



# TerraSAS Software

Installation and User Manual

*Programmable Power Solutions*



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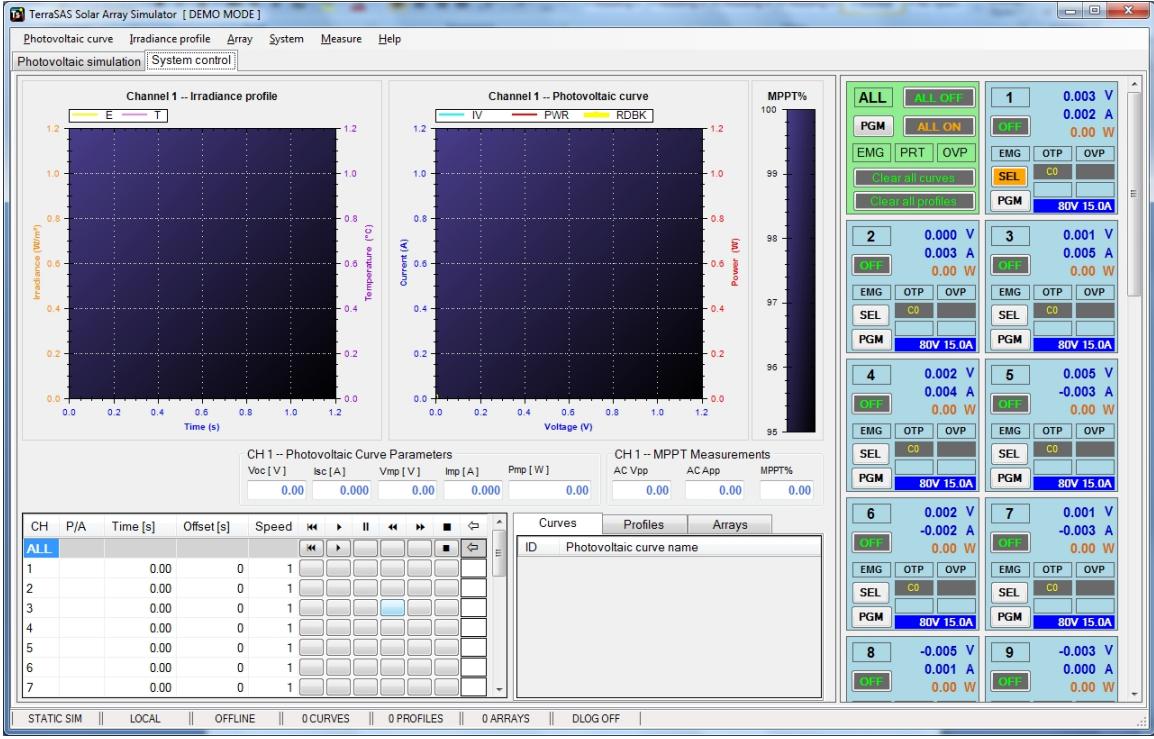
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## **Contact Information**

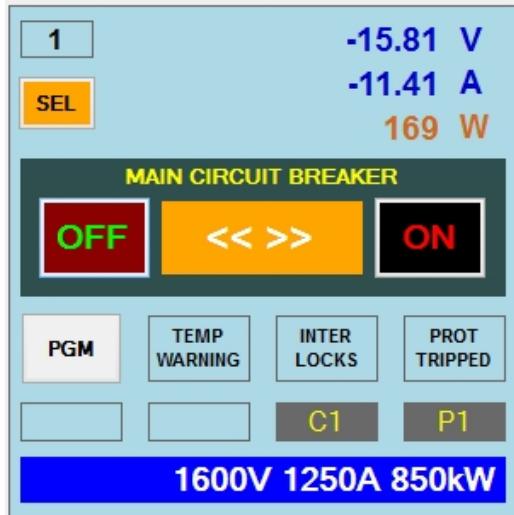
Telephone: 800 733 5427 (toll free in North America)  
858 450 0085 (direct)  
Fax: 858 458 0267  
Email: [sales@programmablepower.com](mailto:sales@programmablepower.com)  
[PPSsupport.PPD@ametek.com](mailto:PPSsupport.PPD@ametek.com)  
Web: [www.programmablepower.com](http://www.programmablepower.com)



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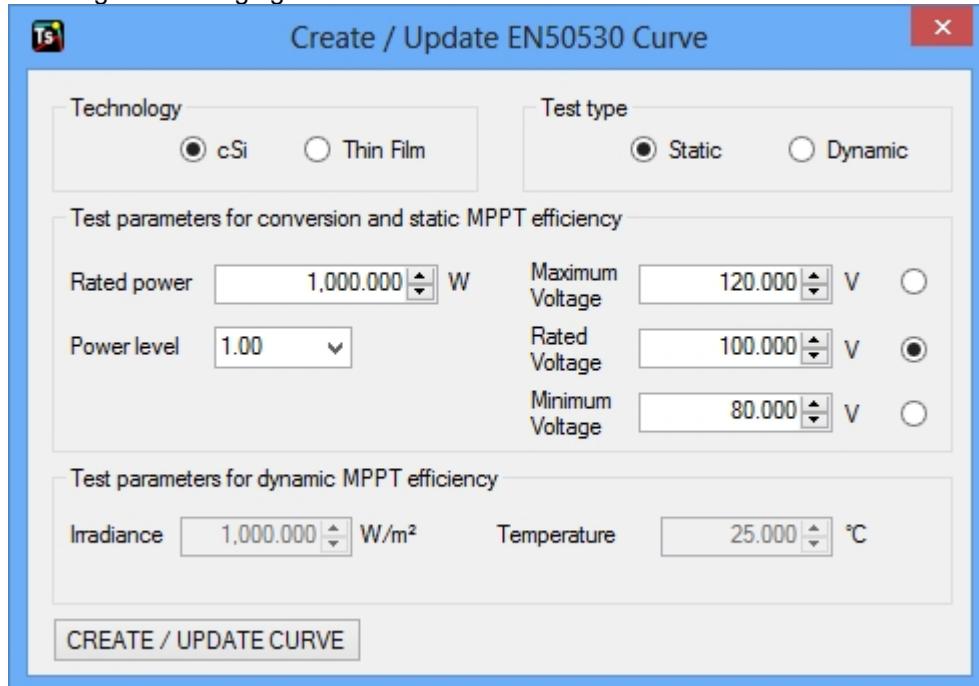
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# Software installation guide

## Computer requirements

### **Supported operating systems**

Microsoft Windows XP Service Pack 3  
Microsoft Windows 7 (32-bit and 64-bit)  
Microsoft Windows 8 (32-bit and 64-bit)  
Microsoft Windows 10 (32-bit and 64-bit)

### **Minimum hardware configuration**

Intel i3-3220 processor, 3.3 GHz or equivalent  
2 GB RAM  
Intel HD Graphics adapter or equivalent.  
One Network Interface Card for small systems (less than 5 channels)  
Two Network Interface Cards for large systems (5 or more channels)  
Keyboard and pointing device (3-button scrolling mouse highly recommended)

## Installation under Microsoft Windows

Some of the following steps can be skipped if the computer had been already configured with the desired user accounts, passwords and Ethernet adapters configuration.  
Account names and passwords are the default ones used during factory setup and can be changed if desired.

### **Setting the computer name and description**

Right Click on the Windows logo (bottom left corner), then select “System”.  
Under “Device specifications” select “Rename this PC”.

Change computer name to **TerraSAS-PC**  
Reboot when asked

### **Creating a user account**

Right Click on the Windows logo (bottom left corner) then select “Settings”, “Accounts and Family & other users”. Under Other users click “Add someone else to this PC”(Skip creating a Microsoft Account).

Click on Create a new account

Type User name: **TerraSAS**

Set password to: **override**

**After User Account is created. Change account type to Administrator.**

Reboot and log in as TerraSAS

### **Deleting the default account**

Right Click on the Windows logo (bottom left corner) then select “Settings”, “Accounts and Family & other users”. Under “Other users” click account to be deleted. Select Remove.

## **Network configuration for on-line desktop systems**

In this configuration computer and PV simulators are connected to the organization's Local Area Network, either directly or through a desktop network switch. Computer and PV simulators must be on the same subnet and the network must support automatic IP address assignment (DHCP, Dynamic Host Configuration Protocol). Make sure the adapter is configured for DHCP and that all network connections are healthy before proceeding. The advantage of this configuration is that simulators can be remotely operated.

**CAUTION:** attempting to simultaneously control a simulator from two or more computers running TerraSAS software will cause faulty operation. However, any number of simulators and computers can share a common network, as long as each simulator is controlled by one computer only.

## **Network configuration for off-line desktop systems**

In this configuration a computer with a single network adapter (usually a laptop) is connected to one or more PV simulators, either directly or through a desktop network switch. By activating the internal DHCP server (see procedure below), all PV simulators are automatically assigned an IP address.

**WARNING: DO NOT CONNECT TO A LOCAL AREA NETWORK WHEN THE DHCP SERVER IS ACTIVE. SEVERE LAN SERVICE DISRUPTION WILL OCCUR.**

## **Network configuration for off-line, single channel desktop systems**

On some computers the internal DHCP server cannot be activated due to security policies set by remote servers that cannot be altered by local users, even when granted administrative privileges. In this case it is still possible to connect to a single simulator through a direct, static IP connection. Connect the computer to the simulator using any Ethernet cable. Set the adapter IP address to 10.0.0.2, subnet mask 255.255.0.0. Since the simulator defaults to IP address 10.0.0.1 if no IP address is assigned, communication is immediately established.

**CAUTION:** connecting more than one simulator in this way will cause an IP addressing conflict and none of the simulators will communicate.

## **Network configuration for factory- configured rack systems**

Rack systems feature computers with dual network adapters. In this configuration all PV simulators are connected to one network adapter, while the other is used to connect the computer to the organization's local area network.

Open Control Panel / Network and sharing center

Select the adapter connected to the PV simulators

Name the adapter "HardwareLink"

Configure the adapter for static IP addressing with IP=1.1.1.1, subnet mask=255.255.0.0

Select the adapter connected to the Local Area Network

Name the adapter "Intranet"

Configure the adapter for dynamic IP (DHCP enabled, leave all defaults unchanged)

## **Software installation**

Insert the TerraSAS Software Install disk

Open the READ ME.txt file and follow the instructions

## **Activating the DHCP server**

**WARNING: DO NOT CONNECT TO A LOCAL AREA NETWORK WHEN THE DHCP SERVER IS ACTIVE. SEVERE LAN SERVICE DISRUPTION WILL OCCUR.**

Open Control panel / Windows Defender Firewall

Click on "Allow an app or feature through Windows Defender Firewall"

Click on Change settings button

Click on the Allow another program... button

Click on the Browse... button and navigate to **C:\TerraSas Configuration** and select **dhcpsrv**

Click on the Open button

Click on Add

Click on Details... button  
Click on Network location type button  
Select both Home and Public networks, then click OK  
Click OK again  
Confirm DHCP Server for Windows is listed, checked and both Home and Public checkboxes are checked.  
Right click on **dhcpsrv** and select “Run as administrator”  
Click on the **Install** button  
Confirm the service is installed and running  
Close DHCP server

**NOTE:** make sure the Ethernet adapter connected to the PV simulators is configured for static IP addressing with IP=1.1.1.1, subnet mask=255.255.0.0. The internal DHCP server will not be active if a different IP address is selected.

