PVS series

PHOTOVOLTAIC SIMULATORS

PV Simulator PVS 1000/LV

The relating standards:*
EN 50530
IEC/EN 62116
IEEE 1547
IEC/EN 61683
IEC/EN 61727
CGC/GF004:2011
CEI 0-21
VDE-AR-N 4105
VDE 0126-2

** The PVS series of amplifiers can be used for certain tests within these standards. Additional equipment might be required. For detailed information, please contact sales@spitzenberger.de.*

- ✓ Arbitrary programmable IV characteristic
- ✓ Different solar cell types / partly shaded modules are possible to simulate
- ✓ Fast response time to load changes: typical less than 100 µs
- ✓ 100/120 Hz ripple on current and voltage of single-phase inverters is reproduced realistically
- ✓ The IV characteristic is simulated very accurately
- ✓ Ability to simulate dynamic irradiance and temperature profiles
- ✓ Simulation of the behaviour of a PV generator during a typical cloudy or clear day
- ✓ Evaluation of static and dynamic MPP tracking efficiency
- ✓ Complies with the requirements according to IEC/EN 50530 and many other specifications
- ✓ Operating modes IV (solar characteristic) and CV (constant voltage with current limitation)
- ✓ Available in standard (up to 1000 V), high voltage (up to 1500 V) and low voltage version (up to 150 V for micro inverter testing)
- ✓ Internal oscilloscope
- ✓ Amplifier control via webinterface and interface commands
- ✓ Test and evaluation software available

HIGH-SPEED PV SIMULATORS

THE PV SIMULATOR – FIELD OF APPLICATION

The PV Simulator reproduces in real time the behaviour of many different solar panels. The parameters influencing this behaviour in the real world are the changing weather conditions, the variation of the irradiation during the day and local conditions like shadowing and pollution. To simulate this condition the PVS has a capability for fast control adjustments.

Fast response time

Due to the fast DSP based regulation system, the response time to load changes is very fast. This fast response time is an absolute necessary requirement for the IEC/EN 50530 and the specified MPP tracking algorithm. See application note: www.spitzenberger.de/weblink/1005

The diagrams below show the measured rise and fall times at different load conditions.

Load changes around MPP

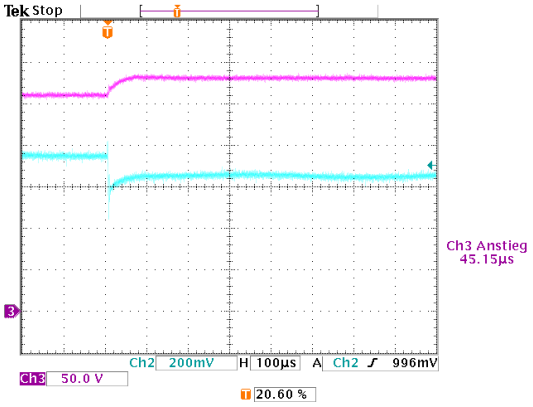

Fig. 1: Rise time voltage and current

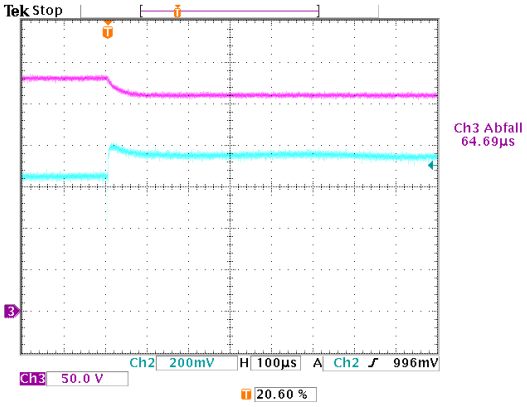

Fig. 2: Fall time voltage and current

Load between open circuit and MPP

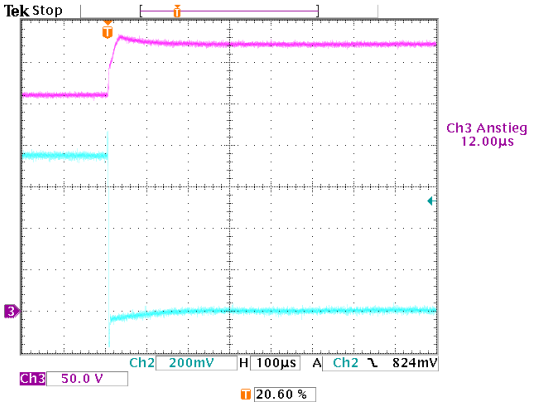

Fig. 3: Rise time voltage and current

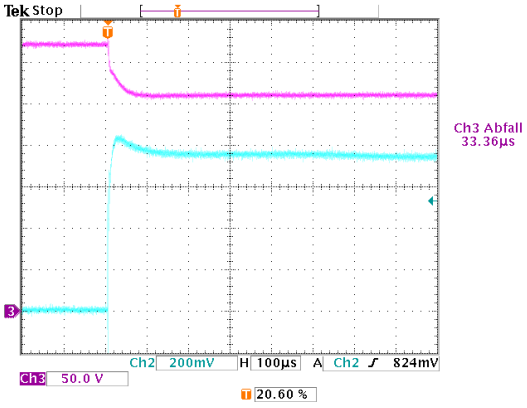

Fig. 4: Fall time voltage and current

100/120 Hz Ripple

One of the requirements of the photovoltaic simulator according to the IEC/EN 50530 is the ripple capability:

“This requires a sufficient dynamic of the PV Simulator in order to follow the dynamic voltage changes that occur in the measurement (e.g. the typical ripple of single-phase inverters with twice the grid frequency).”

With real photovoltaic generators this typical 100/120 Hz ripple on current and voltage when operating with a single-phase inverter can be measured. Some inverters use this for a fast MPP tracking.

When operating with the PV Simulator this ripple behaviour is exactly as it is in reality, because of the very fast response time capability.

