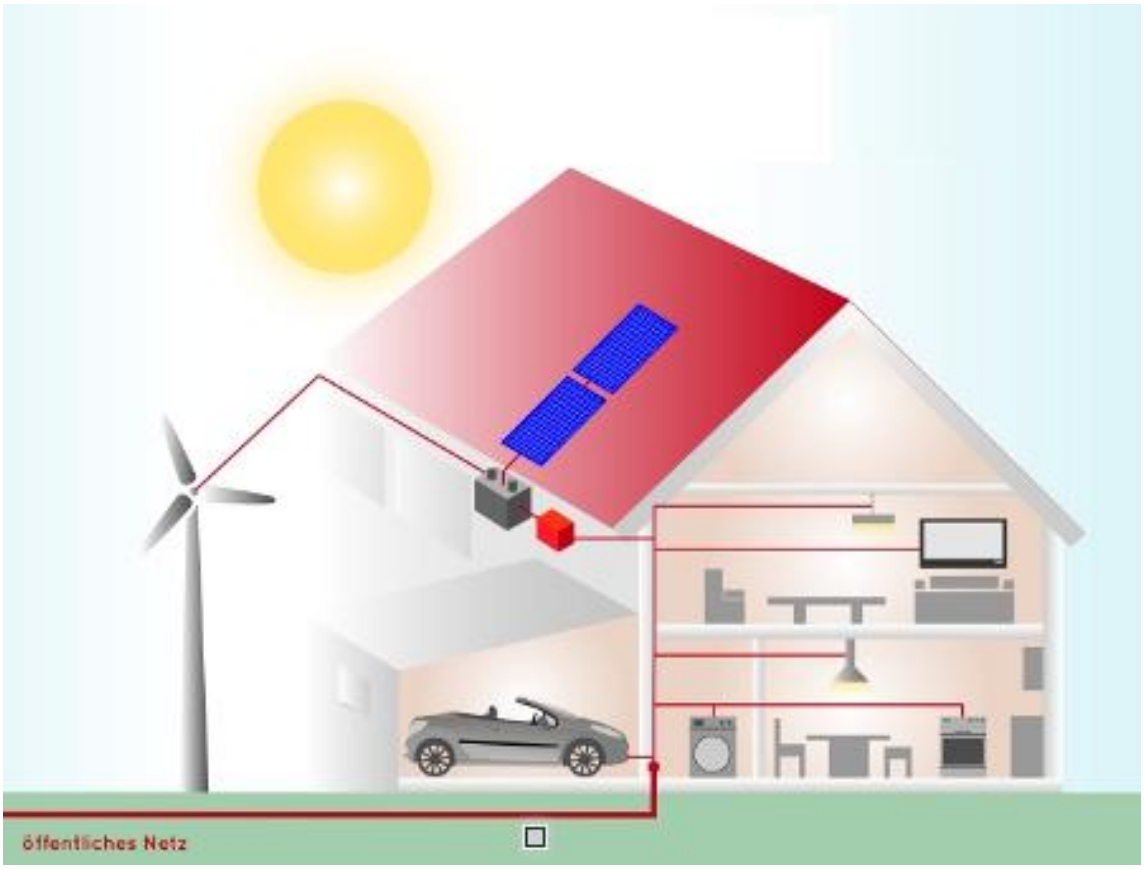


[19] www.involar.com

Model	MAC210	MAC250	MAC250-B	MAC300
Input Data (DC)				(available soon)
Maximum input DC power	210W	250W	250W	300W
Maximum input DC voltage	50V	50V	150V	50V
MPPT voltage range	24V~40V	24V~40V	72V~120V	24V~40V
Maximum DC input current	8.7A	10.4A	3.5A	10A
Output Data (AC)				
Rated AC output Power	180W	235W	235W	280W
Maximum AC output current	0.78A	1.07A	1.07A	1.22A
Rated AC output voltage	184V~264.5V	184V~264.5V	184V~264.5V	184V~264.5V
Maximum AC output frequency	47Hz~51Hz	47Hz~51Hz 59.3Hz~60.5Hz	47Hz~51Hz 59.3Hz~60.5Hz	47Hz~51Hz 59.3Hz~60.5Hz
Power factor	0.99	0.99	0.99	0.99
Total Harmonic Distortion	<3.5%	<3.5%	<3.5%	<3%
Maximum units per branch	20	16	16	13
Efficiency				
Peak inverter efficiency	95%	95%	95%	96%
CEC weighted efficiency	94%	94%	94%	95%
Nighttime power consumption	170mW	170mW	170mW	170mW
Mechanical Data				
Enclosure environmental rating	IP65/NEMA6 (outdoor)	IP65/NEMA6 (outdoor)	IP65/NEMA6 (outdoor)	IP65/NEMA6 (outdoor)
Operating temperature range	-40°C ~ +65°C	-40°C ~ +65°C	-40°C ~ +65°C	-40°C ~ +65°C
Dimensions (W×H×D)	230×138×35mm	230×138×35mm	230×138×35mm	230×138×35mm
Weight	2.4kg	2.4kg	2.4kg	2.4kg
Features				
PV Module Type	(Si 60/72 Cells)	(Si 60/72 Cells)	(Thin Film)	(Si 60/72 Cells)
Communication	PLCC	PLCC	PLCC	PLCC
Compliance	CE/CQC/ENEL	CE/VDE0126-1-1 /EN50438/ENEL /G83/SEMKO/CQC /UL1741/AS4777	CE/VDE0126-1-1 /EN50438/ENEL /G83/SEMKO/CQC /UL1741/AS4777	CE/VDE0126-1-1 /EN50438/ENEL /G83/SEMKO/CQC /UL1741/AS4777
Warranty	15-25 Years	15-25 Years	15-25 Years	15-25 Years

4.8 Dorfmüller Solaranlagen[20]

Dorfmüller Solaranlagen GmbH was founded in 1986 and is known for its high-quality photovoltaic products. From 2000 to 2010, the predominantly focus was on the planning and construction of photovoltaic installations. The priority since 2010 has exclusively returned to the production and ongoing development of inverter technology. Together with the Centre for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW), there is also a development of inverter for fuels cells.