## **Running TerraSAS for the first time**

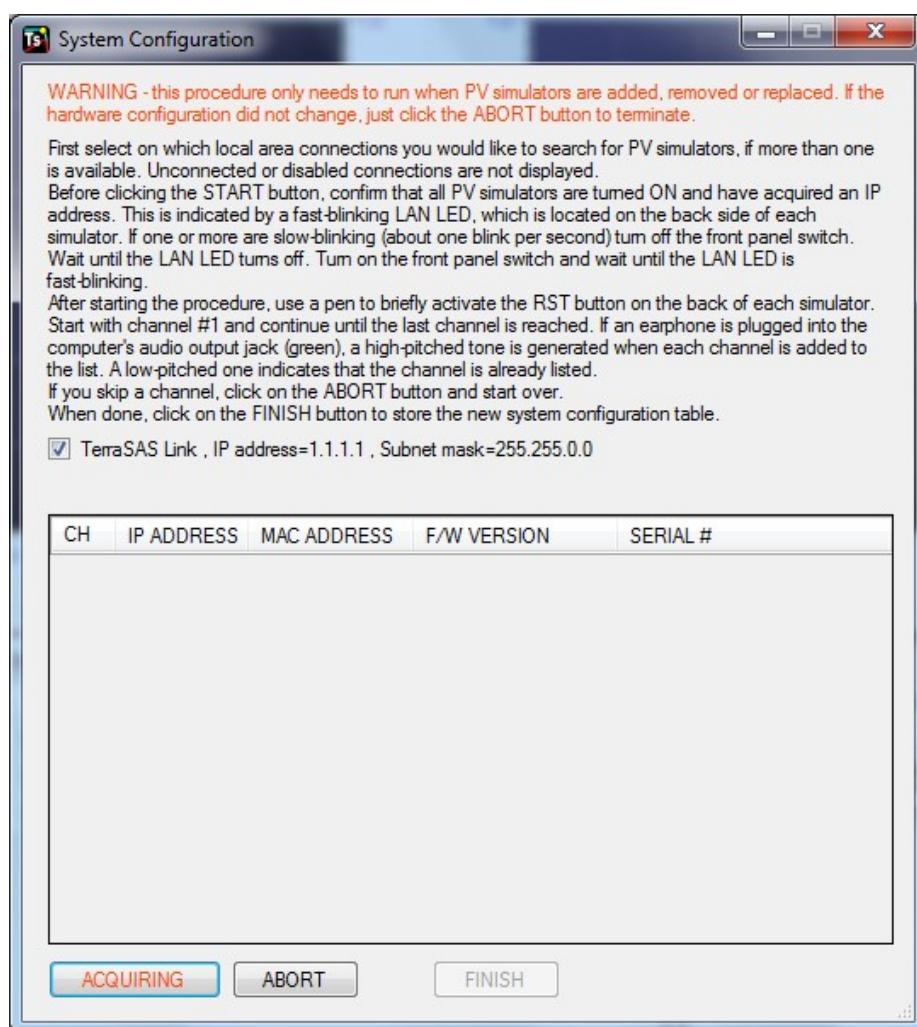
### **Creating system configuration tables**

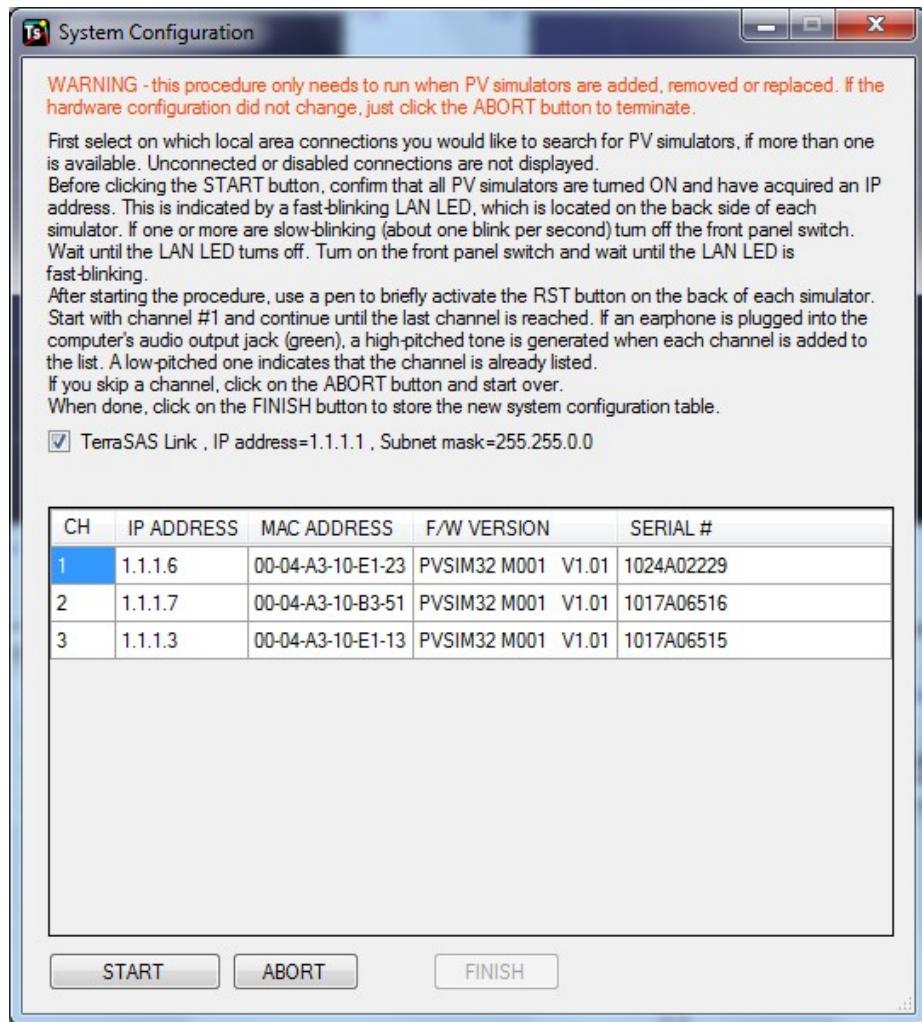
Each table contains information about each PV simulator channel and allows TerraSAS to correctly locate the hardware and establish communication with it. The corresponding file is named "System channels.txt" and is located in the folder C:\TerraSas Configuration

When launching TerraSAS for the first time, a message informs that the system configuration is missing and brings up this dialog automatically.

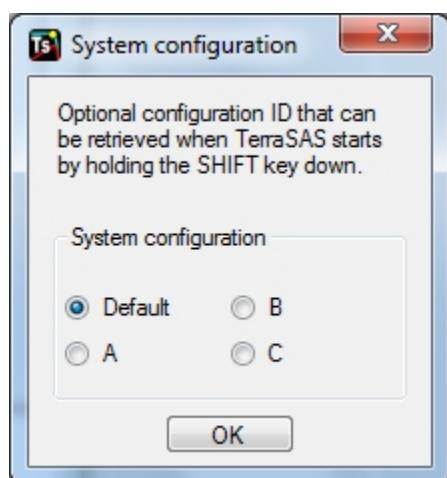
To make changes, select System / Configure / PV Simulators

Follow the instructions to create and store a new system configuration table.





When all desired simulators are located, click the FINISH button. The following dialogue will then be displayed:



Up to four different configurations can be saved.

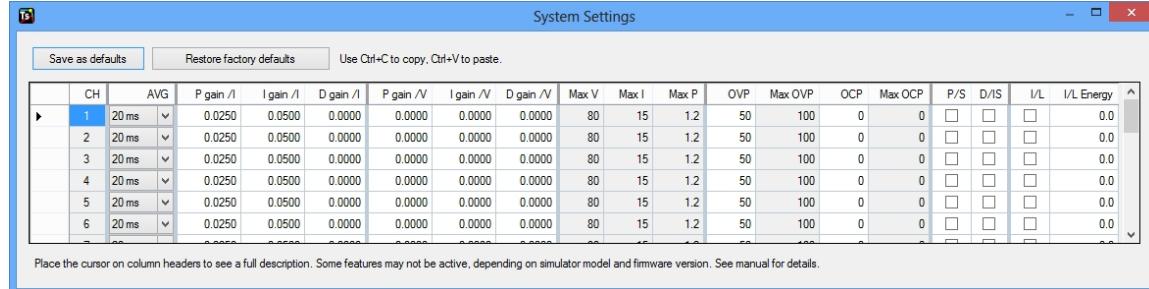
When finished, TerraSAS terminates and needs to be manually restarted.

When TerraSAS starts, the default configuration is used. To select a different one, hold down the **[SHIFT]** key while launching the application. A similar dialogue will allow selecting configurations A, B or C.

After restarting, select the System control tab and confirm that all desired channels are online (online channels have a blue tile, offline channels have a grayed-out tile)

## Saving customized system settings

From the main menu select System / Configure / Settings to display the system settings table



The screenshot shows a Windows-style application window titled "System Settings". At the top, there are buttons for "Save as defaults", "Restore factory defaults", and a note: "Use Ctrl+C to copy, Ctrl+V to paste.". Below is a table with 6 rows and 17 columns. The columns are labeled: CH, AVG, P gain /I, I gain /I, D gain /I, P gain /V, I gain /V, D gain /V, Max V, Max I, Max P, OVP, Max OVP, OCP, Max OCP, P/S, D/IS, I/L, I/L Energy. The first row (CH 1) has values: 20 ms, 0.0250, 0.0500, 0.0000, 0.0000, 0.0000, 0.0000, 80, 15, 1.2, 50, 100, 0, 0, 0, 0, 0, 0.0. The other five rows (CH 2-6) have identical values. A note at the bottom of the table says: "Place the cursor on column headers to see a full description. Some features may not be active, depending on simulator model and firmware version. See manual for details."