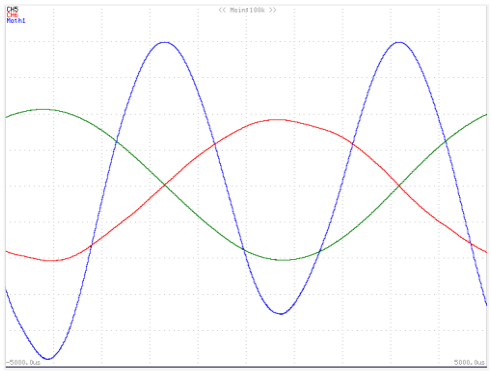

Fig. 5: 100 Hz ripple of voltage, current and power

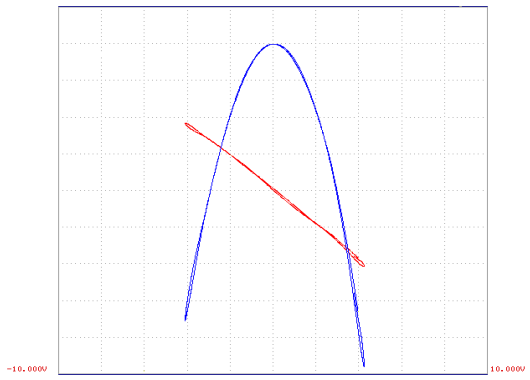

Fig. 6: XY-view: no hysteresis observably - current, power

Arbitrary programmable curves

IV curves are adjustable via software over a wide range to simulate various conditions for dynamic irradiances and temperature changes. This includes “in the field” measured IV curves, stored and imported into the SPS Photovoltaic control software.

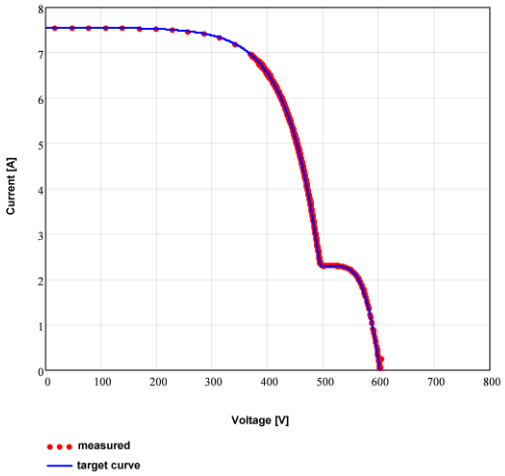

Fig. 7: Arbitrary IV curves

SIMULATION OF DYNAMIC IRRADIATION

Irradiation

The value of the solar radiation density – the irradiation – is varying during the day. Slow variations occur because of the changing position of the sun. Fast variations can occur at cloudy days, if the sun is shadowed within seconds and cleared several minutes later and again shadowed. Various curves – corresponding to different irradiance values – can be defined with specified time course. The transition between two curves will be interpolated; the transition time is arbitrarily programmable. The specified curves are reproduced exactly during a complete measurement session.