[20] http://dorfmueller-solaranlagen.de/en/products/device-overview.html

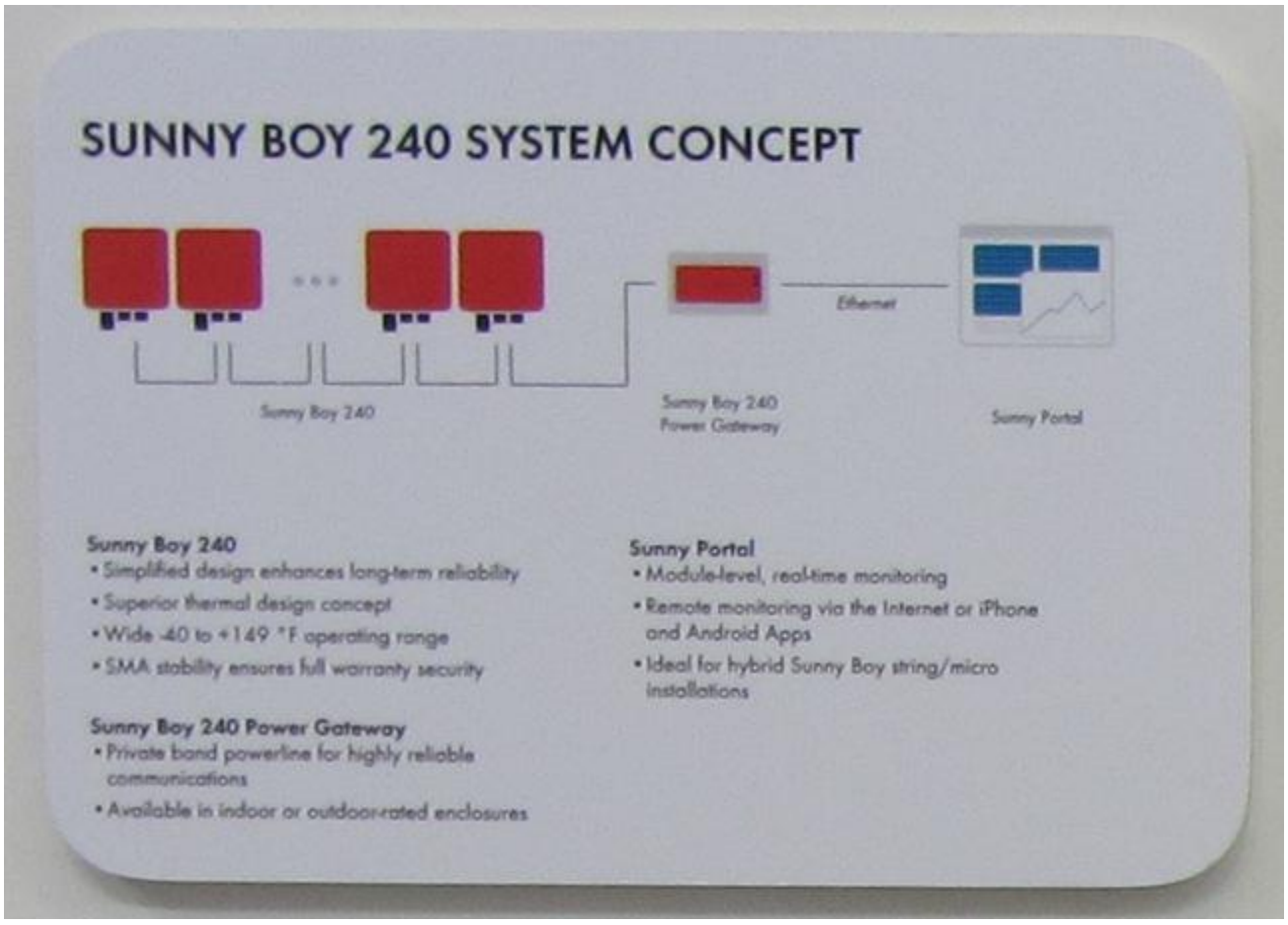
Technical Specifications

Model	DMI 350/35
Nominal Input Power (T_U = 30°C, 3h Permanent Run)	330 W
Maximum Input Power	330 W
Nominal Power Output	300 W
Maximum Power Output	300 W
Maximum Efficiency	92,5 %
EURO Efficiency	90,9 %
Mains Input from	4 W
Standby Losses	0 W
Maximum DC Input Voltage	85 V
MPP Voltage Range	29 V – 70 V
Nominal and Turn On Voltage	35 V
Output Voltage	230 VAC (depending on country)
Output Current	Regulated sine wave, mains frequency 50 Hz
Cos φ	1 regulated
Ambient Temperature Range	-25°C up to +70°C
Permissible Humidity	0 – 95 %
Type of Enclosure	IP 65
Circuit Feedback	DIN VDE 0838 (EN61000-6 part 1 – 4), EN60555
Conformity to VDE-AR-N 4105	For plants <3,68 kVA, ext. grid protection required
Over Temperature Protection	Dynamic power management
Noise Emission	35 dB
Potential Separation	Toroidal transformer
Certificate	CE
Dimensions (LxWxH) in mm	385x170x95 mm
Weight in kg	7,3 kg

4.9 SMA AG[21]

SMA Solar Technology AG is a global leader in the development, production and sales of PV inverters and, as an energy management group, offers innovative key technologies for future power supply structures. SMA is represented in all important photovoltaics markets in 19 countries on four continents. The company has a staff of over 5,500 and reached a sales volume of EUR 1.7 billion in 2011.

Finally SMA agreed to develop a micro-inverter solution after acquiring the Dutch OKE Services. A preliminary data sheet has been published but details of the product are still subject to change.



[21] http://www.sma-america.com/en_US/products/grid-tied-inverters/sunny-boy/sunny-boy-240-us.html

Technical data	Sunny Boy 240-US
Input (DC)	
Max. DC power (@ cos ϕ = 1)	250 W
Max. input voltage	45 V
MPP voltage range/rated input voltage	23 V - 32 V / 29.5 V
Min. input voltage/max. initial input voltage	23 V / 40 V
Max. input current	8.5 A
Max. input current per string	8.5 A
Number of independent MPP inputs/strings per MPP input	1/1
Output (AC)	
Rated power (@ 240 V, 60 Hz)	240 W
Max. apparent AC power	240 VA
Nominal AC voltage/range	2 x 120 V / 211 V – 264 V
AC power frequency/range	60 Hz / 59.3 Hz - 60.5 Hz
Rated power frequency/rated grid voltage	60 Hz / 240 V
Max. output current	1 A
Power factor at rated power	1
Feed-in phases/connection phases	1/2
Efficiency (AC)	
Max. efficiency/CEC efficiency	95.5% / 95%
Protective devices	
Ground fault monitoring/grid monitoring	yes/yes
DC reverse polarity protection/AC short-circuit current capability/galvanically isolated	yes/yes/yes

4.10 Altenergy Power Systems[22]

APS was founded in October 2009 in Silicon Valley. Then a joint venture was established in Jiaxing, Zhejiang in March 2010. APS is devoted to R&D and commercialization of micro-inverter system and has become a professional supplier of Microinverter products and system solution. By March 2013, APS products have been shipped out to dozens of countries and regions including Europe, North America, Australia, China, etc. The cumulative shipments reach to 80,000 units and the installation capacity is 20 MW. More than thousands of APS microinverter systems have been installed and running smoothly around the world. APS business covers microinverter system development, AC module, Solar kits, domestic and international microinverter system EPC and residential distributed PV system solutions. APS has become the most comprehensive strength high-tech innovation enterprise and the leading brand in the microinverter industry.

[22] http://en.altenergy-power.com/company/index.aspx

YC250 Microinverter

TYPE	YC250-SAA Australia	YC250-CN China	YC250-EU Europe	YC250-NA USA	YC250-MX Mexico
Input Data (DC)					
Recommended PV module power (STC) range (W)	180~310	180~310	180~310	180~310	180~310
MPPT voltage range (V)			22~45		
Operation voltage range (V)			16~45		
Maximum input voltage (V)			55		
Startup voltage (V)			16		
Maximum input current (A)	12	12	10.5	10.5	10.5
Output Data (AC)					
Maximum output power (W)	250	250	250	225	225
Maximum output current (A)	1.09	1.14	1.08	0.937	1.77
Maximum output voltage (V)	230/180-270[1]	220/180-242[1]	230/207-253[1]	240/211-264[1]	127/95-155[1]
Nominal output frequency (Hz)	50/45-55[1]	50/45.5-54.5[1]	50/47-53[1]	60/59.3-60.5[1]	60/55-65[1]
Power factor			>0.99		
Total harmonic distortion			<3%		
Maximum units per branch	22	22	14	17/21	8/10
Efficiency					
Peak inverter efficiency			95.5%		
Mechanical Data					
Operating ambient temperature (℃)			-40 ~ +65		
Operating internal temperature (℃)			-40 ~ +85		
Storage temperature range (℃)			-40 ~ +85		
Dimensions (W x H x D, mm)			160 × 150 × 29		
Weight (kg)			1.5		
Enclosure rating	IP65	IP65	IP65	NEMA 3R	NEMA 3R
Cooling			Nature Convection		
Features & Compliance					
Communication			Powerline		
Design lifetime (year)			25		
Emissions & immunity (EMC) compliance	EN61000-6-3 : 2007	CNCA/CTS0004-2009A	EN 61000-1/2/3/4	FCCPART15,ANSIC63.4IECS-003	
Safety class compliance	AS/NZS 3100:2009	IEC2109-1:2010CNCA/ CTS004:2009A	EN 62109-1&2	UL Std.1741,CSA Std.C22.2 NO.107.1-01	NOM
Grid connection compliance	AS4777.2:2005 AS4777.3:2005	CNCA/CTS0004-2009A	EN 50438	IEEE 1547	

Programmable through ECU to meet customer need.

APS America
Add: 19925 Stevens Creek Blvd, Suite 100, Cupertino, CA 95014
Tel: 01 408 973 7888
Washington office: 1015 Hostmark St.Suite 104 Poulsob, WA 98370
Tel: 01 206 855 5100

APS Australia
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Tel: +61 2 9633 3478

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Add: No. 1, Yatai Road, Nanhu District, Jiaxing, Zhejiang
Tel: +86 573 8398 6967

APS Shanghai China
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Tel: +86 21 3392 8205

APS Beijing China
Add: Room 505, No. 10 Building, Jianwai SOHO, No. 39 East Sanhuan zhong Road, Chaoyang District, Beijing.
Tel: +86 010 5266 5807

24-hour Hotline: 400-100-8470
info@altenergy-power.com

4.11 Darfon[23]

Darfon Electronics Corp. was founded in May 1997 and is dedicated to providing “one stop shopping” precision components to ODM and OEM clients. Darfon’s product lines include: Human Interface Devices, Power & Energy Devices, Integrated Components & Material, and Green Devices. Darfon is dedicated to producing high-quality solar products. From its micro inverters to its web-based monitoring system, Darfon believes in creating a solar power solution that is efficient and dependable, as well as, user-friendly.

[23] http://www.darfon.com/English/GP_MicroInverter.asp

Input Data (DC)	Type 1	Type 2
Recommended input power (STC)	240W	240W
Maximum input DC voltage	60V	60V
Peak power tracking voltage	30~50V	30~50V
Min./Max. start voltage	25V/60V	25V/60V
Max. DC short circuit current	12A	12A
Max. input current	10A	10A
Output Data (AC)	Type 1	Type 2
Maximum output power	220W	220W
Nominal output current	1.833A	0.916A
Nominal voltage/range	120V/105~132V	240V/211~264V
Nominal frequency/range	60.0/59.3~60.5Hz	60.0/59.3~60.5Hz
Power factor	>0.95	>0.95
Efficiency		
Peak inverter efficiency	95%	95%
CEC weighted efficiency	94%	94%
Nominal MPP tracking	99%	99%
Mechanical Data		
Operating temperature range	-40°C to +65°C	-40°C to +65°C
Night time power consumption	45mW	45mW
Dimensions (WxHxD)	22cm x 1.3cm x 3.25cm	22cm x 1.3cm x 3.25cm
Features		
Communication	Power-line	Power-line
Warranty	15 Years	15 Years

4.12 AE Conversion GmbH[24]

AE conversion GmbH is a newly formed independent corporation, originating from APtronic's solar-division and under the management of APtronic Co-Founder and former CEO. The company is now owned by Phoenix Contact. APtronic-Solar core personnel, technology, products and facilities for R&D and manufacturing have been transferred to AEconversion with its registered office in Soest, Germany. AEconversion is dedicated to adaptive power conversion for the renewable energy sector, including but not limited to the development, production and distribution of micro-inverters for PV applications. It is AEconversion's commitment to continue developing innovative products and to focus on expanding technical competence and sales.

