Elgar TerraSAS

1kW-1MW

Programmable Solar Array Simulator

80-1000 V

≈			
	115	208	400
	480		

ETHERNET LXI

- Simulate dynamic irradiance and temperature ranging from a clear day to cloud cover conditions
- Ramp the voltage, temperature or irradiance level over a programmed time interval
- Readback of voltage, current, irradiance level and temperature setting
- Tests for inverter Maximum Power Point Tracking (MPPT)
- Provides programmable I-V curves for PV Inverter testing
- Simulates different types of solar cell material
- Multi-Channel, Up to 1MW

Why power supply is critical for PV simulations

Many solar inverters generate AC ripple on their DC input, which is connected to the photovoltaic array. For single phase inverters, the frequency of this ripple is twice the line frequency (120 Hz for US models). The simulator's power supplies must not supress this ripple as a function of their regulation loop. An increasing number of inverters (and virtually all micro-inverters) accurately measure amplitude and phase of the ripple voltage and current to quickly track the MPP of the array. This approach allows tracking the MPP at a much higher speed when compared to conventional dithering techniques (also called perturbate-and-observe). Faster tracking of the MPP results in a much higher overall efficiency in cloudy conditions, where the irradiance is constantly changing. It is likely that all solar inverters will use this approach in the near future, since end users are very sensitive to the overall efficiency of their solar energy installations.

To satisfy this requirement, the PV simulator must be capable of reproducing the voltage / current behavior of a solar array at the ripple frequency. Most standard switching power supplies employ very large output capacitors and inductors in their output circuits and are unable to deliver the required performance - regardless of the response speed of the I/V curve controller.

Elgar's line of PV simulators are based on high speed versions of our standard products, where output capacitors and other speed-limiting components have been adjusted. This results in a speed improvement of 10 times or better. Proprietary features built into the PV controller hardware and firmware, combined with our high speed power supplies, deliver the required performance. This technology was extensively tested on micro-inverters and is ready to test the next generation of inverters.

Strengths of using DSP signal processing

Our technology avoids using linear amplifiers, which are fast but bulky and inefficient. The required performance is delivered by high speed switching power supplies and advanced DSP signal processing techniques. Competitors data sheets mentions that speed requirements may not be met in some conditions, "...depending also on the type of MPP tracking principles". An additional linear module is required to satisfy the new requirements. Some competitor's power supplies specifications say that it uses "... innovative IGBT and transformer technology". Our power supplies use Power MOSFETs, which typically switch ten times as fast as the most recent IGBTs. Higher switching frequency translates to smaller output capacitors and inductors - which is the key to a successful high speed power supply design.

Product Overview

The Elgar TerraSAS System, (TSAS) provides an easily programmable means of simulating the characteristic behavior of a PV array. The system provides a turn-key approach to testing the maximum peak power tracking (MPPT) characteristics for grid-tied inverters and DC charge controllers. The ability to simulate virtually any fill factor or solar cell material allows the customer to validate the MPPT algorithm with a power source. Hardware control is accomplished by an application running on the local controller that communicates directly to the PV simulator using RS422, which operate as a dedicated IV curve generation processor. The local Graphical User Interface (GUI) is accomplished via another application that provides all of the user controls to the TerraSAS system. Imbedded in the application is the Ethernet (LAN) parser for remote communication and control. All of the

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functions available locally through the controller are also available remotely.