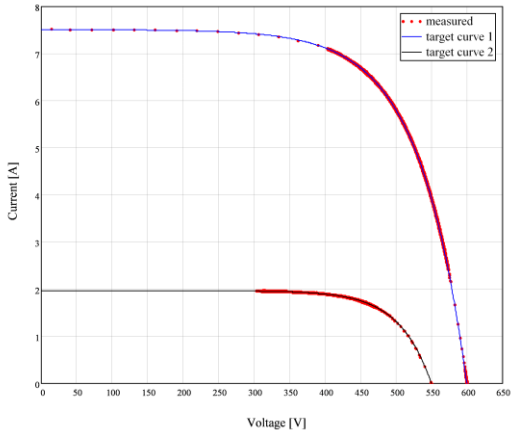

Fig. 8: Various IV curves

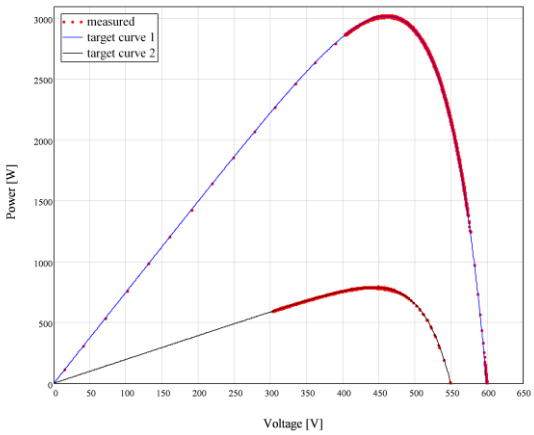

Fig. 9: Various VP curves

TOUCHSCREEN USER INTERFACE

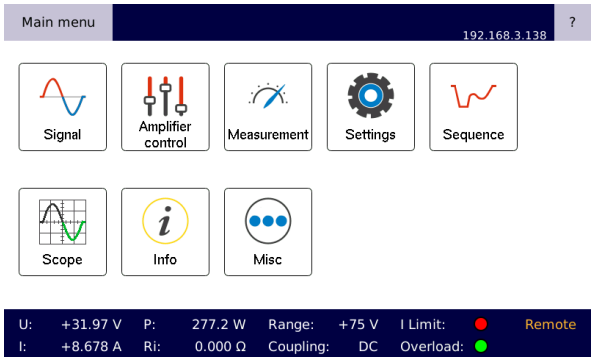

Fig. 10: Main menu

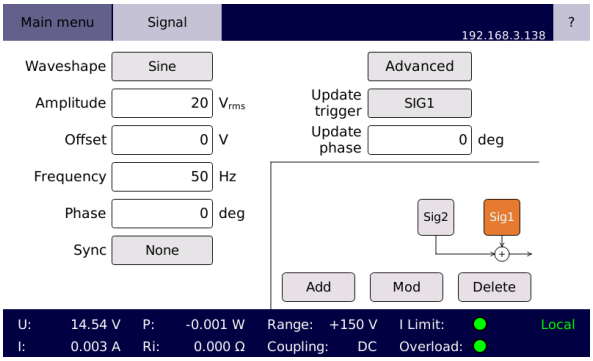

Fig. 11: Signal settings

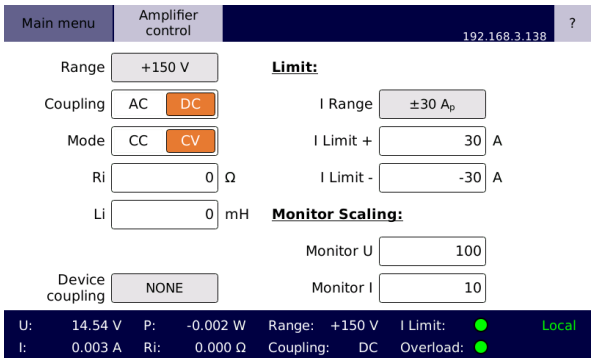

Fig. 12: Amplifier control

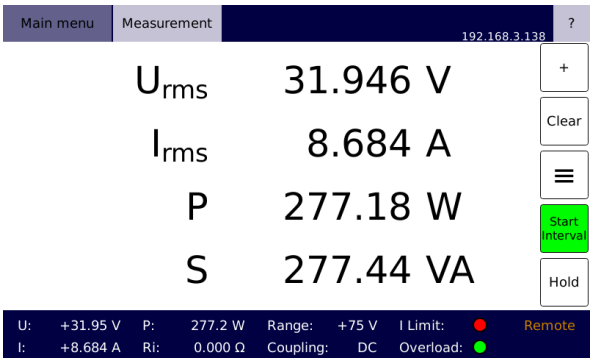

Fig. 13: Measurement

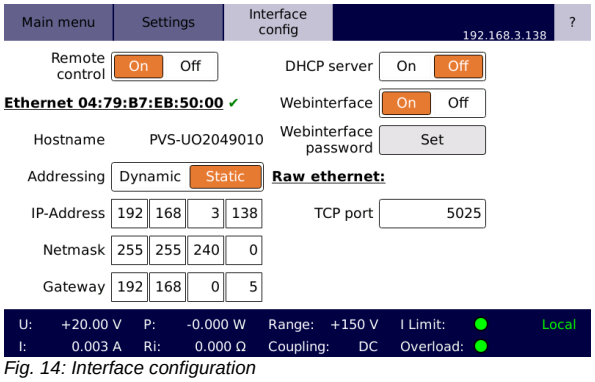

Fig. 14: Interface configuration

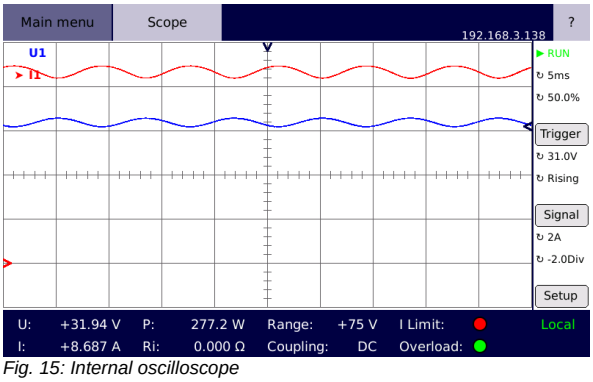

Fig. 15: Internal oscilloscope

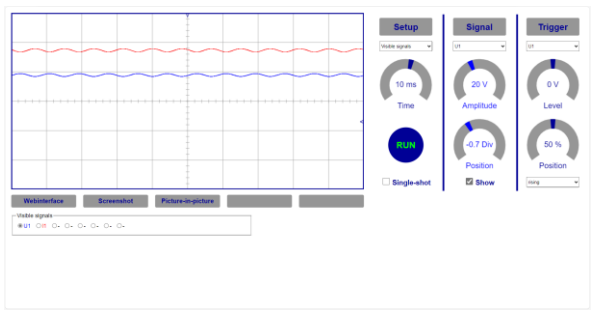

Fig. 16: Web oscilloscope

SOFTWARE CONTROL

SPS Photovoltaic

- ✓ IV characteristics of various solar cells
- ✓ Arbitrarily programmable sequence of irradiance and cell temperature
- ✓ Allows simulation of partly shaded PV generators
- ✓ Import of irradiance and temperature data from CSV file
- ✓ Visualisation of measurement data