[24] http://www.aptronic-solar.com/en/index.html

INV250-45

Micro-Inverter

Description

The AEconversion Micro-Inverter INV250-45 converts the generated energy into grid-compliant alternating current. For this, the INV250-45 is directly connected to a module. The Individual conversion allows optimal utilization of solar energy.
The micro-inverter INV250-45 operates up to a maximum power of 250W with a maximum PV input voltage of 45V.

In systems with central or string inverters, the series connection of the PV modules often causes energy losses. If the output from a module drops, for example through shading, it reduces the performance of the whole string. This problem is solved by micro-inverters, because in systems with these inverters, the modules work independently and guarantee the highest possible.

Input
- Maximum PV power: 250 W
- Maximum DC voltage: 45 V
- Min./Max. start voltage: 18 V / 45 V
- MPP range: 20 ... 40 V
- Maximum DC current: 11 A

Output
- Maximum AC Power: 240W
- Nominal Current: 1.0A
- Power factor: > 0.99

Efficiency
- Peak inverter efficiency: 93.5%
- European efficiency: 92.6%
- Nominal MPP efficiency: 99.8%

Features
- Communication Versions: Powerline / RS-485 / No Com
- MSD integrated acc. to VDE AR-N 4105
- Safety class: Class I

Mechanical Data
- Operating Temperature: -25°C ... +70°C
- Night time power consumption: 30mW
- Max. altitude a.s.l.: 2000m

Housing
- 314mm x 267mm x 66.5mm (BxHxT)
- Weight: 2.5kg
- Cooling: Natural convection
- Enclosure mterial: Aluminum

50 Hz-Version
- Nominal AC voltage: 230V
- Nominal AC voltage range: 184V ... 264V
- Frequency: 50.0 Hz
- Frequency range: 47.5 Hz ... 51.5 Hz
- Productsafety: IEC 62103:2003, IEC 62109-1:2010, IEC 55011B, EN 50178:1997
- EMC: EN 61000-6-2, EN 61000-6-3

60 Hz-Version
- Nominal AC voltage: 208 V or 240 V
- Nominal AC voltage range: 184V ... 264V
- Frequency: 60.0 Hz
- Frequency range: 59.5 Hz ... 60.3 Hz
- Productsafety: UL 1741:2010, IEEE 1547:2003, CSA C22.2
- EMC: FCC Part 15 Class B

4.13 Apparent Inc[25]

Apparent, Inc., a clean technology company, provides products and services to maximize the performance of renewable energy assets. Apparent's patented and breakthrough technologies enable renewable energy assets to extract more energy from renewable sources, and produce apparent energy (consisting of both real and reactive energy) as needed. Renewable energy assets employing Apparent's technology operate on parity with traditional energy resources. Which means renewable energy assets can fully integrate with the grid to participate in markets previously limited to traditional systems.

[25] http://www.apparent.com/

Electrical Characteristics	
Power Source	Photovoltaic Only
Startup Time Initial Power On	300 Seconds
Overload Current Protection Circuit	Current Limiting
Power Extraction Method	Proprietary Power Transfer and Tracking
Efficiency	91%
PV Panel (input)	
Max PV Open Circuit Voltage	42 VDC
Min PV Operational Voltage	18 VDC
Min Solar Panel Wattage	100W
Max Solar Panel Wattage	240W
Reverse Polarity Protection	Yes
Rated Input Current	8A
Max Input Short Circuit Current	10A DC
Overcurrent Protection	Yes
AC (output)	
AC Output Voltage	108-132VAC 60Hz
AC Output Rated Current	1.67A
AC Output Maximum Current	2.36A
AC Output Continuous Real Power	200 Watts
AC Output Continuous Apparent Power	283 VA
AC Output Power Factor Range	-0.7 to +0.7
AC Output Maximum Fault Current	6.3A
AC Overcurrent Protection	Yes

Physical Characteristics	
Solar Panel DC Input Connector	Positive Latch Locking
Output Connector	Dual Power/Communication
Wire Size	AC Cable, 12 Gauge
Dimensions	8.25" x 5.375" (7.75" w/bracket) x 2.30"
Weight	7.0 lbs. / 3.2 kg
Outdoor Use	Yes
Enclosure Rating	NEMA 6/IP67
Mounting	Indoor/Outdoor
Environmental	
Operating Temperature Minimum	-40°C
Operating Temperature Maximum	60° C
Monitoring	
Input /Output Status	Ethernet

4.14 Samil Power[26]

Samil Power Co., Ltd. is an international company, which was emerged out of the Samil Group in 2008. Samil Power covers the whole product portfolio - from micro inverter over string inverter up to MW station, which helps customers to maximize the yield and reduce the investment payback period of their photovoltaic plants - from small residential rooftop to midsize commercial rooftop/ground mounted and large utility-scale PV plants. To date more than 200,000 string inverter from Samil Power have been installed in more than 20 countries.

[26] www.samilpower.com

Inverter model	SolarPond 240HF
Input (DC)	
Max. DC input power [W]	250
Max. DC input voltage [V]	48
Start voltage [V]	26
MPPT voltage range (full load) [V]	27~40
Operating voltage range [V]	21~48
Max. DC input short circuit current [A]	15
Max. DC input current [A]	9.5
GFDI [mA]	1000
Output (AC)	
Max. AC output power (-40~+65 °C) [W]	240
Output power factor (%)	>95%
Nominal voltage [V]	AC 230
Nominal voltage range [V]	AC 207~264
Max. AC output current [A]	1.16
Nominal frequency [Hz]	50.0
Nominal frequency range [Hz]	47.5~52.5
Max. AC output over current protection [A]	20
Max. AC output fault current & duration [A]	1.5Arms over 3 cycles, 37.8Apeak 1.74ms duration
Max. inverters per 20amp AC branch circuit	17
THDi (at rated power)	<5%
Power consumption at night [mW]	50
Efficiency	
Max. efficiency	96.0%
EURO efficiency	95.0%
CEC efficiency	95.5%
MPPT efficiency	>99.9%
General Data	
Dimensions (WxHxD) [mm/in]	165x170x32/6.5x6.7x1.3
Weight [kg/lb]	2/4.4
Ingress protection (IP)	IP67
Cooling	Natural convection
Communication	ZigBee (standard)
Warranty (10 years)	Standard
Operating temperature range [°C/°F]	-40~+85/-40~+185
Night consumption [mW]	50
Certificates	CE, AS 4777:2005-2&3, AS 61000-6.3, IEC 62109-1&2, C-Tick

4.15 iEnergy[27]

Founded in 2009, i-Energy is a pioneer in advanced PV power optimization and conversion products for residential and commercial applications, dedicated to making smart renewable energy for all. i-Energy's solar micro inverter solutions offer high reliability, increased energy optimization, enhanced safety and simplified installation and service to the solar energy field.

[27] http://www.i-energyinc.com/en/products/i-micro-inverter.html

DC Input Data

Recommended input power	**240-265 W**
Peak power tracking range@230W	**30-50V**
MPPT operating range	**25-50V**
Solar panel input voltage range	**25-59V**
Max. DC short circuit current	**12A**
Max. input current	**10A**

Efficiency

CEC weighted efficiency	**93%**
Peak inverter efficiency	**94%**
Static MPPT efficiency	**99.30%**
Night time power consumption	**<30 mW**

Features

Communication	**PLC**
Warranty	**10 years limited warranty/ 15,20,25 years warranty opt. Insured by CHUBB**
Compliance	**EN62109-1, EN50438: 2007 VDE-0126 IEC61000-6-3, IEC61000-6-1**

AC Output Data

TECHNICAL DATA

Max. output power	**230W**
Nominal output current	**1A**
Nominal/extended voltage range	**230V/184-253V**
Nominal/extended frequency range	**50Hz/48-51Hz**
Power factor	**>0.95**
Total harmonic distortion	**<3%**
Max. units per 20A branch circuit	**17pcs**