Description

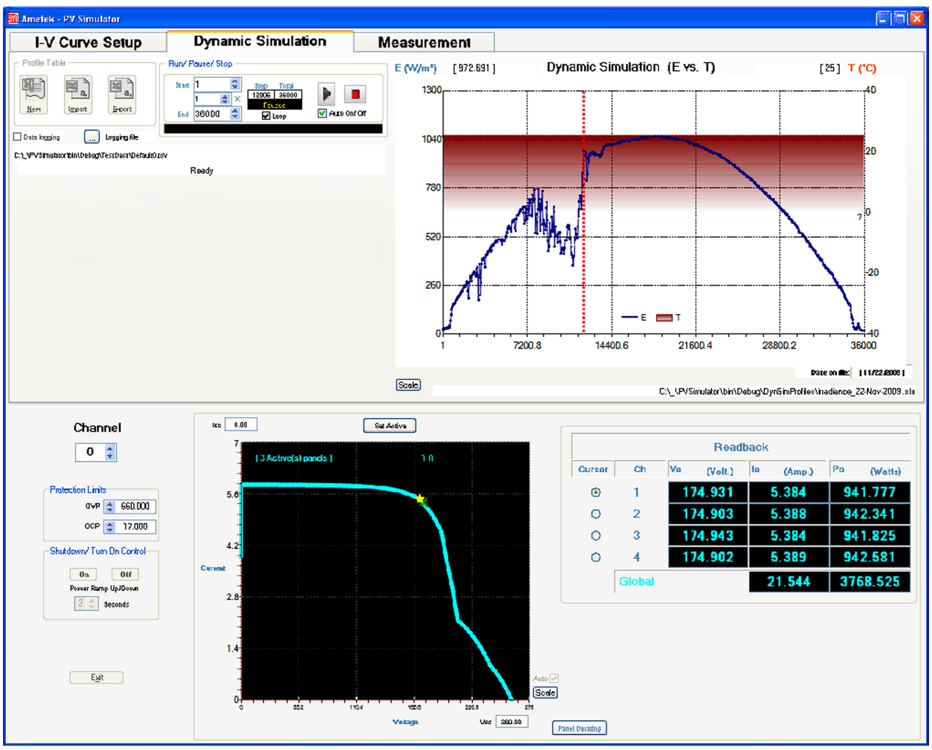
As shown in the rack drawing, the TerraSAS consists of programmable DC power supplies, a rack mounted controller, keyboard and LCD display with control software and GUI interface, output isolation and polarity reversing relays and a unique PV simulation engine that controls the power supply. This combination of hardware allows the TerraSAS to simulate most test protocols or combination of events that a solar installation will be subjected to. Power supplies are available in 1-15KW increments to simulate arrays up to 1MW.

The included software, as displayed below, allows modeling of a PV panel without an extensive knowledge of solar array parameters. The only parameters required for a simulation are the open circuit voltage and short circuit current. The slope of the VI curve can then be modified by the peak power parameters, Vmpp and Impp. Changes to these parameters will allow the shape of the VI curve to be adapted to any fill factor between 0.5 and 1. Once an IV curve has been generated, changes to the irradiation level or temperature can be changed on the fly so that the behavior of a grid tied inverter can be tested under realistic conditions for cloud shadowing and panel temperature rise. Long term weather simulations can be run to determine the amount of energy delivered in a given situation. Inverters can be optimized for real MPP search modes, because shadowing and temperature changes can be simulated realistically.

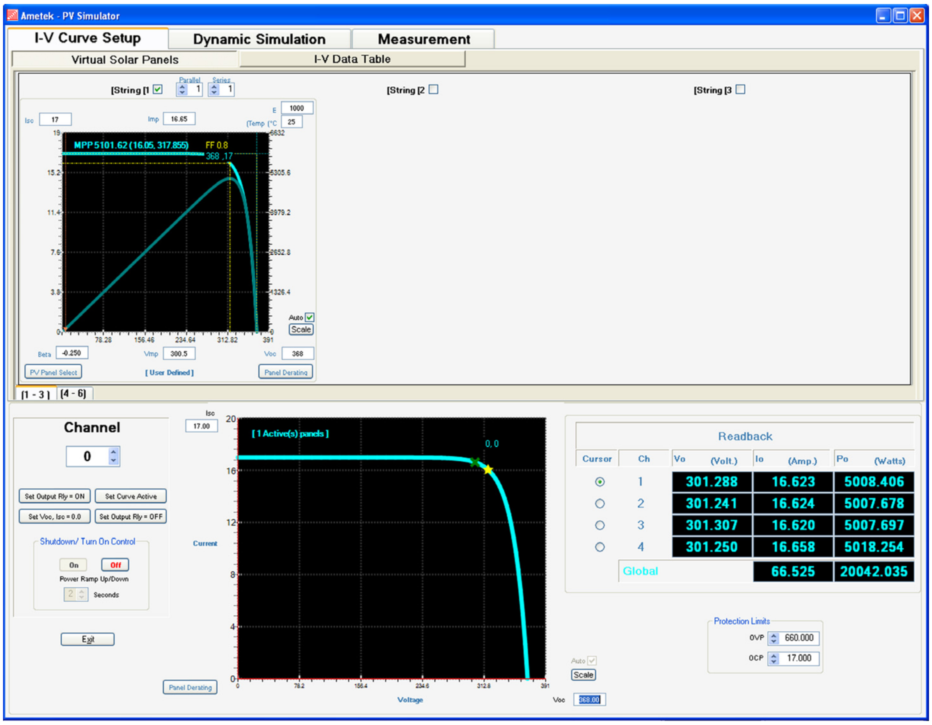
The PV simulation software allows definition of key parameters like Voc, Isc, Vmpp and Isc at 25 °C and 1000W/m2, so that the resulting VI curve is calculated according to a standard solar cell model.