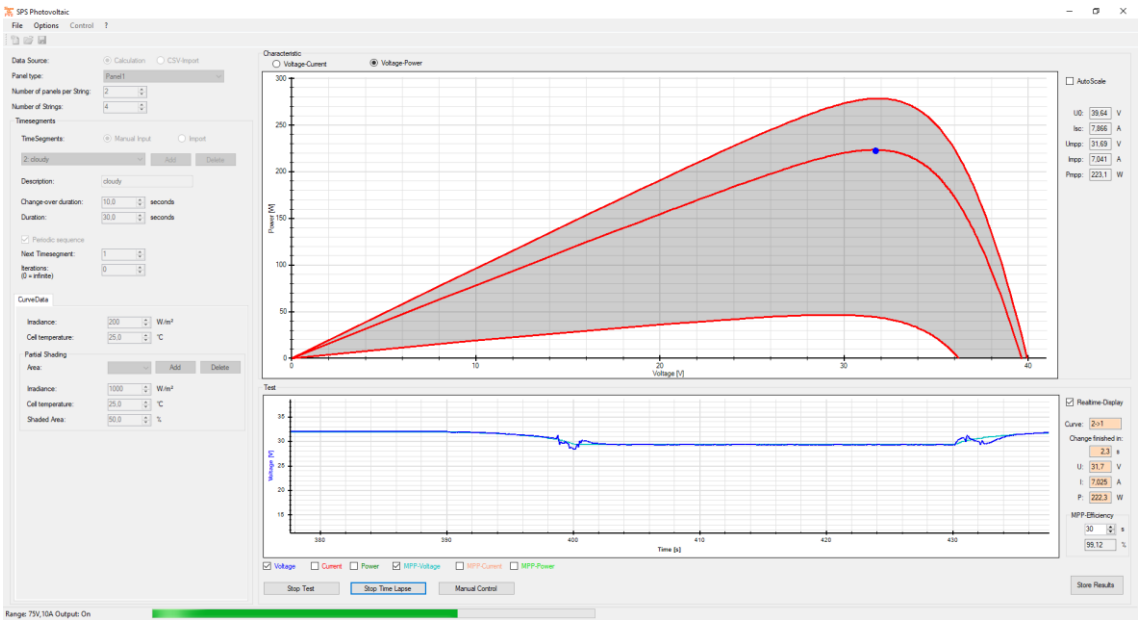

Fig. 17: SPS Photovoltaic software

Command interface

- ✓ Easily integrate the device into your own software applications
- ✓ Remote control commands are based on the SCPI standard

Webinterface

- ✓ Monitor and control the connected device via a web browser
- ✓ Oscilloscope function

SPS InverterTest

- ✓ Perform automated tests by controlling PVS, AC simulator (APS), RLC and power meter
- ✓ Efficiency measurement of grid connected photovoltaic inverters according to EN 50530
- ✓ Anti islanding tests
- ✓ Detailed test report available

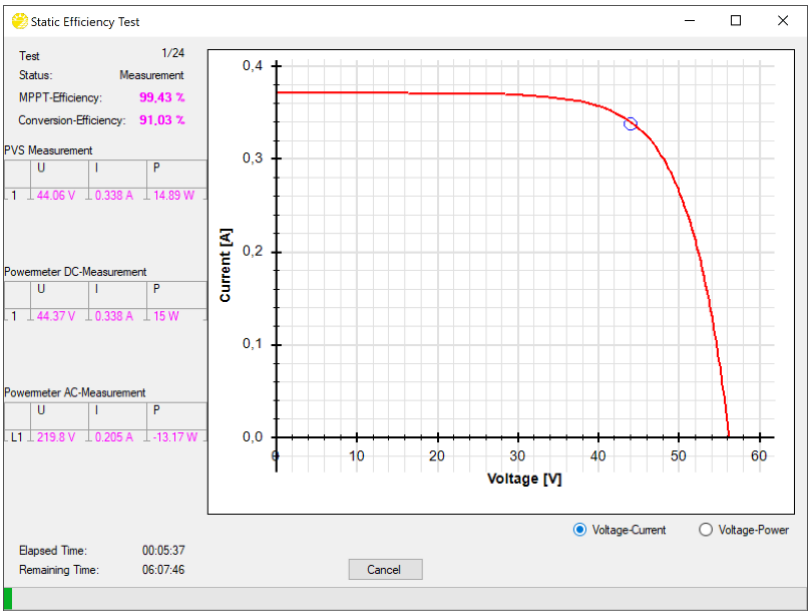

Fig. 18: SPS InverterTest software

TECHNICAL DATA - GENERAL

		PVS	PVS/HV	PVS/LV
Nominal voltage ranges *(DC)*		400 V 500 V 600 V 800 V 900 V 1000 V	400 V 500 V 750 V 1000 V 1250 V 1500 V	37.5 V 75 V 150 V
Measurement				
	Voltage accuracy	DC: ±0.1 % of reading ±0.02 % of range		
	Voltage noise (peak - peak) *Voltage noise (RMS)*	< 1 V < 100 mV		
	Current accuracy	DC: ±0.2 % of reading ±0.04 % of range		
	Current noise (peak - peak) *Voltage noise (RMS)*	< 0.25 % of $I_{MaxRange}$ < 0.025 % of $I_{MaxRange}$ current noise is depending on the maximum current measurement range value $I_{MaxRange}$		
Slew rate		< 250 µs (typ. < 100 µs)		
Stability *(1 h)*		gain: < 0.1 % / offset: < 0.02 % of range at constant load and temperature		
Line regulation		< 1.5 x 10^{-4} per 10 V line-voltage change		
Protection circuits		overload / short circuit / overtemperature		
Floating output				
		PVS	PVS/HV	PVS/LV
	max. voltage between earth and the amplifier's ground output	-1000 V ... +400 V	-1500 V ... +400 V	< 300 V (RMS)
Memory capacity for IV curves		up to 10000 curves		
External input *(optional)*	*Max. peak voltage*	0 … U_{ExtMax} (U_{ExtMax} is adjustable between ±2 V … ±25 V)		
	Input impedance	approx. 10 kΩ		
	Delay time	signal delay between amplifier's external input and amplifier's output < 5 µs		
Internal oscillator unit				
	Type	4-channel synthesiser		
	Wave forms	DC, sine, square, triangle, ramp, arbitrary		
	Amplitude resolution	17 Bit		
	Frequency range	DC … 1 MHz		
	Frequency resolution	1 µHz		
	Frequency accuracy	25 ppm		
	Phase range	0° … 360°		
	Phase resolution	0.001°		
	Memory depth	1 MSample		
	Synthesiser functions	ADD, AM, FM, PM, PWM		
	Sequence memory	1024 steps		
Internal control unit				
	Display	7.0" touchscreen (17.8 cm, resolution 800 x 480)		
	Sequencer	user defined sequences memory		
	User interface	touchscreen / front panel button / incremental encoder webinterface		