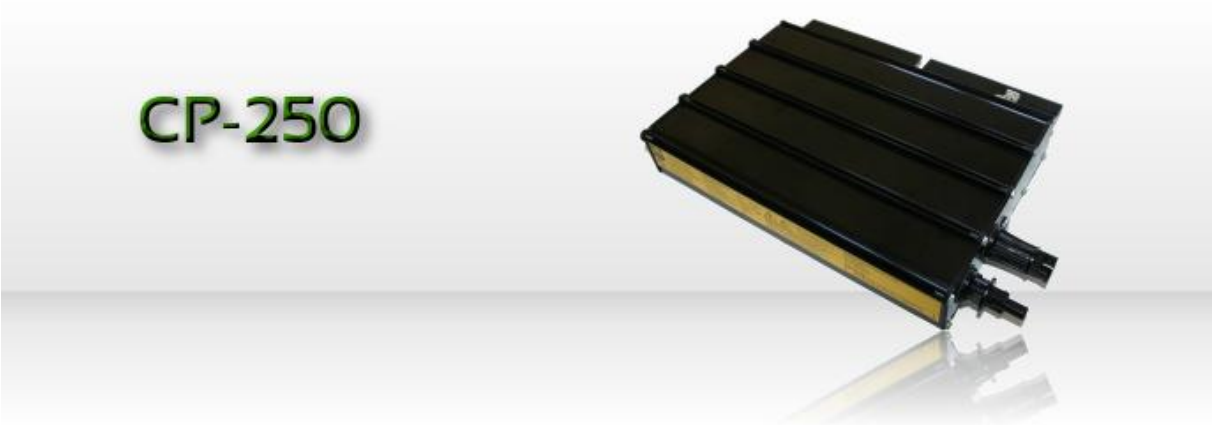
Mechanical Data

Ambient temperature range	**-40°C to +65°C**
Operating temperature range (internal)	**-40°C to +85°C**
Dimensions (WxHxD)	**23.2* 21.2*4.26cm**
Weight	**2.2 kg (4.8 lbs)**
Cooling	**Natural convection - no fans**
Enclosure environmental rating	**IP66**

VDE0126

4.16 Chilicon Power[28]

Having been involved with generously financed startups in the past, the founders know the inefficiencies that can develop and the further reality that often a small core group provide the 'heavy lifting' for the rest of the enterprise. Chilicon Power is afforded tremendous flexibility through this approach. Chilicon Power micro inverters are designed and manufactured in California USA.



[28] http://www.chiliconpower.com/index.php/products/cp-250

CP-250-60-208/240-MC4 Microinverter Specifications

INPUT DATA (DC)		
Recommended input power (STC)	190 - 300 W	
Maximum DC input voltage	40 V	
MPPT voltage range	22 – 38.5 V	
Operating range	18 – 38.5 V	
Min./Max. start voltage	22 – 40 V	
Max. DC input short circuit current	21 A	
Max. DC input current	12 A	
Ground fault protection	Isolated 2500 Vrms input/output/chassis	
OUTPUT DATA (AC)	**@ 208 V**	**@ 240 V**
Peak sustainable output power	250 W	250 W
Rated output power	220 W	220 W
Max. continuous output current	1.20 A (250 W @ 208 V)	1.04 A (250 W @ 240 V)
Nominal output voltage / range	208 / 183 – 229 V	240 / 211 – 264 V
Extended output voltage range	133 / 150 / 166 – 250 V	153 / 173 / 192 – 288 V
Nominal frequency / range	60.0 / 59.3 – 60.5 Hz	60.0 / 59.3 – 60.5 Hz
Extended frequency range	54.22 – 66.75 Hz	54.22 – 66.75 Hz
Power factor	> 0.95	> 0.95
Maximum units per 20 A branch circuit	13	15
Maximum output fault current & duration	1.6 A peak for > 10% of any cycle	1.6 A peak for > 10% of any cycle
Maximum output overcurrent protection	6.3 A	6.3 A
EFFICIENCY		
CEC weighted efficiency	96.09 %	
Peak inverter efficiency	96.6 %	
Static MPPT efficiency (EN 50530)	99.5 % - 99.8 %	
Night time power consumption	40 mW @ 208V, 80 mW @ 240 V	
MECHANICAL DATA		
Ambient temperature range	-40°C to +65°C	
Dimension (W x H x D) including connectors	12” x 8” x 1.8”	
Weight	1.55 kg (3.4 lbs)	
Enclosure rating	NEMA 4X	
FEATURES		
Communication	Power line (130.2 kHz carrier)	
Monitoring	Free monitoring via gateway or online software	
Compliance	UL1741, IEEE std 1547, IEEE std C62.41.2, CSA C22.2 NO. 107.1 & CISPR 22 Class B	
Compatibility	Most 60-cell PV modules	

Brands	Model	weighted eff (%)	Mppt range (V)	topology	enclosure	communication	monitoring	power range (W)	warranty (years)	dimensions (mm)	weight (kgr)	Market entry	Estimated shipments (MW)
Apparent Inc	MGI220	91,0	n.a	n.a	IP67	ethernet	Energy Review	100-240	15	203,2 x 127 x 50,8	3,2		
Dornmuller	DMI 350/35	90,9(Euro)	29-70	electrolytic capacitors	IP65	power line	n.a	300	n.a	385 x 170 x 90	7,3	n.a	n.a
Enecsys	SMI-S240W-60	91,5(Euro)	23-35	thin film capacitors	IP66	wireless	n.a	260	20	262 x 160 x 35	1.8	Q2 2010	<50
AE Conversion	INV250-45	92,6 (Euro)	20-40	n.a	n.a	power line	n.a	250	n.a	314 x 267 x 66,5	2,5	Q1 2010	n.a
iEnergy	iMicro inverter	93 (CEC)	25-50	n.a	IP66	power line	n.a	240-265	10	232 X 212 X 42,6	2,2	2010	<15
Sparq Systems	S215NA2240	93,1(CEC)	22-40	n.a	IP67	power line	n.a	230	25	195 x 127 x 30	1,36	Q4 2011	<10
Darfon	MIG300VD00	94 (CEC)	30-50	n.a	n.a	power line	n.a	240	15	220 x 32,5 x 13	n.a	Q2 2012	<7,2
Samil Power	SolarPond 240HF	95 (Euro)	27-40	n.a	IP67	wireless	n.a	250	25	165 x 170 x 32	2	2013	n.a
SolarBridge	P250 LV-208/240	95(CEC)	18-37	thin film capacitors	n.a	power line	n.a	235-280	25	273 x 201 x 35	1,6	Q3 2011	<50
Involar	MAC300	95(CEC)	24-40	n.a	IP65	power line	n.a	210-300	15	230 x 138 x 35	2,4	Q2 2010	<30
SMA	Sunny boy 240US	95(CEC)	23-32	n.a	IP14	power line	Sunny Portal	250	10	188 x 218 x 43	1,3	Q4 2012	<10
Altenergy Power Systems	YC250-EU	95,5 (Peak)	22-45	n.a	IP65	power line	n.a	180-280	25	160 x 150 x 29	1,5	Q2 2011	<20
Enphase	M215	96(CEC)	22-36	electrolytic capacitors	IP67	power line	Enlighten software	190-260	25	173 X 164 X 25	1,6	Q2 2008	>850
Power One	micro-0.25-I-OUTD/240	96(CEC)	25-60	thin film capacitors	IP56	wireless	Aurora CDD	265-320	10	266 x 246 x 35	1,65	Q4 2012	<20
Helios	SMI250	94,5(Euro)	16-48	thin film capacitors	IP66	power line	n.a	275	25	264 x 245 x 34	1,65	Q1 2015	n.a
Chilicon Power	CP250	96,09 (CEC)	22-38,5	thin film capacitors	IP66	power line	Cloud monitoring	190-300	10	304,8 x 203,2 x 45,7	1,55	Q32013	<5
Enphase	M250	96,5 (CEC)	27-39	electrolytic capacitors	IP67	power line	Enlighten software	210-300	25	171 X 173 X 30	2	Q2 2013	n.a

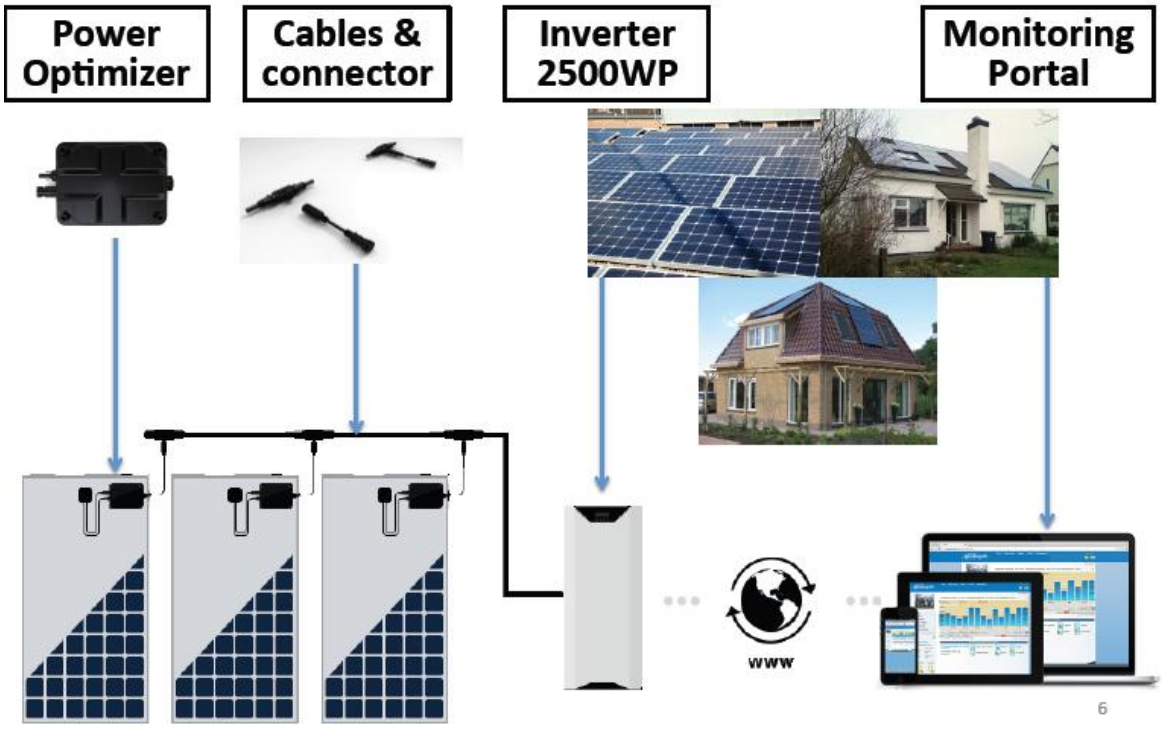
Table 1 : Comparison table of micro inverters according to data sheet