The PV simulator has the ability to simulate ideal IV curves as well as irregular characteristics for peak power tracking that result when solar panels with different output characteristics are paralleled as shown on the following two graphs below. With the simulator programmed for different values of irradiance or temperature, the characteristic “multiple hump” IV curve will result. By programming the changes in irradiance and temperature in a table, dynamic simulation of compressed time profiles of a 24 hour day can be run in a loop to simulate the day and night periods for extended periods of time.

Dynamic simulation showing changes in Irradiance and Temperature over time



IV Curve Control Interface : Parameters are programmable through sliding scale or direct input of value



Control Displays

The graphic above shows the GUI interface displays. The entered set of IV curves is displayed as soon as the parameters are entered. The actual measured data is then overlaid on the screen so that the operating point can be viewed in real time. The display times can be set from minutes to days to allow for long term testing.

Programmable Parameters

Set a specified irradiance level
Set a specified temperature value
Set a specified voltage level
Set a specified current level
Set a specified temperature coefficient

Ramp of voltage, temperature or irradiance level over a programmed time interval Readback of voltage, current, irradiance level, and temperature setting Programmable calibration of system

Curve Formula

The PV curves for the simulator are derived from the formula shown below.

Io as a function of Vo:
Io=Isc (1-C1 (exp (V/(C2 x Voc))-1))
C1=(1-(Imp/Isc)) (exp(-Vmp/(C2 x Voc)))
C2=((Vmp/Voc)-1)/(ln(1-Imp/Isc))

Where the Reference Irradiance conditions for the simulated arrays is 1000W/m2 and the Reference Array Temperature is 25°C

The simulated PV arrays are provided in terms of array fill factor, Maximum Power Point Voltage and Maximum Power Point Power. The curves generated are based on the Sandia Labs simplified PV Array model defining the relationship between

these values and other parameters as provided below:

Where:

$$P = Pref \times \frac{Irr}{Irref} \times \left(1 + \frac{\beta}{100} \times (T - Tref)\right)$$

$$V = Vref \times \frac{\ln Irr}{\ln Irref} \times \left(1 + \frac{\beta}{100} \times (T - Tref)\right)$$

$$P = V \times I$$

$$FF = \frac{Vmp \times Imp}{Voc \times Isc}$$

Where:

β Array temperature Coefficient, %/°C
T= Cell temperature, °C
V= Voltage, V
I= Current, A
FF= Fill Factor

Subscripts:

Ref= Reference (i.e., at reference or rated conditions)
MP= Maximum Power
OC= Open Circuit
SC= Short Circuit

DC Output Connections

The output connections will use finger safe, pressure type connectors or terminal blocks of suitable ampacity on the rear I/O panel depending on output current requirements.

"Multiple Hump" IV Curve

Utilizing data gathered from the Solar Advisor Model (SAM) data base, the TerraSAS allows the user to model systems made up of two or more subsystems. For example, a PV system that consists of three arrays with different orientations, thus creating a "Multiple Hump" as shown below.