CH	AVG	P gain /I	I gain /I	D gain /I	P gain /V	I gain /V	D gain /V	Max V	Max I	Max P	OVP	Max OVP	OCP	Max OCP	P/S	D/IS	I/L	I/L Energy
1	20 ms	0.0250	0.0500	0.0000	0.0000	0.0000	0.0000	80	15	1.2	50	100	0	0	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0.0
2	20 ms	0.0250	0.0500	0.0000	0.0000	0.0000	0.0000	80	15	1.2	50	100	0	0	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0.0
3	20 ms	0.0250	0.0500	0.0000	0.0000	0.0000	0.0000	80	15	1.2	50	100	0	0	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0.0
4	20 ms	0.0250	0.0500	0.0000	0.0000	0.0000	0.0000	80	15	1.2	50	100	0	0	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0.0
5	20 ms	0.0250	0.0500	0.0000	0.0000	0.0000	0.0000	80	15	1.2	50	100	0	0	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0.0
6	20 ms	0.0250	0.0500	0.0000	0.0000	0.0000	0.0000	80	15	1.2	50	100	0	0	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0.0

See section "Main menu items description", System > Configure > Settings for an explanation of the available settings and their meaning.

Make changes if desired, then click on "Save as defaults" to create the system settings file, which is named "System settings.txt" and is located in the folder C:\TerraSas Configuration.

Changes to this table are immediately passed to the hardware, but only after clicking "Save as defaults" are stored as new defaults. This includes the button "Restore factory defaults", which changes all parameters only for the current session. If factory defaults are intended to become the new defaults when TerraSAS is launched, click on "Save as defaults".

**NOTE:** each system configuration has its own settings table.

## Folders and example files

Immediately after launching TerraSAS for the first time, the following directories are created and filled with example and system files:

```
<root>
  <TerraSas>
    <Curves>
      BP Solar - BP 3230T (60 cells).crv
      GE Energy - GEPVp-200-M (54 cells).crv
      Sunpower 230 (72 cells).crv
      Sunpower 315 (96 cells).crv
    <Datalogging>
      (Empty)
    <Profiles>
      Cloudy day.irtp
      EN 50530 Table B1.irtp
      EN 50530 Table B2.irtp
      EN 50530 Table B3.irtp
      EN 50530 Table B1.irtt
      EN 50530 Table B2.irtt
      EN 50530 Table B3.irtt
      Fast ramp.irtp
      Heavy clouds day.irtp
      Irradiance test.irtp
      Slow ramp .irtp
      Sunny day.irtp
      Temperature test.irtp
      Triangle ramp .irtp
    <Sessions>
      (Empty)
```

#### <TerraSas Configuration>

dhcpsrv.exe  
dhcpsrv.ini  
READ ME - IMPORTANT NOTICE.txt  
Simulated system channels.txt  
Simulated system configuration.txt  
Serial.txt

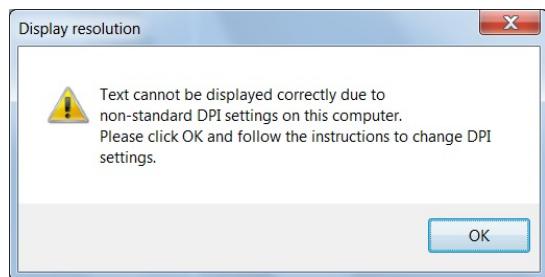
Curve files were created using the application and data from each manufacturer's data sheet. Irradiance profiles were created using Microsoft Excel and sample irradiance data provided by Sandia National Laboratories.

Files Fast, Slow and Triangle ramp were coded under the guidelines for MPP tracking tests described in the document: "Performance Test Protocol for Evaluating Inverters Used in Grid-Connected Photovoltaic Systems", October 2004, Sandia National Laboratories.

Files added to any of the above folders by the user are not altered by the installer when updating the software to later versions. If the directory structure is moved, modified or deleted, a new structure is automatically created. The application never deletes or alters a disk file, even when its corresponding graphics representation is deleted from the graphic pool.

#### Display resolution

In order to properly display text and graphics, the default screen resolution of 96 dpi (dot per inch) must be in place. If not, the following message is displayed when TerraSAS starts:



In Microsoft **Windows**, to reset the display resolution to the Windows default, click on the **Windows logo** (bottom left corner of the screen), then click on **Settings**, **System** then Click on **Display**:

## Windows Settings

## System

Display, sound, notifications,  
power

## Devices

Bluetooth, printers, mouse



## Phone

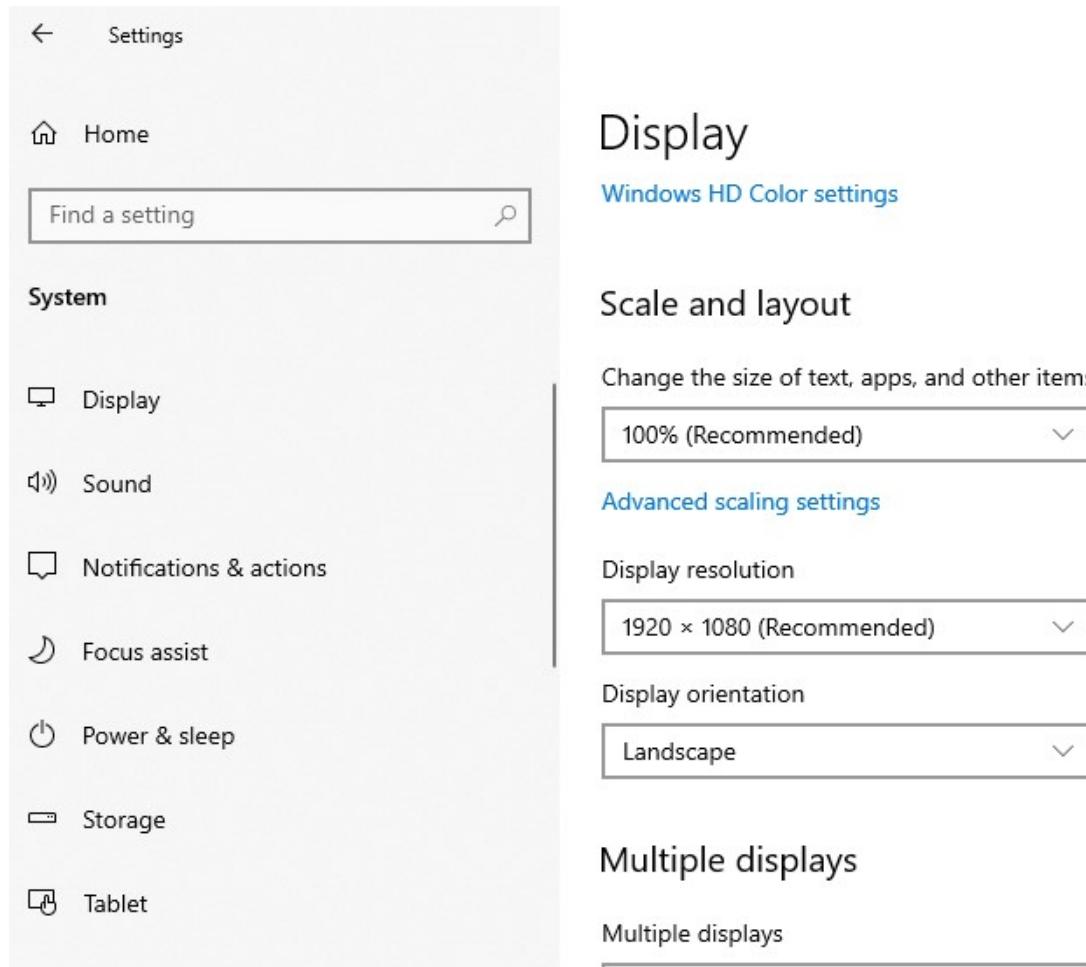
Link your Android, iPhone



## Network &amp; Internet

Wi-Fi, airplane mode, VPN

Under "Scale and layout" set text, apps, and other items to "100% (Recommended)":



← Settings

Home

Find a setting

System

- Display
- Sound
- Notifications & actions
- Focus assist
- Power & sleep
- Storage
- Tablet
- ...

Display

Windows HD Color settings

Scale and layout

Change the size of text, apps, and other items

100% (Recommended)

Advanced scaling settings

Display resolution

1920 × 1080 (Recommended)

Display orientation

Landscape

Multiple displays

Multiple displays

Launch TerraSAS and confirm the warning message is no longer displayed. Text and graphics are now displayed correctly.

# Software User Guide

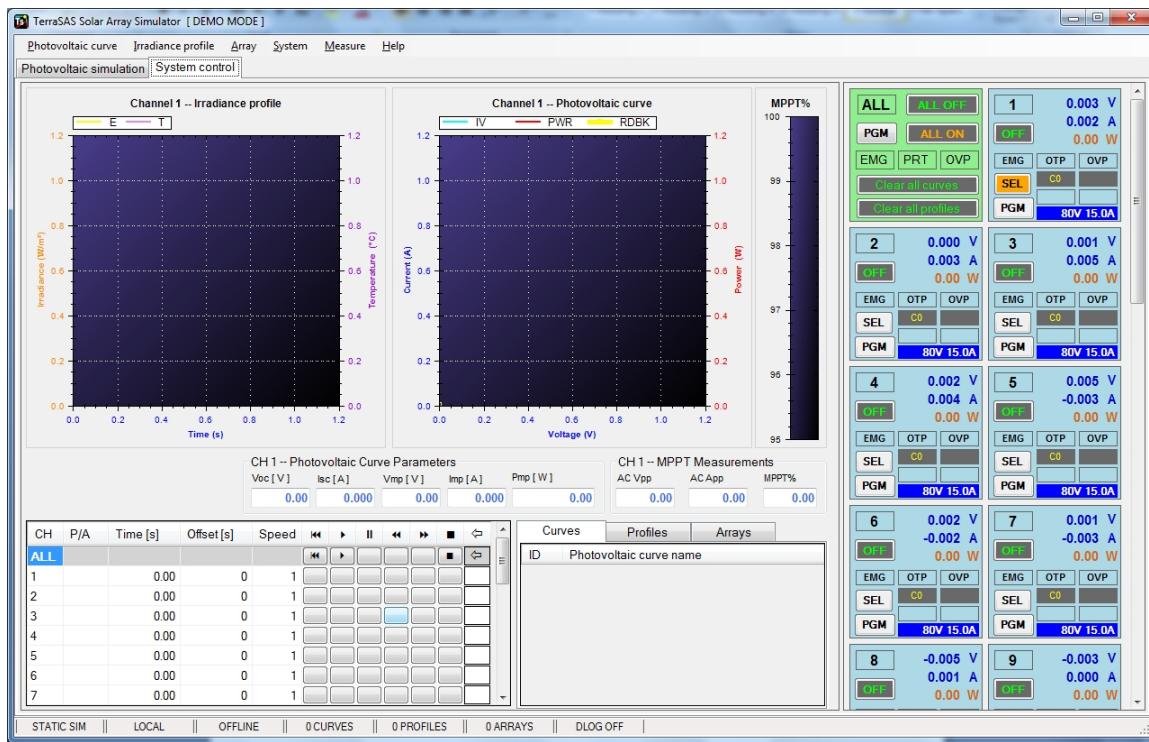
## **Basic concepts**

### **Overview**

TerraSAS is designed to provide powerful features and ease of use. Its main design goals are:

- Easily create photovoltaic curves from manufacturer supplied data, based on the Sandia National Labs model
- Create and manage photovoltaic curves based on the EN 50530 model
- Easily create irradiance / temperature profiles by entering ramp and dwell timing data
- Import photovoltaic curves created with third party applications
- Import irradiance / temperature profiles created in Microsoft Excel, third party applications or using real-time data acquisition from actual solar panels
- Organize any number of curves and profiles into graphic, filmstrip like pools for intuitive, easy access
- Create any number of solar array configurations, organized into a graphic, filmstrip like pool.
- Intuitive drag-and-drop interface to easily assign curves and profiles to individual array elements, to support accurate modeling of array shadowing patterns
- Simulation preview of each configured array
- Comprehensive remote interface based on the SCPI Language
- Fully configurable real time trigger, measurement and data logging features
- Full hardware monitoring and fault reporting system
- Real time control of TerraSAS digital photovoltaic simulator systems (up to 50 channels)
- Real time control of standalone, desktop TerraSAS digital photovoltaic simulator units

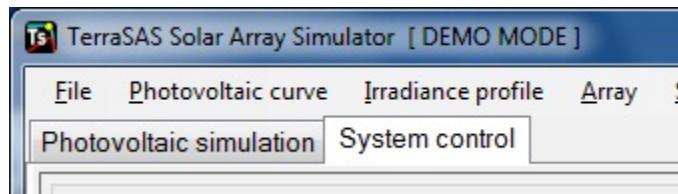
The picture below shows the System control tab from the main screen.



## DEMO MODE operation

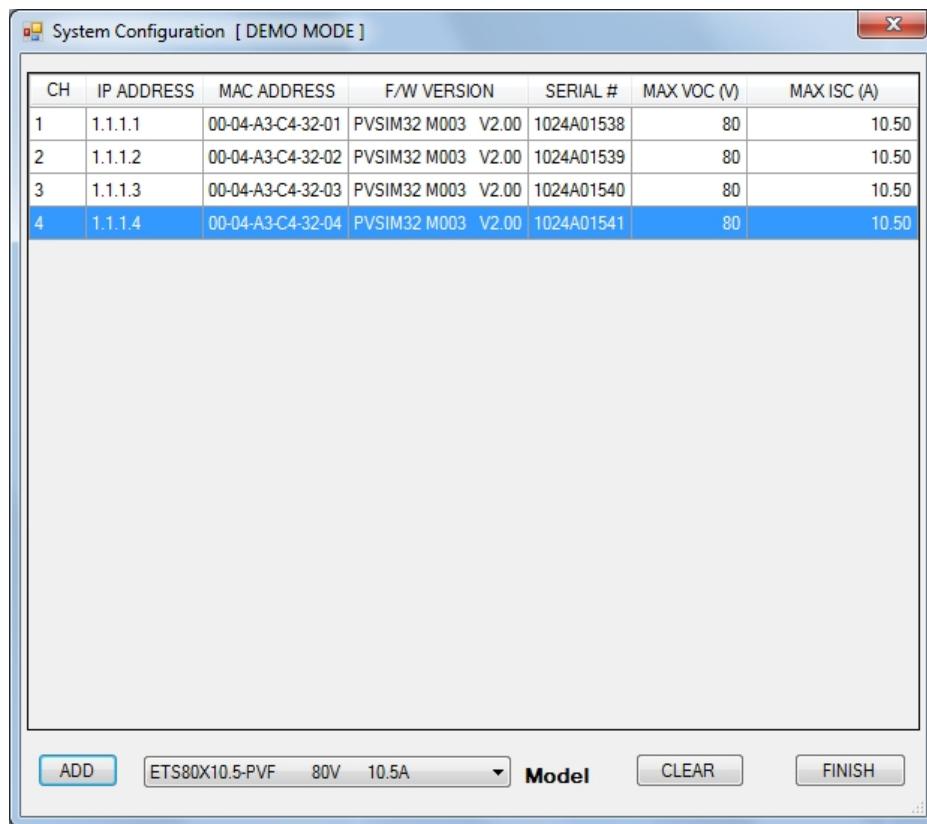
Click on the TerraSAS icon to select.

Hold down the SHIFT and CTRL keys on your keyboard, then double-click the icon to launch TerraSAS. Release both keys when the application starts. By default, DEMO MODE simulates a TerraSAS rack system with 24 low voltage PV simulators (DCS 80V 15A). This can be useful for demonstration or training purposes when physical PV simulators are not available. DEMO MODE operation is indicated on the user interface:



DEMO mode is also useful when developing SCPI scripts. The target system is often busy performing long test sessions and cannot be disturbed. In this case, TerraSAS can be installed on a test computer, launched in DEMO MODE and be remotely controlled by another machine.

It is possible to simulate any system architecture by manually building a system configuration file.



While in DEMO MODE, select System>Configure>PV Simulators. Click on the CLEAR button to remove the existing configuration. Select the desired simulator from the pull down control. Click one or more times on the ADD button to add the desired channels. A system (including actual ones) can have any combination of simulator models, up to 48 total channels. Click the button FINISH when done.

TerraSAS will terminate and will need to be manually restarted. Restart in DEMO MODE to interact with the new system configuration.

## Turning the system on and off

PV simulators need to acquire an IP address each time they are turned on. On desktop systems with a single network adapter the IP address is assigned by the organization Intranet.

On rack systems, IP addresses are assigned by the DHCP server that runs as a Windows service on the system computer. This service is automatically activated as soon as Windows is loaded and a user logs in. When TerraSAS is launched, it attempts to communicate with all PV simulators listed in the system configuration table.

Any off-line channel is tagged as dead and no further communication attempts are made.

Dead channels are assigned a grayed-out tile and they only appear in the system configuration table. They are removed from all other locations, such as system setting and programming forms.

## Recommended system turn on sequence

Make sure all PV simulators are turned OFF

Turn on the main circuit breaker (cabinet systems only)

Turn on the computer if not turning on automatically

Wait until Windows loads

Log in

Turn on the front panel ON/OFF switch on all PV simulators

Wait about 10 seconds

Launch TerraSAS and confirm all channels are online (blue tiles)

If one or more channels are dead (gray tiles), close and restart TerraSAS

## Recommended system turn off sequence

Select System > Reset

Close TerraSAS by clicking on the upper-right [X] on the form

Click the Windows logo (bottom left corner) then select Power, Shutdown to turn off the computer

Turn off the main circuit breaker (rear panel of rack systems) and the front panel ON/OFF switch on all PV simulators

## Graphic chart features in the Photovoltaic simulation tab

When the cursor is in a graphic pane (cross hair shape), use the mouse or touchpad to access the following features:

Zoom in: left click, hold down then drag to draw a rectangle and release to zoom to that rectangle

Pan: center click and hold down, and then drag to pan in any direction. If using the touchpad, press and hold the CTRL key, left click and hold down, then drag.

Menu: right click to access the graphics context menu. This allows to un-zoom, un-pan, show point values, save graphic data to the clipboard, disk file, etc.

## Graphic chart features in the System control tab

When the cursor is in a graphic pane (cross hair shape), use the mouse or touchpad to access the following features:

Zoom in: left click, hold down then drag to draw a rectangle and release to zoom to that rectangle

Zoom in/out: roll the scrolling wheel to zoom in and out. If using the touchpad, slide your finger next to the right edge of the pad to zoom in and out.

Pan: center click and hold down, and then drag to pan in any direction. If using the touchpad, press and hold the CTRL key, left click and hold down, then drag.

Restore default scale factors: double click just outside the graphic pane (arrow-shaped cursor)

Note: all charts in the system control tab are refreshed 20 times per second to show real-time data. When the cursor enters their area, refreshing is suspended to allow the user to interact with the chart. Refreshing is resumed as soon as the cursor leaves the chart.

## **Main menu items description**

### **File > Load Test Session**

Select the desired test setup file (previously saved) and click **[Open]**.

### **File > Save Test Session**

Enter a session name and click the **[OK]** button. This saves the entire test setup to a single XML file. This includes the system configuration, system settings, channels grouping, loaded curves, loaded profiles, arrays and output channels configuration.

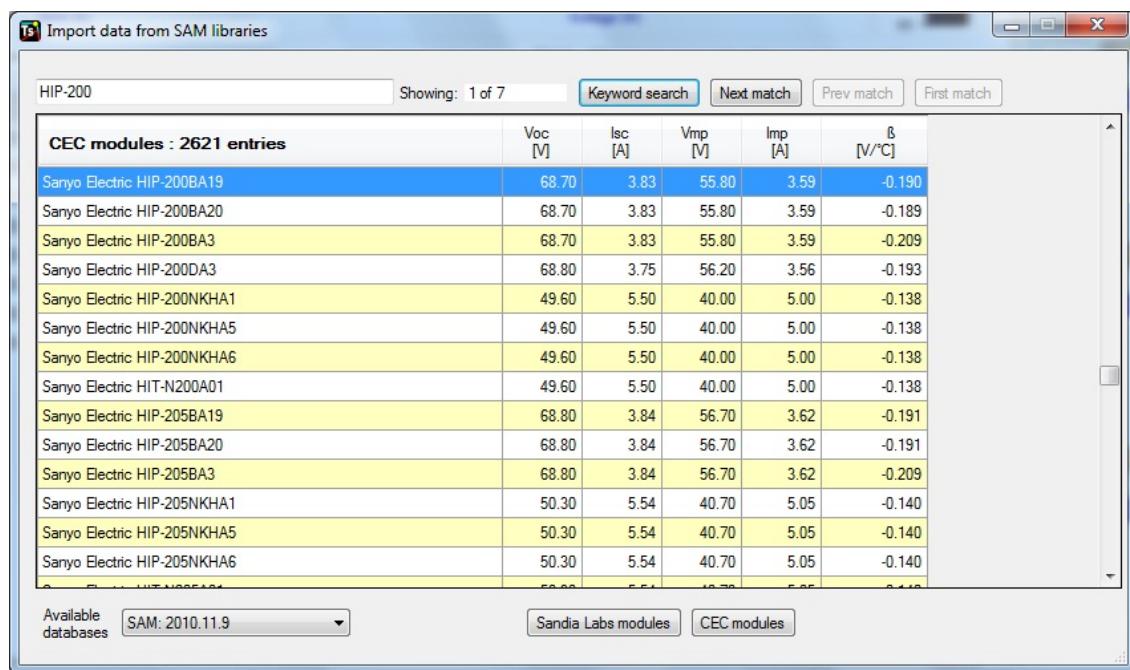
### **Photovoltaic curve > Load (SNL)**

Select the desired curve file, and then click Open. The curve is loaded into the graphic pool and can be executed on one or more output channels, or assigned to an array.