Monitoring unit *(optional)*		voltage		current	
	Max. peak output	±10 V			
	Scaling factor 'sf' (adjustable)	sf: 0.2 … 1000		sf: 0.1 … 1000	
	Bandwidth	300 kHz		200 kHz	
	Monitoring accuracy	± (% of reading + % of range + error(sf))			
	Frequency	DC 45 Hz … 450 Hz	10 Hz … 45 Hz 450 Hz … 5 kHz	5 kHz … 15 kHz	15 kHz … 30 kHz
	Voltage monitor accuracy	0.12 + 0.02 + 2 mV * sf	0.3 + 0.2 + 2 mV * sf	0.7 + 0.4 + 2.2 mV * sf	1.4 + 0.8 + 2.3 mV * sf
	Current monitor accuracy	0.22 + 0.04 + 2 mA * sf	0.5 + 0.4 + 2 mA * sf	1.1 + 0.8 + 2.2 mA * sf	2.2 + 1.6 + 2.3 mA * sf
	Noise of ADC measurement (RMS)	< 20 mV (DC … 300 kHz)		< 1.5 mA (DC … 300 kHz)	
	Noise DAC output (RMS)	< 0.2 mV (DC … 300 kHz)			
	Delay time	< 1 µs			
	Output impedance	47 Ω			
	Isolation	earth / remaining electronics / each other			
	Protection	short circuit			
Interface		Ethernet 100 Mbit/s (HiSLIP SCPI) USB 2.0 Host			
Synchronisation bus *(multiple devices)*		device synchronisation and internal communication optical fibre, LC duplex: - synchronised sequence start - parallel operation - only one ethernet connection required			
Insulation resistance		> 1 MΩ			
Peak withstand voltage *(max. 10 s, output to earth)*		> 2000 V			
Peak withstand voltage PVS/HV *(max. 10 s, output to earth)*		> 3000 V			
Cooling		temperature-controlled forced air cooling			
Ambient temperature		+10 °C up to +40 °C			
Storage temperature		-25 °C up to +60 °C			
Relative humidity		non condensing, max. 80 % for temperature < 31 °C, decreasing linearly to 50 % at 40 °C			
Ingress protection		IP20			

TECHNICAL DATA – PVS and PVS/HV series

		PVS 1000	PVS 3000	PVS 7000
Power DC *(at nominal voltage)*	*continuous*	1000 W	3000 W	7000 W
Continuous DC current				
U_{OUT} = 320 V (400 V range)		3.2 A	9.4 A	22 A
U_{OUT} = 400 V (500 V range)		2.5 A	7.5 A	17.5 A
U_{OUT} = 480 V (600 V range)		2.1 A	6.3 A	14 A
U_{OUT} = 640 V (800 V range)		1.6 A	4.7 A	11 A
U_{OUT} = 720 V (900 V range)		1.4 A	4.2 A	9.8 A
U_{OUT} = 800 V (1000 V range)		1.25 A	3.8 A	8.8 A
Continuous DC current HV series				
U_{OUT} = 320 V (400 V range)		3.2 A	9.4 A	22 A
U_{OUT} = 400 V (500 V range)		2.5 A	7.5 A	17.5 A
U_{OUT} = 600 V (750 V range)		1.7 A	5.0 A	11.7 A
U_{OUT} = 800 V (1000 V range)		1.25 A	3.8 A	8.8 A
U_{OUT} = 1000 V (1250 V range)		1 A	3.4 A	7 A
U_{OUT} = 1200 V (1500 V range)		0.85 A	2.5 A	5.9 A
Power supply *(±10 %, 50/60 Hz)*		230 V	230 V / 400 V	
Line protection, connection		16 A, Schuko	3 x 16 A, CEE	3 x 20 A, CEE
Housing		plug-in unit or rack, light grey (RAL 7035)		
	approx. dimensions (H x W x D)	19", 7 U 311 x 483 x 700 mm	19", 10 U 444 x 483 x 700 mm	19", 12 U 533 x 483 x 700 mm
Weight	*approx.*	50 kg	115 kg	145 kg

TECHNICAL DATA – PVS and PVS/HV series

		PVS 10000	PVS 15000	PVS 25000
Power DC *(at nominal voltage)*	*continuous*	10000 W	15000 W	25000 W
Continuous DC current				
U_{OUT} = 320 V (400 V range)		31 A	50 A	80 A
U_{OUT} = 400 V (500 V range)		25 A	38 A	63 A
U_{OUT} = 480 V (600 V range)		21 A	32 A	53 A
U_{OUT} = 640 V (800 V range)		16 A	25 A	40 A
U_{OUT} = 720 V (900 V range)		14 A	21 A	35 A
U_{OUT} = 800 V (1000 V range)		12.5 A	19 A	32 A
Continuous DC current HV series				
U_{OUT} = 320 V (400 V range)		31 A	50 A	80 A
U_{OUT} = 400 V (500 V range)		25 A	38 A	63 A
U_{OUT} = 600 V (750 V range)		17 A	25 A	42 A
U_{OUT} = 800 V (1000 V range)		12.5 A	19 A	32 A
U_{OUT} = 1000 V (1250 V range)		10 A	15 A	25 A
U_{OUT} = 1200 V (1500 V range)		8.5 A	13 A	21 A
Power supply *(±10 %, 50/60 Hz)*		230 V / 400 V		
Line protection, connection		3 x 40 A, CEE	3 x 50 A, CEE	3 x 63 A, CEE
Housing		plug-in unit or rack, light grey (RAL 7035)		
	approx. dimensions (H x W x D)	19", 20 U 888 x 483 x 700 mm	19", 29 U 1288 x 483 x 700 mm	19", 35 U 1555 x 483 x 700 mm
Weight	*approx.*	280 kg	320 kg	370 kg