Chapter 5: Power Optimizers

5.1 Femtogrid Energy Solutions[29]

Femtogrid is a power management company founded in Amsterdam. Femtogrid has contributed to the installation of about 1 MWp PV systems. The majority of the installations have been executed in the Netherlands. Installations average between residential and small commercial rooftop installations from 0.66 kWp up to and including 24.5 kWp. The products are certified for the Netherlands, Belgium, Germany, Spain, Italy and the United Kingdom.

Femtogrid's solutions for renewable energy installations are available business to business (B2B).



[29] www.femtogrid.com

Specifications Femtogrid Solar Power Optimizer PO310

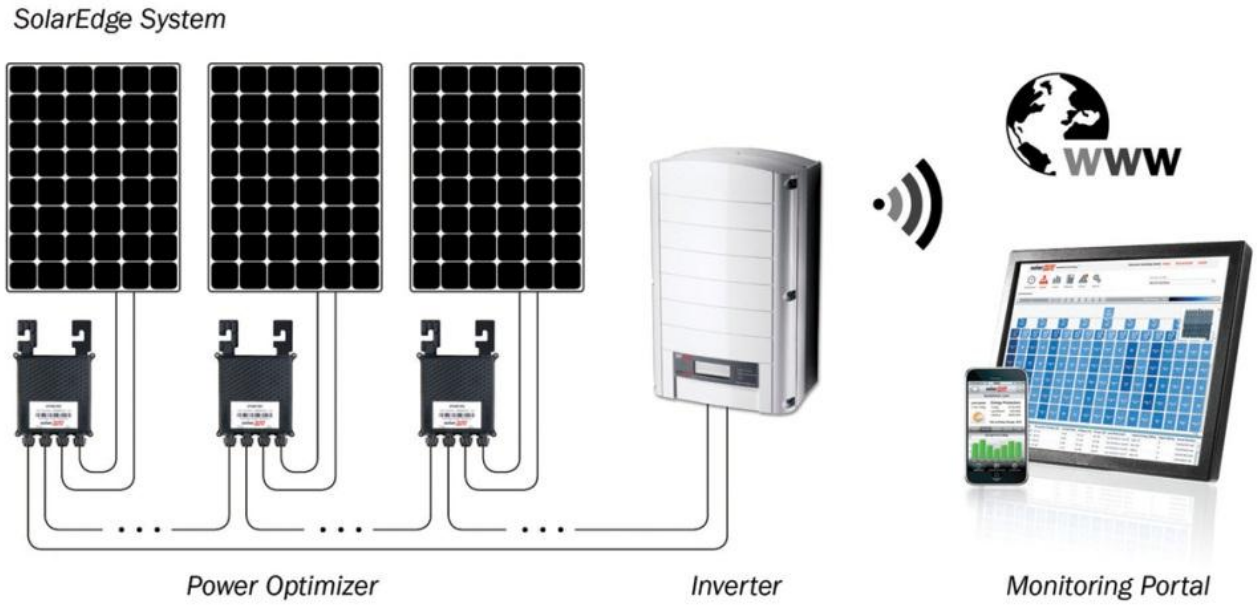
Solar Input (DC from modules)		
Maximum DC power	310	W
Nominal DC power	300	W
MPPT operating voltage range	8 - 42	Vdc
Vin min-max	5 - 55	Vdc
Maximum DC current	11	A
MPPT	Decentralized per module	
Compatible with types of modules	Mono- and polycristalline	
Power Optimizer Output (DC out)		
Nominal DC power	310	W
Nominal output voltage (Femtogrid voltage)	380	Vdc
Maximum output current	0.9	A
Eficiency	>97	%
MPPT efficiency	>99.9	%
Efficiency, European related (Euro ETA)	>97	%
Standard Compliance		
EMC: Immunity	EN61000-4-2/3/4/5/6/11	
EMC: Emission	EN55022/EN60601-1-2	
	EN55022/EN61000-3-3	
Safety	EN60950	
CE/RoHS/WEEE/REACH	Yes	
Safety class	Class II	
Degree of protection	IP67	
General		
Relative humidity (non-condensing)	0 - 95	% RH
Dimensions with bracket (WxLxH)	135x225x50	mm
Ambient temperature	-40/+65	°C
Weight	0.75	kg
DC connections	MC4	Type
Output connections	3 Pole ALTW/Femtogrid	Type
Switch-on power	0.5	W
Safetyline voltage ('safety')	48	Vdc

Specifications PO300

Solar Input (DC from solar panels)		
Maximum DC power	300	W
Nominal DC power	250	W
MPPT operating voltage range	8 - 42	Vdc
Maximum DC current	10	A
MPPT	decentralized per panel	
Compatible with types of solar panels	mono- and polycristalline	
Power Optimizer Output (DC in operation)		
Nominal DC power	250	W
Nominal output voltage (Femtogrid voltage)	380	Vdc
Maximum output current	0.8	A
Maximum efficiency	97.4	%
MPPT efficiency	>99	%
Efficiency, European related (Euro ETA)	95.7	%
Standard Compliance		
EMC: Immunity	EN61000-4-2/3/4/5/6/11	
EMC: Emission	EN55022/EN60601-1-2	
	EN55022/EN61000-3-3	
Safety	EN60950	
CE/RoHS/WEEE/REACH	Yes	
Safety class	Class II	
Degree of protection	IP65	
General		
Relative humidity (non-condensing)	0 - 95	% RH
Dimensions with bracket (WxLxH)	288x342x51	mm
Ambient temperature	-40/+65	°C
Weight	1.45	kg
DC connections	MC4	Type
Output connections	Custom made by Wieland for Femtogrid	Type
Switch-on power	0.5	W
Safetyline voltage ('neutral')	48	V
Femtogrid feed through current in-out	20	A

5.2 SolarEdge[30]

SolarEdge provides an end-to-end distributed solar power harvesting and PV monitoring solution, maximizing the power generation of residential, commercial and large-scale PV system installations. Founded in 2006, SolarEdge established the DC power optimizer segment and is leading it with over 70% market share. By Q4 2013, SolarEdge has shipped over 2,700,000 power optimizers to more than 50 countries worldwide. With strategic partnerships across the PV value-chain from module manufacturers to integrators. The SolarEdge portfolio of products includes power optimizers, highly efficient PV inverters and a web portal for module-level monitoring and fault detection.