### **Photovoltaic curve > Import (SAM)**

This feature allows to quickly import data from solar module libraries. The most recent libraries become available after installing the Solar Advisor Model (SAM). This software can be downloaded from <http://www.nrel.gov/analysis/sam/download.html> free of charge.

The embedded libraries reflect the SAM version available at the time a TerraSAS software release is published, and are listed as TerraSAS: YYYY.MM.DD.



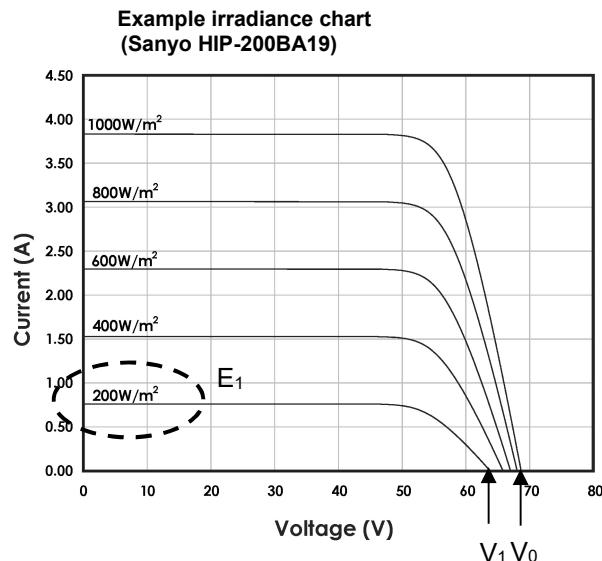
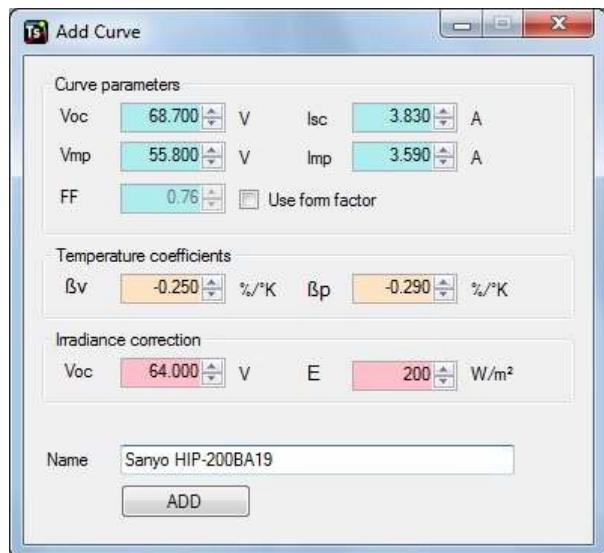
If more than one release of SAM was installed, the pull-down window allows selecting the desired one. The latest one is of course recommended.

After loading the desired modules library (Sandia Labs or CEC), browse the list of available solar modules or enter a specific part number (or part of it) to quickly locate it. Press the **[ENTER]** key or click on the **[Keyword search]** button to begin searching.

When the search is completed, the number of matching modules is reported. Buttons **[Next match]**, **[Prev match]** and **[First match]** allow the user to review all matching entries.

Double click on the desired module to export all available data to the **Add Curve** form (see next page). Note that not all parameters in the form are available from the library. Additional data from the manufacturer data sheet can further improve the accuracy of the simulation.

## Photovoltaic curve > Create (SNL)



Enter the desired  $V_{oc}$ ,  $I_{sc}$ ,  $V_{mp}$ ,  $I_{mp}$  and temperature coefficients normally found in the manufacturer data sheet. Note that some manufacturers provide the voltage coefficient in  $V/K$  or  $mV/K$ . In this case, divide by  $V_{oc}$  to obtain the required percentage figure.

If an irradiance chart is available, also enter values  $V_1$  and  $E_1$  into the Irradiance correction parameters. This significantly improves the simulation accuracy. If not, just leave the default values.

By checking the "Use form factor" checkbox,  $V_{mp}$  and  $I_{mp}$  are calculated from the desired form factor.

Assign a name to the curve and click **[ADD]** to create the disk file and add it to the pool.

Note: the curve name is unique and cannot be duplicated. If an identical name exists, an error message is generated. To delete a curve file, use Windows Explorer and navigate to the Curves folder.

## Photovoltaic curve > EN 50530:2010 > Create / Update Curve

This feature allows creating and managing an EN 50530 curve. See the advanced programming section for full details.

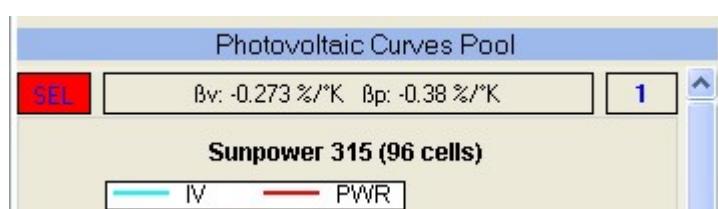
## Photovoltaic curve > EN50530:2010 > Edit coefficients

This feature allows modifying the table of coefficients used in the EN 50530 curve equations. See the advanced programming section for full details.

## Photovoltaic curve > Remove > All

This removes all curves from the pool. Disk files are not deleted.

## Photovoltaic curve > Remove > Selected



Click on **[SEL]** to select one or more curves, then access this feature to remove them from the pool. Disk files are not deleted. To deselect, click again on **[SEL]**.

To delete a curve file, use Windows Explorer and navigate to the Curves folder.

## Irradiance profile > Load

Select the desired profile file, and then click Open. The profile is loaded into the pool and can be executed on one or more output channels.

## Irradiance profile > Remove > All

This removes all profiles from the pool. Disk files are not deleted.

## Irradiance profile > Remove > Selected



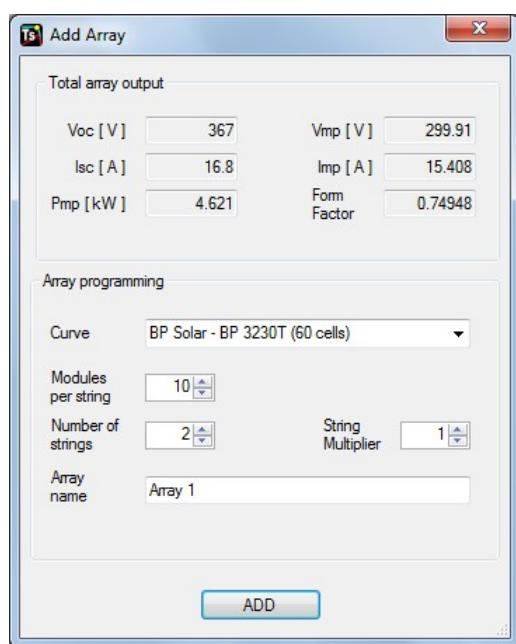
Click on **[SEL]** to select one or more profiles, then access this feature to remove them from the pool. Disk files are not deleted. To deselect, click again on **[SEL]**.

To delete a profile file, use Windows Explorer and navigate to the Profiles folder.

## Irradiance profile > Create

This feature allows creating and editing irradiance / temperature profiles. See the advanced programming section for full details.

## Array > Add



Enter the desired array size, assign a name and click on the **[ADD]** button. The array is added to the pool.

Note: the array name is unique and cannot be duplicated. If an identical name exists, an error message is generated.

The maximum number of modules within an array is 100.

A warning message informs the user when this limit is reached.

The newly created array can now be populated, programmed and executed on one or more channels. See section "Executing a static array simulation" for details.

## Array > Remove > All

This removes all arrays from the pool. Any channel with an array assigned is switched to curve zero.

## Array > Remove > Selected

Select an array by clicking on its perimeter. Selected arrays become highlighted. To deselect, click again. Then access this feature to remove all selected arrays from the pool.

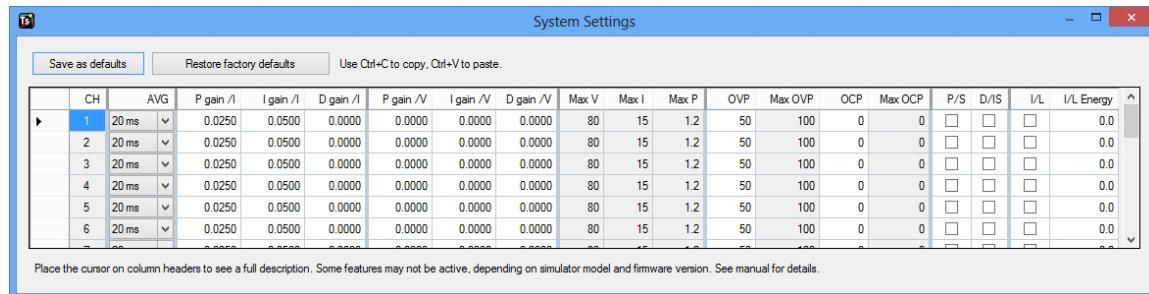
When one or more arrays are removed, channels executing these arrays will switch to curve zero.

## System > Configure > PV Simulators

This feature is used during system configuration. See section "Running TerraSAS for the first time" for details.

## System > Configure > Settings

This feature can be accessed at any time to change system settings as needed.



Changes are not saved permanently to disk until the [Save as defaults] button is clicked. The [Restore factory defaults] button returns all settings to their default values.

Please see below a brief description of all programmable parameters.

### AVG – Averaging digital filter

This parameter controls the length of the time window over which measurements' averaging is performed, including true rms power sampling. For best results, AVG should be set to the MPPT sweep period or longer. Low voltage, DCS based simulators allow 0-80ms while high voltage, SG and ETS based simulators allow 0-400ms. Some recent string inverters sweep the MPP at 5 Hz, which equates to 200ms. These inverters will work best with the 200 or 400 ms selection.

### PID gain coefficients – Overview

Default PID coefficients are suitable for most test scenarios and are automatically assigned based on the simulator model. Default PID coefficients work in most situations, however fine tuning them for a specific inverter can improve tracking performance and stability.

**CAUTION:** the output can become unstable during tuning. Always set the OVP (overvoltage protection) to a safe level to prevent damage to the inverter. The OVP setting should be no higher than 80% of the maximum inverter input voltage during tuning.