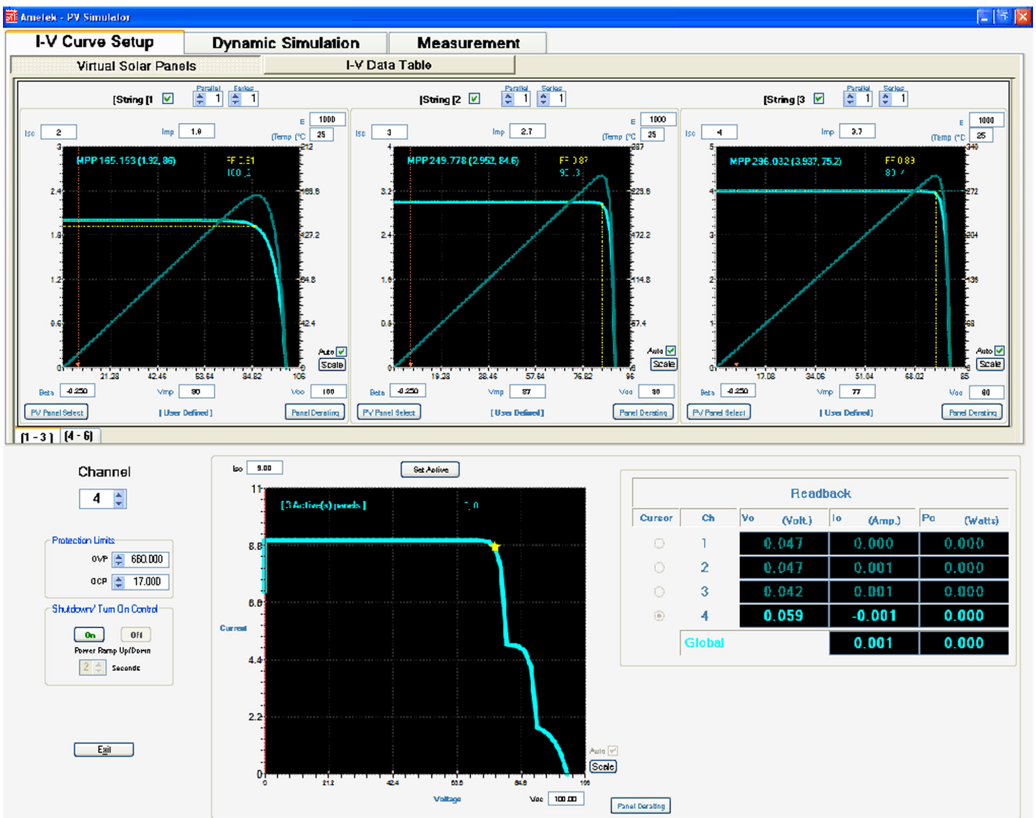
Safety

The system includes a shutdown function that will disable the output with an open interlock contact. In the event of an open interlock, the PV simulator chassis will program down the DC output and open the output relays, and provides complete qalvamic isolation

The benefit of simulators is simply that they offer the ability to test and invert without reliance on a real array and can simulate PV behaviors that a real array cannot be easily manipulated to do.

This assumes that the PV simulator can behave like a real panel of course.

Characteristic "multiple hump" IV curve results when three PV profiles are added



TerraSAS - Specifications

Specifications	
AC Power	AC Input Voltage: 115V (for DCS) 208VAC three phase Std, 400VAC and 480VAC three phase are optional (Input current depends on power rating)
DC Output	Open circuit voltage, Voc: 0 - 1000VDC Short circuit current, Isc: 0 – 1000A Maximum output power at MPP: 1MW (Lower voltage ranges will provide proportionately higher currents) 1-6 channel output, consult factory for additional channels.
Programmable Parameters	Irradiance level: 0 to 2000 W/m^2 Temperature: -40 to 90°C Temperature Coefficient: 0 to -65,000 mV/°C Simulation Times: 0 to 65,000 seconds Isolation relay and polarity relay closure
Accuracy	Voltage Readback: 0.2% of rated max voltage Current Readback: 0.5% of max current
Programming Interface	Ethernet with RJ-45 connector / LAN
AC Input Connections	Finger safe, pressure type connectors three phase AC four wire plus safety ground stud AC input circuit breaker
DC Output Connections	Finger safe, pressure type connectors positive and negative
Safety	The output isolation relay operates as a disconnect relay in the event of a malfunction or an open interlock contact

Output Voltage and Current Ranges

Power (MPP)	1 kW	5 kW	10 kW	15 kW	RMS	P-P	DC Leakage Current
Voc							
80V	Isc=12.5	Isc=83A	Isc=167A	Isc=250A	20 mV	100 mV	
600Voc	Isc=1.6A	Isc=8A	Isc=16A	Isc=25A	60 mV	350 mV	335mA
1000Voc	N/A	Isc=5A	Isc=10A	N/A			<1mA

MMPT	
Scalable (MPPT)	1000W to 1.0MW
Response to MPPT	Up to 120Hz
Current Slew Rate	3msec/A
Control Loop Sampling Rate	1usec / 10kHz

Static and Dynamic Programmable PV Array Parameters	
Irradiance Level	0-2,000W/m2
Temperature	-100 to +100*C
Voltage Level	0-600/1,000V 80V - Consult factory for other voltages
Current level to rated output current	0-Rated Output (see MPP Chart)
Voltage Temperature Coefficient	0 to -2% / *C
Arbitrary VI Curve	Up to 4096 data points