[30] http://www.solaredge.com/

TECHNICAL DATA

	OPA250-RV	OPA300-LV	OPA400-MV	OPA400-EV	
INPUT					
Rated Input DC power (*)	250	300	400	400	W
Absolute Maximum Input Voltage (Voc)	47	55	75	130	Vdc
MPPT Operating Range	5 - 47	5 - 55	5 - 75	15 - 130	Vdc
Maximum Input Current (Isc)	10	10	12.5	7	Adc
Maximum Efficiency	99.5				%
Weighted Efficiency	98.9				%
Overvoltage Category	II				
OUTPUT DURING OPERATION (POWER OPTIMIZER CONNECTED TO A SOLAREDGE INVERTER)					
Maximum Output Current	15				Adc
Operating Output Voltage	5 - 60				Vdc
Total Maximum String Voltage - US and EU 1-ph	500				Vdc
Total Maximum String Voltage - EU 3-ph	950				Vdc
PV SYSTEM DESIGN USING A SOLAREDGE INVERTER					
Minimum Number of Power Optimizers per String (1 or More Modules per power optimizer)	8 (1-ph system) / 16 (3-ph system)				
Maximum Number of Power Optimizers per String (1 or More Modules per power optimizer)	Module power dependent; maximum 25 (1-ph system) / 50 (3-ph system)				
Maximum Power per String	5250 (1-ph system) / 11250 (3-ph system)				W
Parallel Strings of Different Lengths or Orientations	Yes				
OUTPUT DURING STANDBY (POWER OPTIMIZER DISCONNECTED FROM INVERTER OR INVERTER OFF)					
Safety Output Voltage per Power Optimizer	1 (**)				Vdc
OUTPUT DURING OPERATION (POWER OPTIMIZER CONNECTED TO A THIRD PARTY INVERTER)					
Maximum Output Current	15		-		Adc
Operating Output Voltage	5 - Voc		-		Vdc
Maximum System Voltage - US	600		-		Vdc
Maximum System Voltage - EU	1000		-		Vdc
PV SYSTEM DESIGN USING A THIRD PARTY INVERTER					
According to Inverter Design Rules					
STANDARD COMPLIANCE					
EMC	FCC Part15 Class B, IEC61000-6-2, IEC61000-6-3				
Safety	IEC-62103 (class II safety), UL1741				
Material	UL-94 (5-VA), UV Resistant				
RoHS	Yes				
INSTALLATION SPECIFICATIONS					
Dimensions includ. mounting bracket (W x L x H)	125 x 132 x 30 / 4.9 x 5.2 x 1.2				mm / in
Dimensions exclud. mounting bracket (W x L x H)	125 x 90 x 25 / 4.9 x 3.5 x 1.0				mm / in
Net Weight (Weight Includ. cables)	400 (800) / 0.8 (1.7)				gr / lb
Output Wire Type	Double insulated PV wire; 6 mm^2 ; MC4				
Output Wire Length	0.95 m / 3 ft	0.95 m / 3 ft	1.2 m / 4 ft	1.5 m / 5 ft	
Operating Temperature Range	-40 - +85 / -40 - +185				˚C / ºF
Input Connector	MC4 / MC3 / Tyco / H+S / Amphenol				
Protection Rating	IP67 / NEMA6				
Relative Humidity	0 - 100				%

(*) Rated STC power of the module. Module of up to +5% power tolerance allowed

(**) When either a SolarEdge Inverter or a SolarEdge Safety and Monitoring Interface (if connected to a 3rd party Inverter) is turned off

USA ■ Germany ■ Italy ■ France ■ Japan ■ China ■ Israel

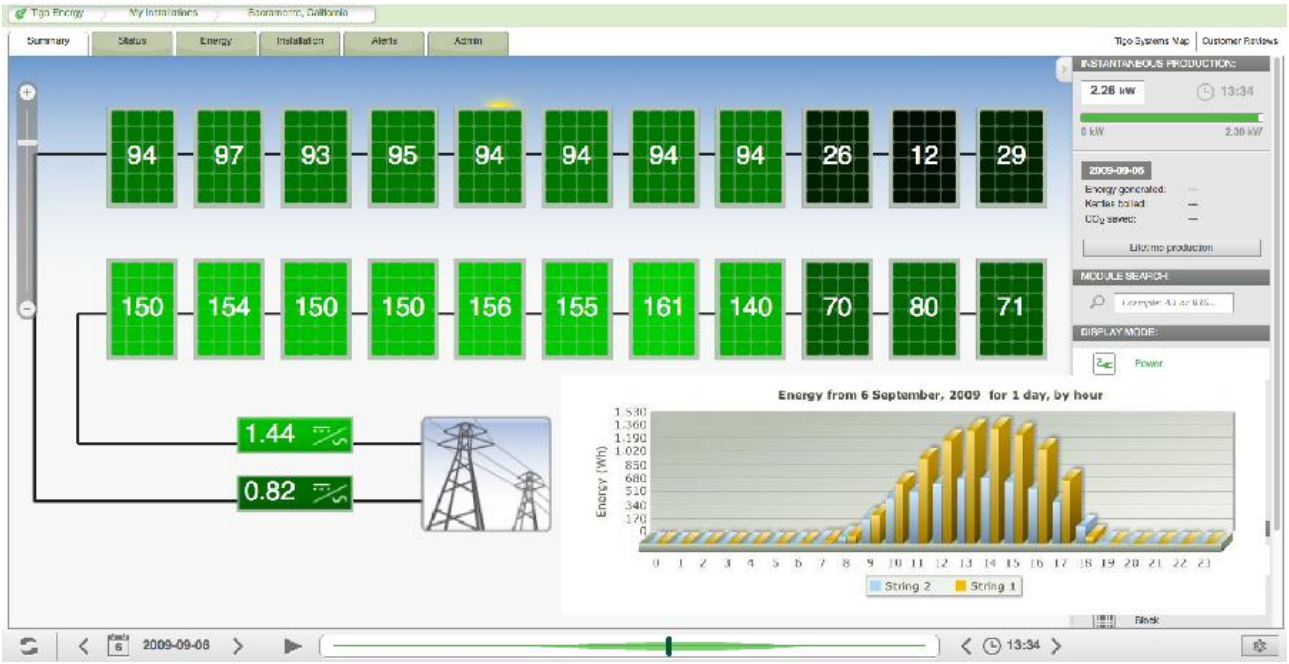
www.solaredge.com

solaredge
architects of energy™

5.3 Tigo Energy[31]

Tigo Energy was founded in 2007 in Los Gatos, California by a group of Silicon Valley technologists. Tigo Energy has grown expanding operations in the USA, across Europe, Japan, Korea, and the Middle East. The company has introduced the Tigo Energy® Maximizer™ Solution for utility scale, commercial and residential systems. Tigo Energy is utilizing the patented impedance matching technology enabling 25% more yield from PV systems with heterogeneous environmental conditions.

Tigo Energy is venture funded and enjoys the counsel of several of the most prominent individuals in the photovoltaic market. The company is currently shipping the series and parallel version of the Tigo Energy Maximizer solution through leading channel partners. Recently Tigo Energy came into agreement with various module manufacturers such as Trina Solar, Hanwha Solar, Upsolar. There is a clear trend of Tigo towards smart modules with integrated power optimizers at the junction box. Add on power optimizers for single panels are discontinued but the company has realized a Dual maximizer which can accommodate 2 solar PV modules.



[31] www.tigoenergy.com

Module Maximizer-ES Technical Specifications

Input data	MM-ES50	MM-ES75	MM-ES110	MM-ES170
Maximum power	350W	350W	350W	350W
Maximum input DC voltage (Voc)	52V	75V	110V	170V
Vmp range *	16-48V	30-65V	30-89V	30-140V
Maximum continuous current (Imp)	9.5A	6.5A	4.7A	2.6A
Maximum input current (Isc)	10A	7.5A	5A	3A

* Vmp = Voltage at maximum power = Maximum power voltage

Output Data (DC)				
Maximum output power	350W	350W	350W	350W
Maximum continuous current	9.5A	6.5A	4.7 A	2.6A
Nominal Voltage/range	0 - Voc	0 - Voc	0 - Voc	0 - Voc

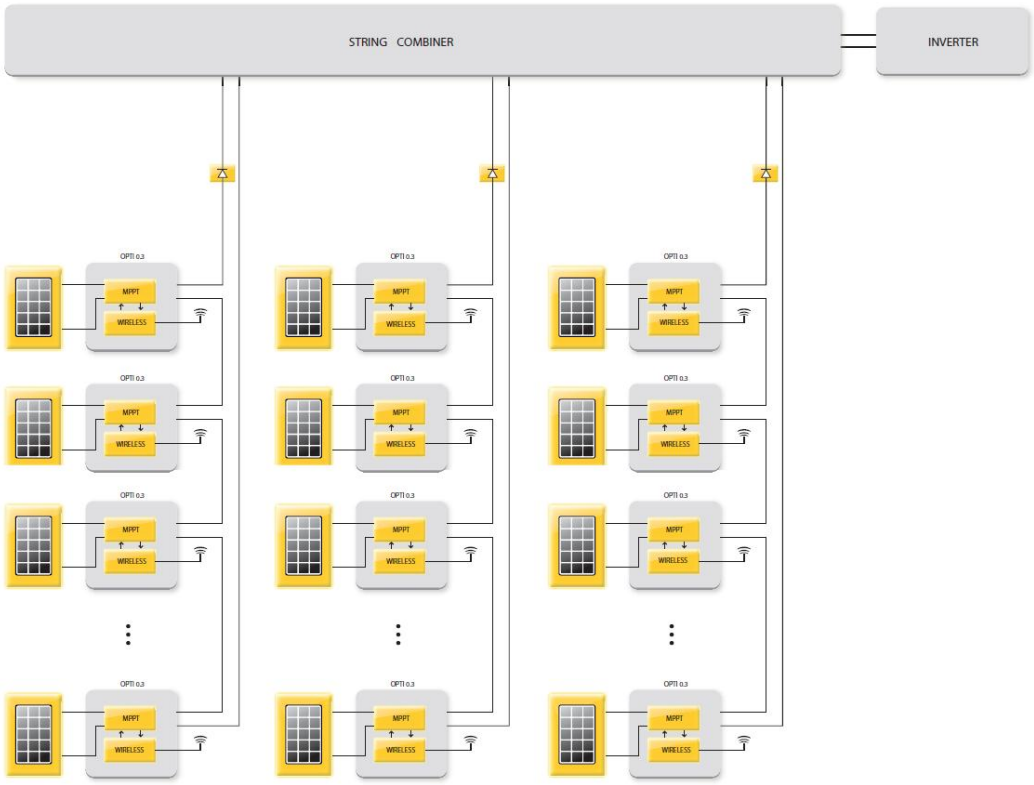
Mechanical Data	
Operating temperature range	-30°C +70°C
Cooling	Natural Convection
Enclosure environmental rating	IP-65, NEMA3R

Features	
Compliance	per UL1741 FCC part 15, class B

Maximizer™ Management Unit (MMU) Module Maximizer™-ES (MM-ES)

5.4 Power One*[32]

Power One has recently establish itself as the second largest provider of solar inverters globally. It is divided in two strategic business units, Renewable Energy Solutions and Power Solutions. As part of its strategy for geographic diversification Power One has entered into the North American and Asia Pacific markets and have established new factories in North America and China, as well as product development laboratories, and continue to build regional sales and service teams. Power One will continue to strategically invest in sales and marketing, R&D and global service team as they believe these are key drivers of their business. They are focused on reducing lead times, improving deliveries to customer request dates, and reducing freight and other transportation costs by localizing the supply chain.