On DCS and legacy simulators, the voltage control loop is analog and the current control loop can be analog or digital. In these models, the PID loop is designed to increase the response speed of the PV simulator. The inverter input current is compared to the current setpoint from the IV curve. The resulting error is fed to the PID controller, which is implemented in the PV simulator firmware. The PID controller output controls the power supply current set input.

The PID control loop can be disabled by setting all three coefficients to zero. This can be useful if the digital loop provides no stability or responsiveness improvements. In this mode of operation, the current reference from the IV curve is directly applied to the power supply current set input.

### PID gain coefficients – Current control [ I ]

These three coefficients set the responsiveness of the current control loop. Increasing their values improves the response time but can make the system unstable. The best tradeoff can be determined by trial and error.

### PID gain coefficients – Voltage control [ V ]

These three coefficients set the responsiveness of the voltage control loop. Increasing their values improves the response time but can make the system unstable. The best tradeoff can be determined by trial and error.

Latest generation ETS...-PVF simulators feature high speed digital control loops for current and voltage, therefore there are two sets of PID coefficients. Voltage mode coefficients affect the voltage regulation when the inverter is idling and a very small current is flowing. When the inverter starts, the simulator switches to current mode and current mode coefficients become active. The simulator will switch back to voltage mode during transients or turn off, when the inverter current becomes very low.

## Max V, Max I, Max P, Max OVP, Max OCP

Maximum output voltage, current and power. Maximum overvoltage and overcurrent protection.

### OVP – Overvoltage protection

When the specified voltage is reached, the output is turned off and the OVP indicator is lit. This is intended to protect the inverter under test from damage. Reduce the voltage and reset the OVP condition by double-clicking on the OVP indicator.

### OCP – Overcurrent protection

This is only supported on High Power systems. See related section.

### P/S – Power Supply Mode

Places the channel in P/S mode when checked. The IV curve is replaced by a rectangle on all graphics. Irradiance / Temperature programming is replaced by Voltage / Current on all programming dialogs. The output tile turns yellow to show the different operating mode. Channels can be grouped in parallel or series when in P/S mode.

### D/IS – Disable Interpolation Slope

When selected, sudden irradiance changes can be executed. This is desirable when evaluating an inverter's response to transients. This mode also enables higher precision dynamic measurements. See the EN50530 section for more details.

### I/L – Inrush Limiter option enable

When checked, the inrush limiter module is activated. See the ETS1000 user manual for details about this optional feature. If the optional module is not present or not in use, leave the box unchecked.

### I/L Energy – Inrush Limiter option threshold programming

This is used to program the behavior of the Inrush Limiter option module. See the ETS1000 user manual for details about this optional module. If not present, this parameter should be programmed to zero.

## System > Configure > Import inverter data

This feature allows to quickly import data from a solar inverter library. The most recent library becomes available after installing the Solar Advisor Model (SAM). This software can be downloaded from <http://www.nrel.gov/analysis/sam/download.html> free of charge.

The embedded library reflects the SAM version available at the time a TerraSAS software release is published, and is listed as TerraSAS: YYYY.MM.DD.

Import data from SAM libraries						
1502xi	Showing: 1 of 2		Keyword search	Next match	Prev match	First match
<b>Sandia inverters : 614 entries</b>	Vnom [V]	Pnom [W]	Vmax [V]	Imax [A]	Mppt Lo [V]	Mppt Hi [V]
Kaco New Energy GmbH: Blue Planet 1502xi 208V [CEC 2009]	195.00	1,593.91	550.00	21.45	125.00	400.00
Kaco New Energy GmbH: Blue Planet 1502xi 240V [CEC 2009]	195.00	1,583.04	550.00	21.45	125.00	400.00
Kaco New Energy GmbH: Blue Planet 2502xi 208V [CEC 2009]	265.00	2,646.95	550.00	21.45	200.00	450.00
Kaco New Energy GmbH: Blue Planet 2502xi 240V [CEC 2009]	265.00	2,633.70	550.00	21.45	200.00	450.00
Kaco New Energy GmbH: Blue Planet 2901xi 240V [CEC 2007]	176.58	3,067.68	400.00	33.00	125.00	300.00
Kaco New Energy GmbH: Blue Planet 3502xi (208V) 208V [CEC 2009]	280.00	3,683.98	550.00	28.00	200.00	510.00
Kaco New Energy GmbH: Blue Planet 3502xi (240V) 240V [CEC 2009]	280.00	3,668.80	550.00	28.00	200.00	510.00
Kaco New Energy GmbH: Blue Planet 3601xi 240V [CEC 2007]	178.63	3,856.22	400.00	48.00	125.00	300.00
Kaco New Energy GmbH: Blue Planet 5002xi (208V) 208V [CEC 2009]	280.00	5,309.48	550.00	40.00	200.00	510.00
Kaco New Energy GmbH: Blue Planet 5002xi (240V) 240V [CEC 2009]	280.00	5,279.73	550.00	40.00	200.00	510.00
Kaco New Energy GmbH: Blue Planet XP100U-H2 208V [CEC 2010]	341.96	104,726.50	600.00	410.00	300.00	600.00
Kaco New Energy GmbH: Blue Planet XP100U-H4 480V [CEC 2009]	342.29	104,185.47	600.00	410.00	300.00	600.00
Magnetek Uncommon Power: PVI-3000-I-OUTD-US (208V) 208V [CE...	330.13	3,033.45	0.00	0.00	150.00	480.00
Magnetek Uncommon Power: PVI-3000-I-OUTD-US (240V) 240V [CE...	358.35	3,324.02	600.00	20.00	90.00	540.00
Magnetek Uncommon Power: PVI-3000-I-OUTD-US (208V) 240V [CE...	331.20	3,026.20	0.00	0.00	150.00	480.00

Available databases: SAM: 2010.11.9

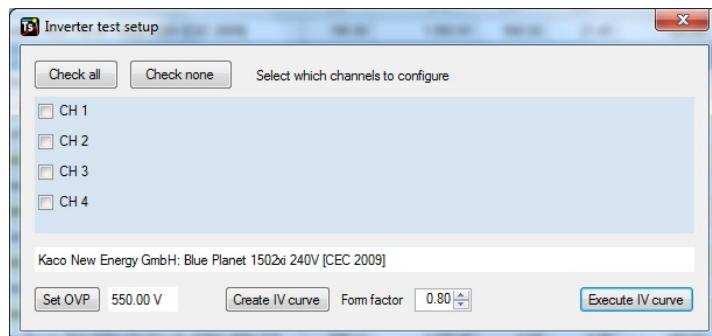
Sandia Labs Inverters

If more than one release of SAM was installed, the pull-down window allows selecting the desired one. The latest one is of course recommended.

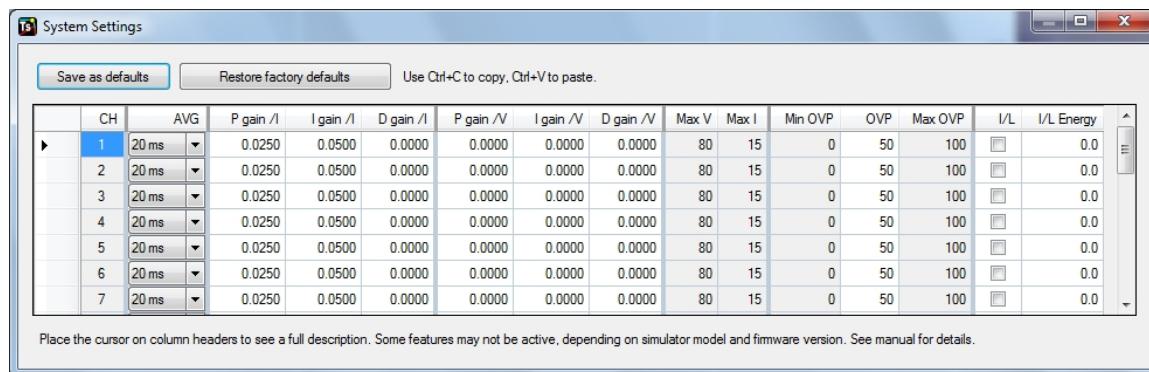
After loading the library, browse the list of available inverters or enter a specific part number (or part of it) to quickly locate it. Press the **[ENTER]** key or click on the **[Keyword search]** button to begin searching.

When the search is completed, the number of matching inverters is reported. Buttons **[Next match]**, **[Prev match]** and **[First match]** allow the user to highlight and review all matching entries.

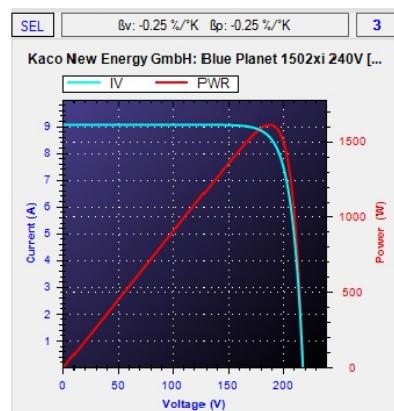
Double click on the desired inverter to export all available data to the form below, which is automatically launched:



Select the channels to configure, then click on the **[Set OVP]** button. This brings up the System Settings form, where the OVP setting is automatically entered for the selected channel(s):



Make any adjustments, if needed, and close the form. Then select the desired form factor and click on the **[Create IV curve]** button. A new curve is created and added to the graphic pool. The maximum power point matches the nominal operating voltage and current of the inverter.



Note that the curve is added to the graphics pool only; it is not saved on disk as usual.

Click on the **[Execute IV curve]** button to execute the curve on the selected channel(s). The inverter is operated at its nominal conditions.

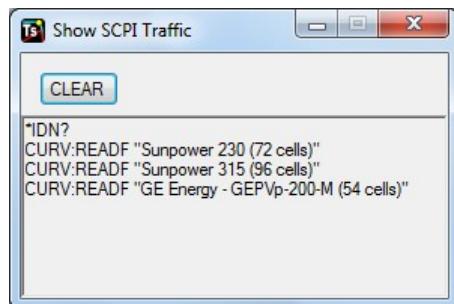
Irradiance and temperature can then be manually controlled, or a profile can be associated and executed as usual.