TECHNICAL DATA – PVS and PVS/HV series

		PVS 32500	PVS 42500	PVS 50000
Power DC *continuous* *(at nominal voltage)*		32500 W	42500 W	50000 W
Continuous DC current				
U_{OUT} = 320 V (400 V range)		100 A	135 A	157 A
U_{OUT} = 400 V (500 V range)		82 A	108 A	125 A
U_{OUT} = 480 V (600 V range)		68 A	90 A	105 A
U_{OUT} = 640 V (800 V range)		51 A	67 A	79 A
U_{OUT} = 720 V (900 V range)		46 A	60 A	70 A
U_{OUT} = 800 V (1000 V range)		41 A	55 A	63 A
Continuous DC current HV series				
U_{OUT} = 320 V (400 V range)		100 A	135 A	157 A
U_{OUT} = 400 V (500 V range)		82 A	108 A	125 A
U_{OUT} = 600 V (750 V range)		55 A	71 A	84 A
U_{OUT} = 800 V (1000 V range)		41 A	55 A	63 A
U_{OUT} = 1000 V (1250 V range)		33 A	43 A	50 A
U_{OUT} = 1200 V (1500 V range)		28 A	36 A	42 A
Power supply *(±10 %, 50/60 Hz)*		230 V / 400 V		
Line protection, connection		3 x 100 A, CEE	3 x 125 A, CEE	3 x 160 A, terminal box
Housing		rack, light grey (RAL 7035)		
	Amplifier approx. dimensions (H x W x D)	19", 33 U 1467 x 483 x 700 mm	19", 39 U 1733 x 483 x 700 mm	19", 46 U 2044 x 483 x 700 mm
	Power supply approx. dimensions (H x W x D)	19", 33 U 1467 x 483 x 700 mm	19", 39 U 1733 x 483 x 700 mm	19", 46 U 2044 x 483 x 700 mm
Weight	*approx.*	on request	on request	on request

TECHNICAL DATA – PVS and PVS/HV series

		PVS 65000	PVS 85000	PVS 100000
		2 x PVS 32500 in parallel	2 x PVS 42500 in parallel	2 x PVS 50000 in parallel
Power DC *continuous* *(at nominal voltage)*		65000 W	85000 W	100000 W

TECHNICAL DATA – PVS 1000/LV

		PVS 1000/LV
Power DC *continuous* *(at nominal voltage)*		1000 W
Continuous DC current		
U_{OUT} = 30 V (37.5 V range)		24 A
U_{OUT} = 60 V (75 V range)		16.7 A
U_{OUT} = 120 V (150 V range)		6.7 A
Power supply *(±10 %, 50/60 Hz)*		230 V
Line protection, connection		16 A, Schuko
Housing		desktop or plug-in unit, light grey (RAL 7035)
	Amplifier approx. dimensions (H x W x D)	19", 4 U 178 x 483 x 700 mm
Weight	*approx.*	55 kg

OPTIONS AND ACCESSORIES

Options			
OPT.01	IEEE488	Not in combination with OPT.02	
OPT.02	RS232	Not in combination with OPT.01	
OPT.05	U/I monitor	Galvanically isolated voltage and current measurement outputs accessible via BNC sockets (includes OPT.14)	
OPT.11		Special voltage	
OPT.11-200/DC	Additional voltage range DC	0 ... 200 V	
		Model	DC Current @ 160 V
		PVS 1000	3.2 A
		PVS 3000	9.4 A
		PVS 7000	22 A
		PVS 10000	31 A
		PVS 15000	50 A
		PVS 25000	80 A
		PVS 32500	100 A
		PVS 42500	135 A
		PVS 50000	157 A
		PVS 65000	200 A
		PVS 85000	270 A
		PVS 100000	314 A
OPT.14	External input	0 … U_{ExtMax} U_{ExtMax} peak is adjustable between ±2 V … ±25 V OPT.14 includes a digital input filter: type Bessel or Butterworth, order 1 ... 6 (adjustable) Filter frequency selectable 100 Hz ... 10 MHz	
NT.18	Special RMS line voltage	Available on request in the range of 110 V … 300 V	
OPT.30	Optical link	Optical interface to real time simulator LC duplex interface / Aurora 8B/10B protocol / 2.5 Gb/s data rate	

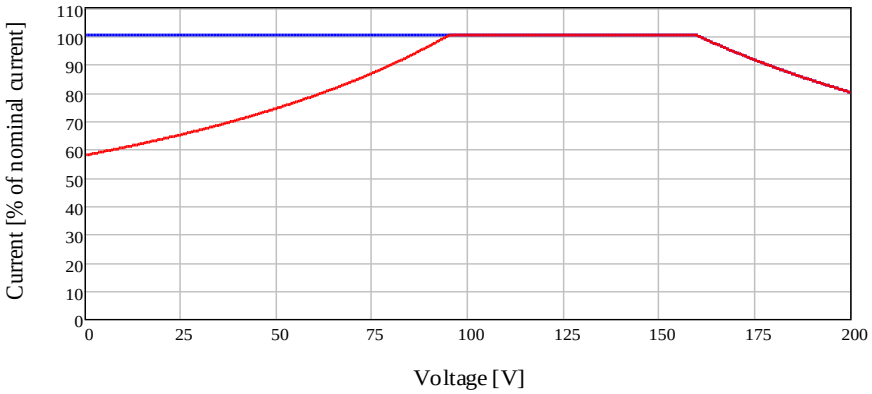

Fig. 19: Current performance for optional voltage range 200 V
- Continuous current capability
- Short time current capability (up to 2 minutes)

Amplifier characteristics PVS and PVS/HV

Due to different types of solar generators the PVS series has six voltage ranges. The figures below show the maximum possible current capability in the according voltage ranges, depending on the adjusted output voltage. This correlates also to the maximum available power capability of the PVS depending on the adjusted output voltage.