[32] www.power-one.com

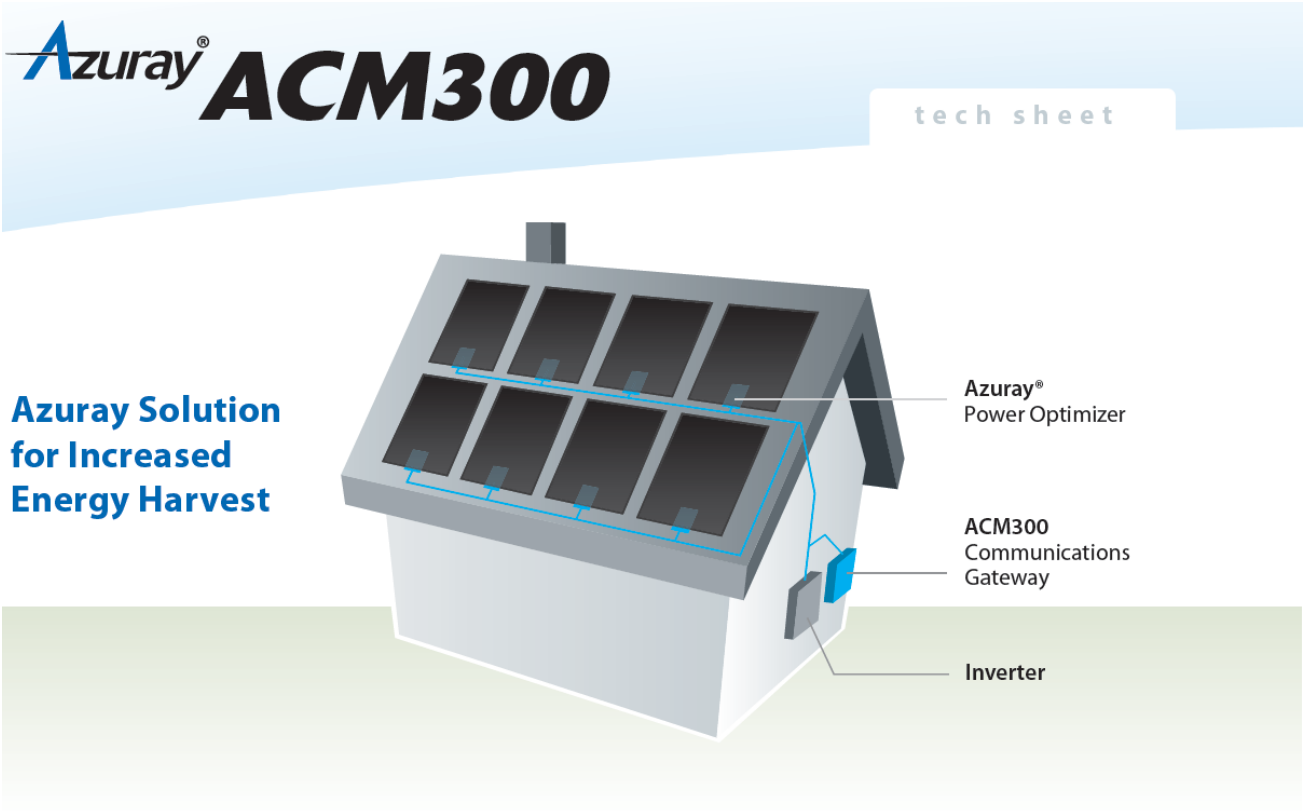
*Power one decided to interrupt sales and further development of the power optimizer solution and offer micro-inverters as the only MLPM solution

TECHNICAL DATA	VALUES	OPTI-0.3-TL-OUTD-US
Maximum Output Power	W	300
Input Side		
Maximum DC Input Power	Wp	300
Absolute Maximum Voltage (Vmax)	V	65
Maximum System Voltage	V	600
Start- Up Voltage (Vstart)	V	25
Operating Voltage Range	V	12-60
Maximum Current (Idcmax, in)	A	10
DC Connection Type		Tool Free PV connector WM/MC4
Output Side		
Adustable Output Voltage Range	V	20-60*
Maximum Current (Idcmax, out)	A	12
Protection Devices		
Output Side		
Reverse Polarity Protection		Yes
Output Over Voltage Protection	V	> 60
Line Blocking Diode		Optional**
Efficiency		
Maximum Efficiency	%	98
Pass Through Efficiency	%	99.3
CEC Efficiency	%	98
Communication		
Remote Control (Data logger; On/Off; Upgrade)		Wireless
Environmental		
Ambient Air Operating Temperature Range	°F (°C)	-40 to 149 (-40 to 65)
Relative Humidity	% RH	0-100 condensing
Acoustic Noise Emission Level	db (A) @1m	< 30
Maximum Operating Altitude without Derating	ft(m)	6560 (2000)
Mechanical Specifications		
Enclosure rating		NEMA 4X
Cooling		Natural Convection
Dimensions (H x W x D)	in (mm)	6.3 x 6.9 x 1.2 (161 x 175 x 31)
Weight	lb/(kg)	<1.32 (0.6)
Mounting System		Panel Mounted
Safety		
Safety and EMC Standard		EN 61000-6-2, EN 61000-6-3, FCC Part15 Class B, UL 1741
Safety Approval		cCSA$_{us}$

5.5 Azuray Technologies*[33]

Azuray Technologies is headquartered near Portland, Oregon US. Azuray Technologies is committed to developing the most reliable solar power electronics on the market. The focus on reliability starts from the early design phase of the product and target a 25 years guarantee.

Currently Azuray Technologies has released 2 power optimizers, one embedded version and an add-on version.



[33] www.azuraytech.com

*Azuray Technologies bankrupt during 2012

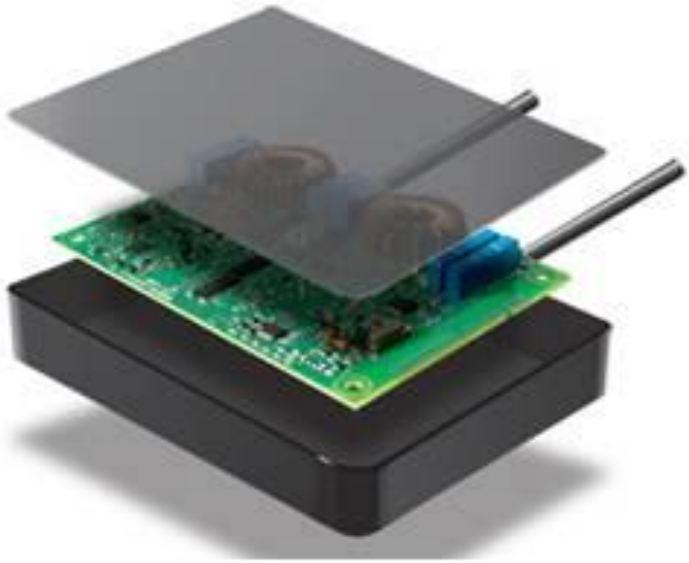
Specifications

		Min	Typ	Max	Units
Input Specifications	**Panel Voltage (Vpv)**	20		80	Volts
	Panel Current		8	10	Amps
	Input Power			250	Watts
Output Specifications	**Output Voltage**			Vpv	Volts
	Output Current			14	Amps
Other Specifications	**Efficiency**		98		%
	Ambient Operating Temp	-40	25	65	C°
Mechanical Specifications	**Dimensions**	136 x 136 x 40			mm
	Weight	970			gr
	Enclosure	NEMA 4			
Qualifications	**ETL Recognized:** UL1741 • CSA22.2C107.1 • IEC 62103				
	CE MARK				
	FCC: FCC Part 15–Class B				

5.6 Ampt[34]

Ampt serves the global market for large-scale PV systems where reliability, predictability, scalability, efficiency, cost and control are paramount. Ampt technology enables active j-boxes for module makers, a new class of lower cost, higher efficiency inverters for inverter manufacturers, and lowest cost cabling and monitoring solutions for balance of system and O&M provider. Recently KACO new energy, one of the world's largest solar inverter manufacturers with more than 6.8 gigawatts (GW) of photovoltaic (PV) inverters in the field, announced the availability of its blueplanet 50 TL3 SM solar PV inverter with Ampt Mode™, a setting that optimizes the inverter for use in a distributed power architecture. Used in combination with Ampt DC/DC module-level optimizers, KACO's 50 kW inverter operates at full rated output power in both 600 VDC and 1000 VDC systems. This technology partnership increases the allowable amount of modules per string, reduces balance-of-system (BOS) costs and increases energy yield from every module.