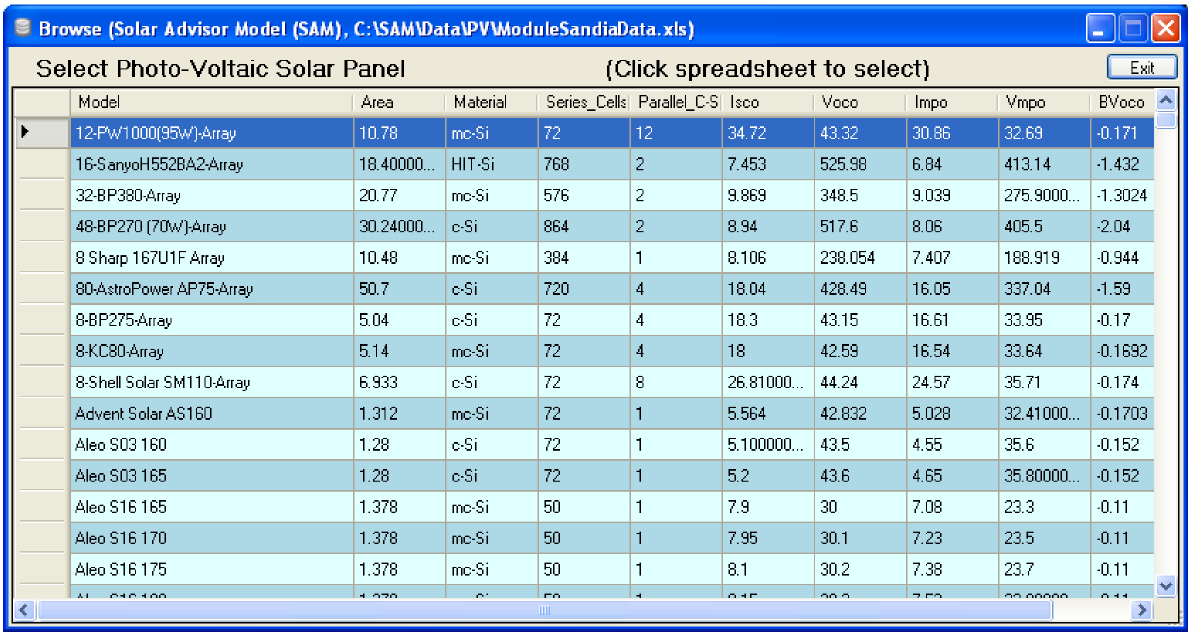
Programmable Setpoints	
Voc	0-Rated output voltage
Fill Factor	0.5 to 0.95
Vmp	0-Voc
Imp	0-Isc
ISC	0-Rated output current
Over Voltage Protection (OVP)	0.1% to 110% of Voc Max

VI Curve Set Point Accuracy	
Voltage	<0.1%, FS
Current	<0.5%, FS

Programming Resolution	
Programming Resolution	<0.002% of FS
Voltage / Current	<0.002% of FS

VI Curve Readback Accuracy	
Voltage	<0.1%, FS
Current	<0.5%, FS
Output Sampling Rate	100usec
IV Curve Update Rate	1sec
IV Curve Interpolation rate	7.8msec
Stability	
CC	0.05
Temperature Coefficient	
CC	0.03
Misc	
Simulation PV Array Channels	1-250
Preloaded Formula	LUFT
SAM Database	Over 100 pre-loaded PV Panels, Series & Parallel capability

Over 100 pre-loaded PV Panels, Series & Parallel capability



Model	Area	Material	Series_Cells	Parallel_C-S	Isco	Voco	Impo	Vmpo	BVoco
12-PW1000(95W)-Array	10.78	mc-Si	72	12	34.72	43.32	30.86	32.69	-0.171
16-SanyoH552BA2-Array	18.40000...	HIT-Si	768	2	7.453	525.98	6.84	413.14	-1.432
32-BP380-Array	20.77	mc-Si	576	2	9.869	348.5	9.039	275.9000...	-1.3024
48-BP270 (70W)-Array	30.24000...	c-Si	864	2	8.94	517.6	8.06	405.5	-2.04
8 Sharp 167U1F Array	10.48	mc-Si	384	1	8.106	238.054	7.407	188.919	-0.944
80-AstroPower AP75-Array	50.7	c-Si	720	4	18.04	428.49	16.05	337.04	-1.59
8-BP275-Array	5.04	c-Si	72	4	18.3	43.15	16.61	33.95	-0.17
8-KC80-Array	5.14	mc-Si	72	4	18	42.59	16.54	33.64	-0.1692
8-Shell Solar SM110-Array	6.933	c-Si	72	8	26.81000...	44.24	24.57	35.71	-0.174
Advent Solar AS160	1.312	mc-Si	72	1	5.564	42.832	5.028	32.41000...	-0.1703
Aleo S03 160	1.28	c-Si	72	1	5.100000...	43.5	4.55	35.6	-0.152
Aleo S03 165	1.28	c-Si	72	1	5.2	43.6	4.65	35.80000...	-0.152
Aleo S16 165	1.378	mc-Si	50	1	7.9	30	7.08	23.3	-0.11
Aleo S16 170	1.378	mc-Si	50	1	7.95	30.1	7.23	23.5	-0.11
Aleo S16 175	1.378	mc-Si	50	1	8.1	30.2	7.38	23.7	-0.11