## System > Reset

This feature performs the following tasks, in the sequence listed below:

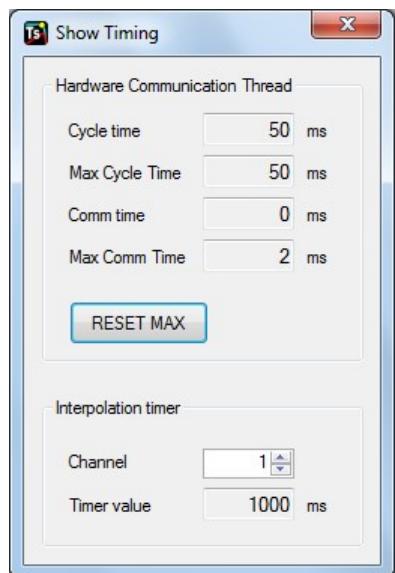
- Stops all dynamic simulations
- Terminates datalogging and closes the file
- Terminates triggered measurements
- Deletes all curves, profiles and arrays
- Resets all channels to curve zero, no profile
- Opens all output relays
- Resets all channels to default irradiance and temperature

System configuration, System settings and Channels grouping are not affected.



## System > Debug > Show SCPI traffic

This feature displays a text window that shows all the incoming traffic from the remote interface. It is useful when troubleshooting a remote connection or a new SCPI command script.



## System > Debug > Show timing

This feature displays critical timing parameters related to the various execution threads that communicate with the PV simulators.

Channel	Errors count	Last error
1	0	0
2	0	0 <span style="border: 1px solid black; padding: 2px;">No errors</span>
3	0	0

**Clear log**      **Refresh log**

## System > Debug > Show errors

This feature logs and displays communication errors that could occur within the PV simulators or on the Ethernet link between TerraSAS and the PV simulators. Place the pointer on the error code to see its description. Possible errors are:

**Receive error**  
**Transmit error**  
**Receive timeout**  
**Flash memory error**  
**RAM memory error**  
**Syntax error**

The first three errors can occasionally occur while testing high power inverters, due to strong electrical noise. However, recurring presence of any errors is an indication of some type of hardware malfunction.

To evaluate the severity of the problem, click the **[Clear log]** button and then close the dialog. Operate the

system for a few hours and then open this screen. If the screen was left open, just click the **[Refresh log]** button to display updated data.

If more than 20 events per hour are logged on any channel, please e-mail error counts and codes from this screen to [service@programmablepower.com](mailto:service@programmablepower.com) for an immediate technical review.

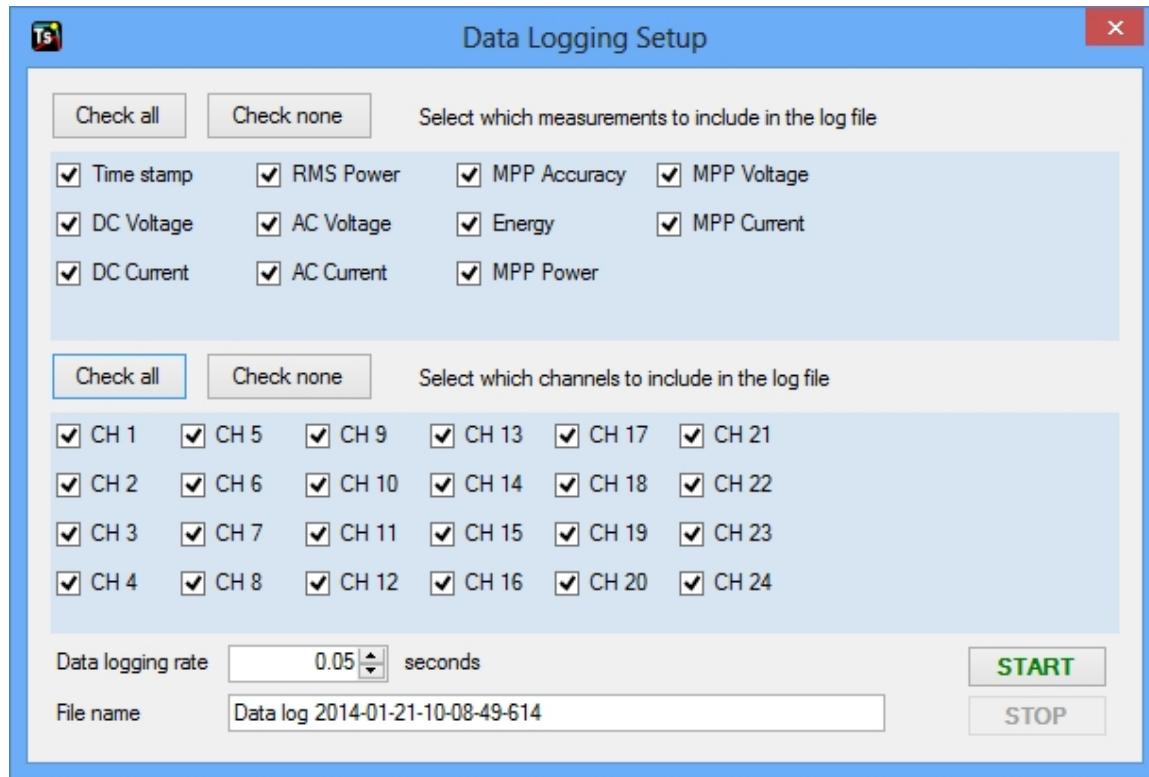
CH	E [W/m <sup>2</sup> ]	T [°C]	Trigger
1	787.5	58.75	<input type="checkbox"/>

## System > Debug > Show External inputs

This screen displays the external analog inputs (irradiance and temperature) and trigger input for each channel. This feature is only available on ETS....-PVE simulators. Refer to the PV simulator user manual for electrical connection details and signal levels.

## System > Data logging

This feature allows creating a disk file containing measurements for one or more channels at a programmable logging rate:



File format details are in the file formats section of this document.

If the specified file already exists in the \\root\\TerraSas\\Datalogging folder, its contents are replaced with the new data.

Once datalogging is started, no changes are allowed until it is stopped.

## System > Channels grouping setup

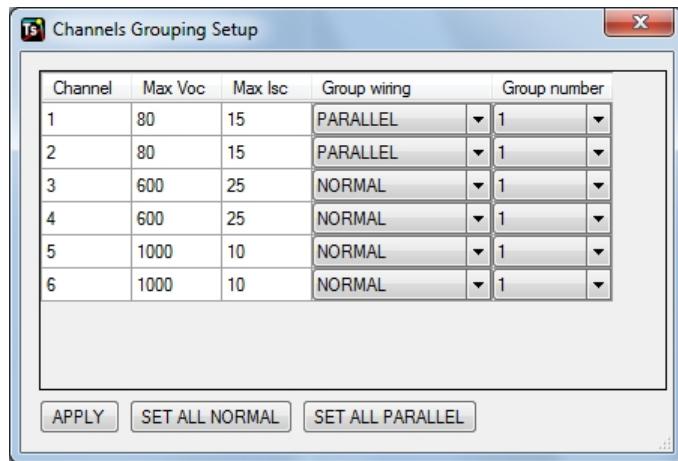
This feature allows creating groups of channels wired in parallel or in series. This creates virtual output channels with higher current or voltage capabilities that behave like physical simulators having higher capabilities. Some restrictions apply when creating channel groups:

- **Parallel**-connected channels must have the same maximum voltage rating. For instance, a 600V SG cannot be paralleled with an 80V DCS.
- **Series**-connected channels should have identical voltage and current ratings. This is strongly recommended and delivers the best performance. However, the software allows connecting 600V and 1000V PV simulators in series. It also allows mixing power ratings (i.e: 600V/17A in series with 600V/25A). When mixing ratings, the overvoltage protection might behave incorrectly when simulators are back-fed from the inverter under test. There could also be stability issues in some cases.

The maximum number of series-connected channels is 3. This is to limit the IV curve distortion that occurs when many channels are wired in series.

Additional restrictions apply on high voltage channels wired in series. Consult the system user manual for specific details.

**IMPORTANT:** PV simulators could be seriously damaged when connected in series, as their maximum output to ground voltage rating might be exceeded. The software has no way of knowing when such limit is reached, as it depends on the inverter under test. It is the user responsibility to verify that PV simulators operate within their specified limits, even when the software allows a particular topology.

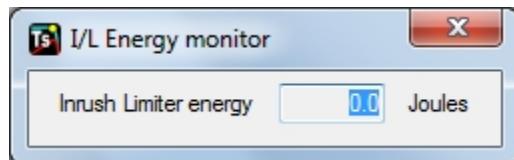


After applying the setup, the lowest channel number within each group becomes the **master** channel of the group. All other channels within the group become hidden: they no longer have a tile, they do not appear on forms and settings and they cannot be addressed using the remote interface (error 19 - Invalid channel is logged when attempts are made to select hidden channels). The only exception is the command SYSTem:CHANnel:SERial? which retrieves the serial number of the PV simulators.

Master channels and their tiles behave like a physical simulator having the combined capabilities of all member channels. The software automatically splits curve and profile data among the physical simulators and calculates measurements accordingly.

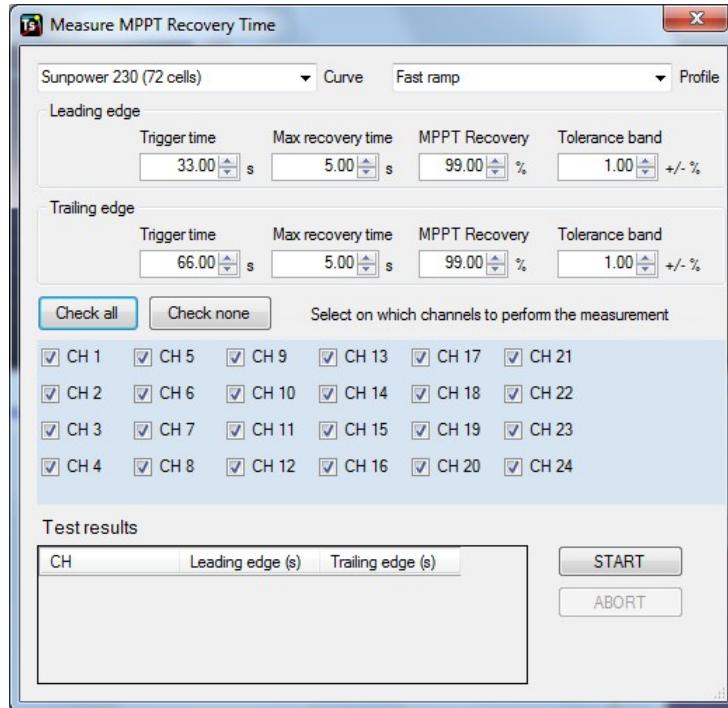
## System > I/L Energy monitor

This feature displays the Inrush Limiter energy monitor for the selected channel. It is used to monitor the behavior of the inverter under test and determine the programming value of the module's energy threshold. See the ETS1000 user manual for further details.