Ampt offers currently two solutions for DC/DC optimizers, one integrated in the junction box aiming for solar module manufacturers and an addon module with ranges from 260W to 360W.



[34] http://www.ampt.com/

Features:

- High efficiency power conversion
- Fast and accurate MPPT per PV module
- Ampt Mode™ technology to increase inverter output power
- String Stretch™ technology to build longer strings
- Output voltage and current limits
- Instrument-grade precision measurement
- Optional two-way wireless communication
- Independent power optimization without reliance on communication
- Inverter and PV module compatible
- Compatible with 3rd party monitoring
- Utility-strength operation and stability
- High reliability
- 25 year warranty

Benefits:

- Decrease inverter cost and increase efficiency with Ampt Mode™
- Decrease the cost of wiring and combiners and reduce wire losses with String Stretch™
- Deliver more power by correcting for mismatch between PV modules and strings
- Recover lifetime degradation losses
- Prevent failed PV modules from dropping a full string
- Optimize system footprint
- Simplify module binning and inventory
- Remove risk of module obsolescence

Results:

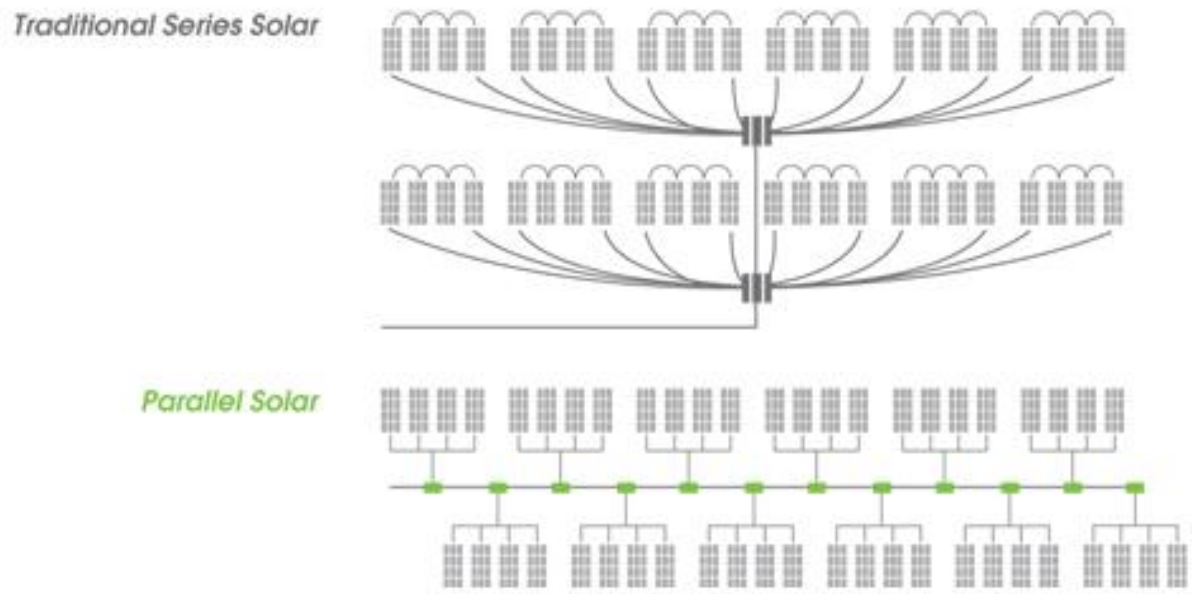
- Reduce the cost of PV system components and installation
- Increase the lifetime performance and uptime of PV systems
- Gain deeper knowledge, predictability, and control to operate system more efficiently
- Reduce PV project risk
- Realize a lower cost of energy and increase return on investment

Ampt-x Converter Model	V40-x	V50-x	V100-x
Electrical*			
Input			
Maximum module power (Pmax) at STC	260 W	320 W	360 W
Maximum module voltage (Voc) at coldest design temperature	46 V	58 V	102 V
Module MPP DC voltage range	10 - 38 V	17 - 48 V	25 - 80 V
Maximum module current (Imp) at STC	8.5 A	9.2 A	6.1 A**
Maximum module short circuit current (Isc) at STC	9.2 A	9.2 A	6.7 A
Output			
Maximum converter output voltage	33.3 V	40.6 V	63.6 V
Maximum converter output current	9.4 A	9.2 A	6.7 A**
Maximum converter output power	260 W	320 W	360 W
Maximum operating efficiency	99.0%	99.2%	99.2%
Mechanical			
Ambient temperature operating range	-40°F to +158°F (-40°C to +70°C)		
Dimensions	5.9 x 4.7 x 1.4 in. (15 x 11.9 x 3.6 cm)		
Weight	12 oz. (0.3 kg)		
Cooling	Convection		
General			
Communication	Two-way wireless (optional)		
Compliance	CSA to UL 1741, FCC Part 15 Class B IEC 62109, 61000-6-1, 61000-6-3		
Demonstrated MTBF at 40°C continuous	90 million hours		
Warranty	25 years		

* Standard test condition (STC) irradiation level of 1000 W/m² at 25°C.
** 6.1 A input and 6.7 A output at 60°C. 5.45 A input and 5.55 A output at 70°C.

5.7 eIQ Energy Inc*[35]

eIQ Energy Inc. designs and manufactures power electronics for solar photovoltaic systems. The company's products include DC-to-DC converter modules, data acquisition communications units, and monitoring systems for Web-based data analysis of solar plants. It serves customers through distributors. eIQ Energy, Inc. was formerly known as Sympagis Technology, Inc. The company was founded in 2007 and is based in San Jose, California. Focus of eIQ Energy is the US market and specifically the commercial roof or large ground mounted installations. In order to penetrate this market eIQ Energy products are simple, robust and relatively cheap.



[35] http://eiqenergy.com/

*eIQ Enegry bankrupt during 2013

Electrical Specifications	vBoost250
Input	
Maximum Input Power	250W
Maximum Input Voltage	50V
Minimum Input Voltage	20V
Maximum Input Current	10A
Output	
Maximum Output Power	250W
Output Voltage Range	250V-350V *(set by inverter)*
Maximum Output Current	1.25A *(internal current limit; 1.5A fuse)*
Conversion efficiency *(peak)*	97-98%
Operating Temperature Range	-40°C to 65°C
Enclosure	NEMA 4 sealed metal case
Maximum Units in Series	9,300 watts at 310 VDC output voltage
Compliance	UL1741/IEEE1547; CSA107.1, CE, FCC P15
EMI Input/Output Filters	FCC Class B
Mechanical	
Dimensions: inches (cm)	10.25" x 5" x 2.25" (26 × 12.7 × 5.7)
Weight	4.6 lbs

Brands	model	weighted eff (%)	Mppt range (V)	topology	enclosure	communication	monitoring	power range (W)	warranty (years)	safety	dimensions (mm)	weight (kgr)	Market Entry
Tigo Energy	MM-ES (discontinued)	99,5(Peak)	16-48	impedence matching	IP65	power line	Tigo monitoring portal	350	25	Yes,DC bus deactivation	142 x 142 x 27	n.a	Q2 2009
SolarEdge	P300	98,9(Euro)	8-48	buck-boost	IP67	power line	SolarEdge monitoring portal	300	25	Yes, SafeDC™	125 x 132 x 30	0.8	Q4 2009
Power One	OPTI-0.3TL-OUTD	98,2(Euro)	25-60	buck boost	IP66	wireless	CCD Aurora	350	10	No	203 x 135 x 30	1,5	2013
Azuray technologies	ACM300	97,6(CEC)	20-80	buck boost	IP66	power line	Azuray Gateway	250	25	Yes but optional	136 x 136 x 40	0,97	Q1 2010
eIQ Energy	vBoost250 (discontinued)	97(peak)	20-50	boost	IP66	power line	n.a	250	n.a	No	260 x 127 x 57	2,08	Q3 2009
Femtogrid	P0310	97(Euro)	8-42	boost	IP65	wireless	Femtogrid monitoring portal	310	25	Yes, spark detection	135 x 225 x 50	1	Q32013
Femtogrid	PO300	95,7(Euro)	8-42	boost	IP65	wireless	Femtogrid monitoring portal	300	25	Yes, spark detection	288 x 342 x 51	1,45	Q42011
AMPT	V50-x	99,2(Peak)	17-48	buck-boost	n.a	wireless	optional	320	25	No	150 x 119 x 36	0,3	

Table 2 : Comparison table of power optimizers according to data sheet

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