The current capability of the PVS is specified as:

- Continuous current capability
- Short time current capability *(up to 2 minutes)*
- Peak current capability *(up to 50ms)*

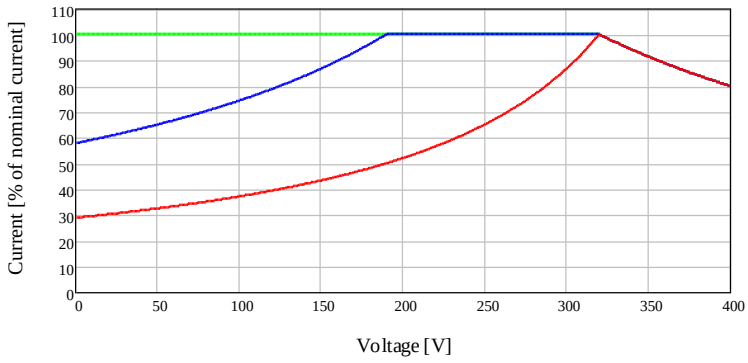

Fig. 20: Current performance for voltage range 400 V

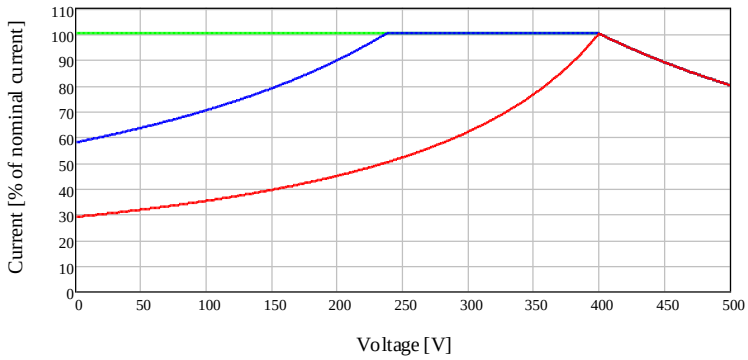

Fig. 21: Current performance for voltage range 500 V

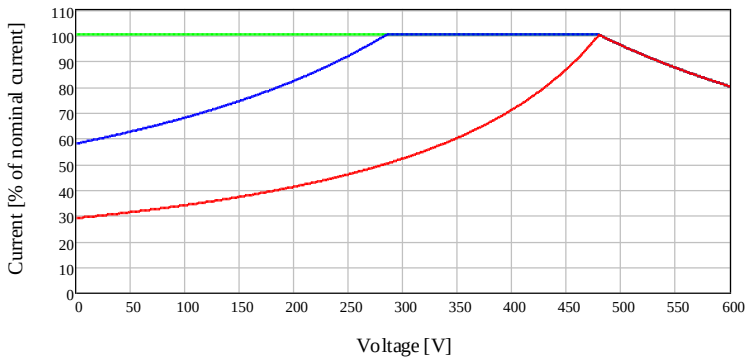

Fig. 22: Current performance for voltage range 600 V

Amplifier characteristics PVS and PVS/HV

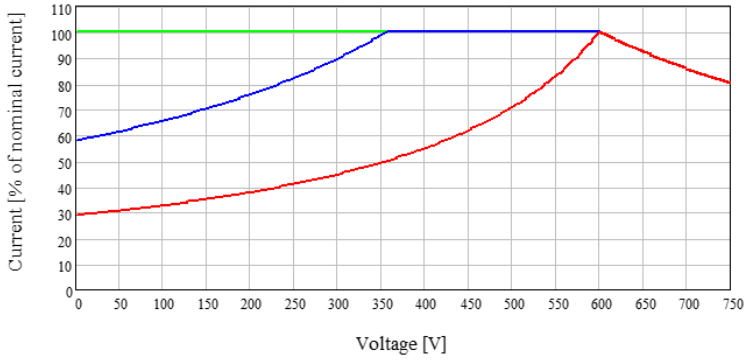

Fig. 23: Current performance for voltage range 750 V

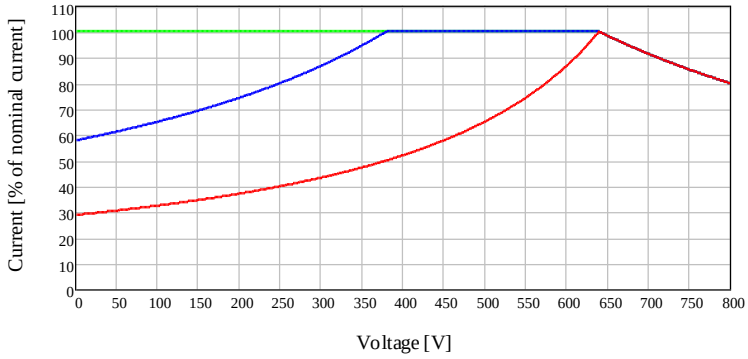

Fig. 24: Current performance for voltage range 800 V

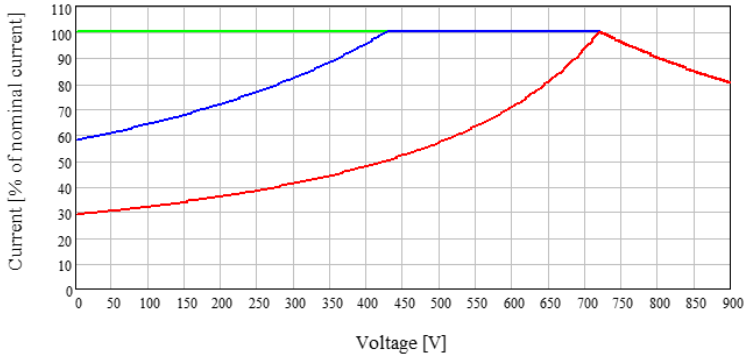

Fig. 25: Current performance for voltage range 900 V

Amplifier characteristics PVS and PVS/HV

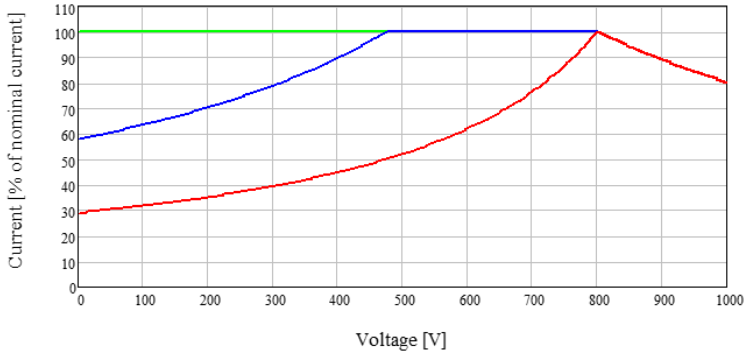

Fig. 26: Current performance for voltage range 1000 V

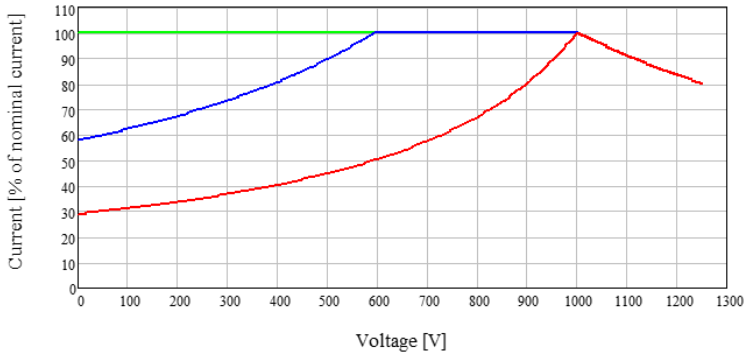

Fig. 27: Current performance for voltage range 1250 V

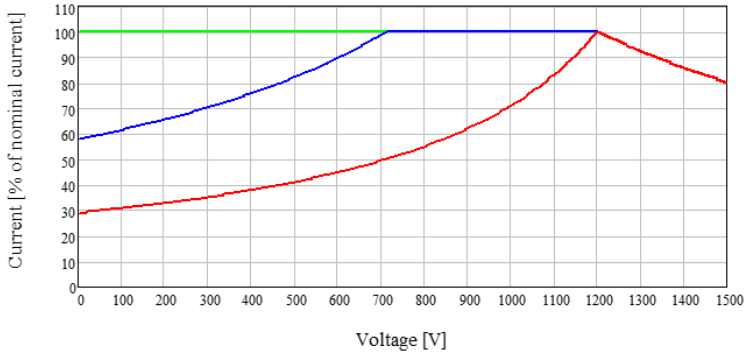

Fig. 28: Current performance for voltage range 1500 V

Amplifier characteristics PVS 1000/LV

The PVS 1000/LV has three voltage ranges. The diagrams below show the maximum possible current capability in the according voltage range, depending on the adjusted output voltage. This correlates also to the maximum available power capability of the PVS depending on the adjusted output voltage.

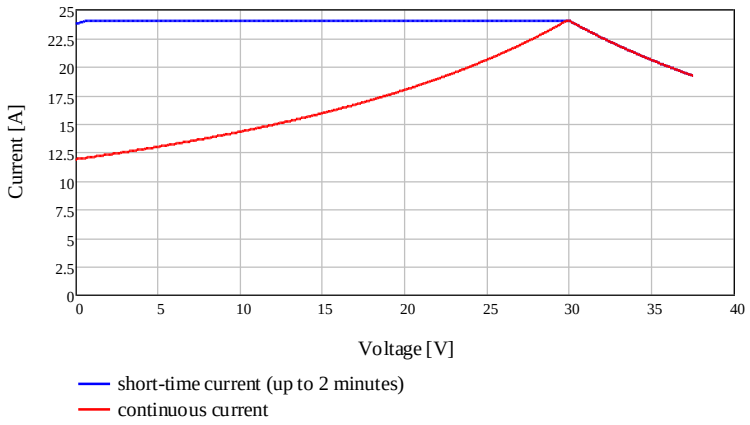

Fig. 29: Current performance for voltage range 37.5 V

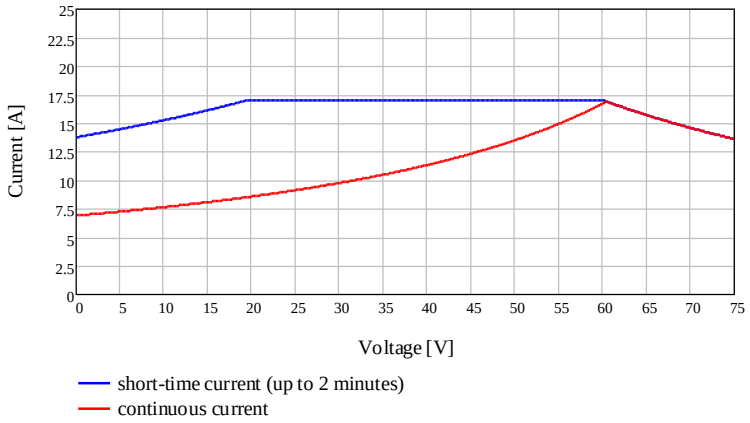

Fig. 30: Current performance for voltage range 75 V

Amplifier characteristics PVS 1000/LV

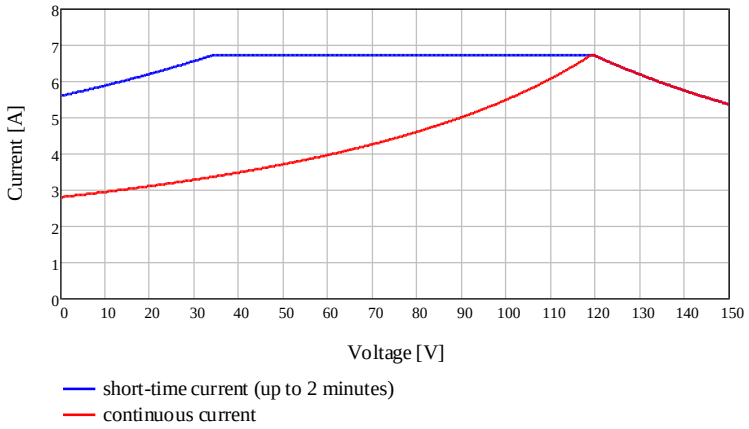

Fig. 31: Current performance for voltage range 150 V