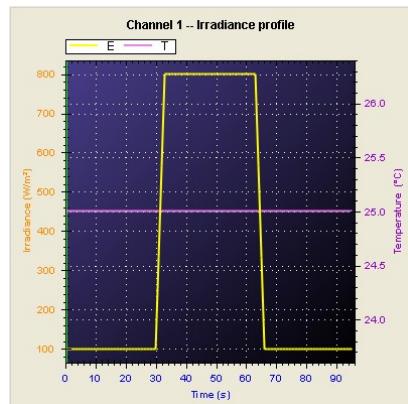


## Measure > Time > MPPT Recovery

This feature allows to measure the Maximum Power Point Tracking recovery time as described in the "Performance Test Protocol for Evaluating Inverters Used in Grid-Connected Photovoltaic Systems", October 2004, Sandia National Laboratories, section 5.6.2.2 Test Procedure - Fast Ramp (Intermittent cloud cover).



Measurements are taken on both edges of the fast ramp profile:



Two sets of parameters are provided for each edge:

**Trigger time:** the measurement starts at the indicated profile time. Defaults indicate the end of the leading edge ramp (33 s) and the end of the trailing edge ramp (66 s)

**Max recovery time:** the maximum expected recovery time for the inverter under test

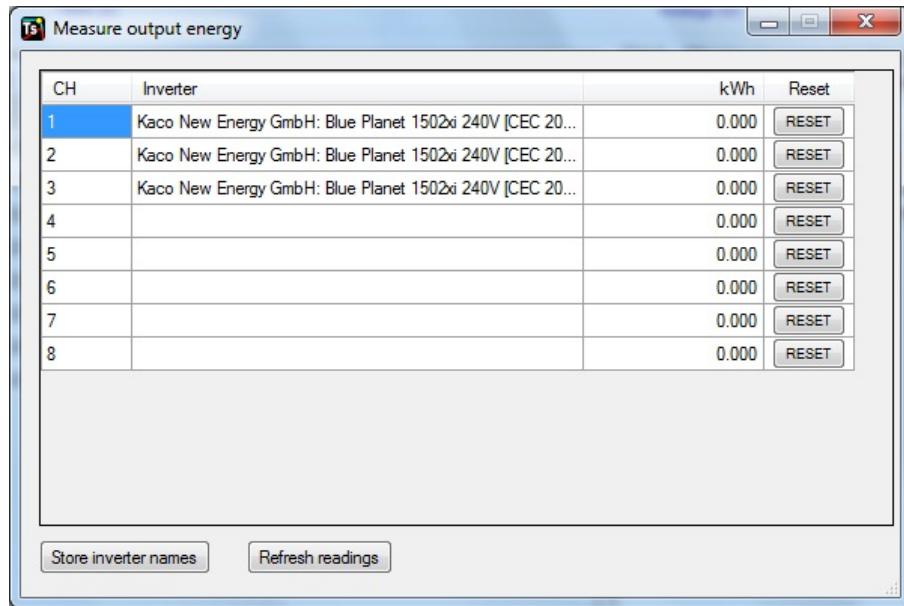
**MPPT Recovery:** the minimum MPPT accuracy that the inverter must meet after recovery

**Tolerance band:** the MPPT accuracy tolerance band that the inverter must meet after recovery.

The inverter must be turned on and tracking the MPP before this test can be started.

## Measure > Energy

The true rms power delivered by each output channel is continuously integrated to maintain accurate, virtual energy meters. Each meter reading (Joules, or Ws) is then divided by  $3.6 * 10^6$  to display the readings below, in kWh:



The screenshot shows a Windows application window titled "Measure output energy". The window contains a table with 8 rows, each representing a channel (CH) and its corresponding inverter. The columns are labeled "CH", "Inverter", "kWh", and "Reset". Each row has a "RESET" button. The "Inverter" column displays the model and manufacturer of the connected inverters. The "kWh" column shows the current energy reading for each channel. The "Reset" button allows the user to clear the current reading. At the bottom of the window, there are two buttons: "Store inverter names" and "Refresh readings".

CH	Inverter	kWh	Reset
1	Kaco New Energy GmbH: Blue Planet 1502xi 240V [CEC 20...]	0.000	RESET
2	Kaco New Energy GmbH: Blue Planet 1502xi 240V [CEC 20...]	0.000	RESET
3	Kaco New Energy GmbH: Blue Planet 1502xi 240V [CEC 20...]	0.000	RESET
4		0.000	RESET
5		0.000	RESET
6		0.000	RESET
7		0.000	RESET
8		0.000	RESET

Each energy meter can be reset by clicking on the **[RESET]** button.

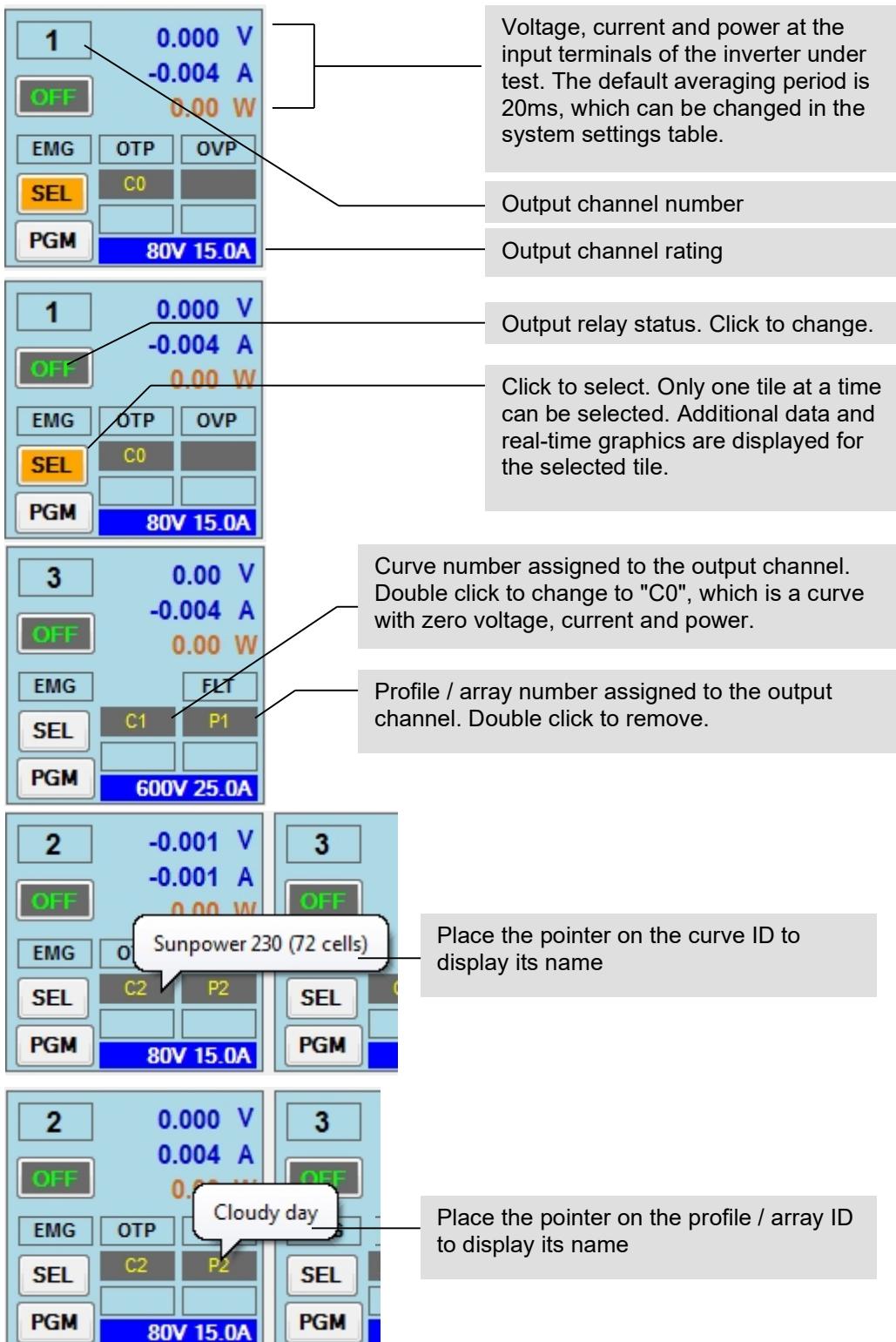
Energy meters are not altered by a system reset, however they are erased when changing channel groups configuration.

The name of the inverter connected to each output can also be entered in this form and stored. When importing an inverter test setup, the imported name is automatically entered here when setting the OVP. (See System>Configure>Import inverter data).

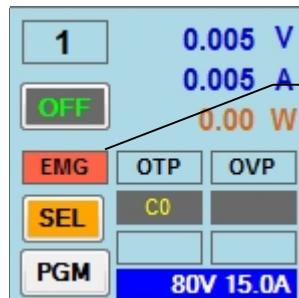
## User interface details

### Output channel tile description

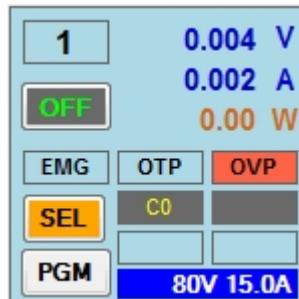
Each PV simulator (or group) is graphically represented by a tile, which shows its operating status and reports the most relevant data associated with it.



## Channel faults and protections

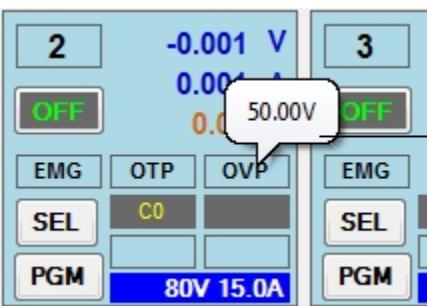


The emergency OFF button or the external interlock has been activated. The PV simulator output is turned off. Deactivate the interlock and push the ON button to turn off this alarm indicator and restore the output.



The output voltage exceeded the OVP threshold programmed in the system settings for this channel. Restore normal conditions and then double click to reset the fault and restore the output.

**NOTE:** this indicator can be marked FLT (fault) depending on the PV simulator model. When this is turned on, an OVP or other power module fault can be the cause. Refer to the PV simulator documentation for more details.



Place the pointer on the OVP box to display the OVP setpoint



The PV simulator power stage overheated and the output has been turned off. Wait until the unit cools down and the output is restored. This should never occur, even on hot days and full power operation and it is an indication of a hardware malfunction.



The assigned curve or array, translated to the programmed irradiance and temperature, exceeded the maximum voltage or current capability of the channel. The curve has been clipped to fit into the channel's voltage and current ratings.

Note: additional features and indicators may be present. Refer to each PV simulator user manual for details.

## Channels grouping



This tile represents a group of parallel-connected channels. Current and power readings show the total value for the group.  
The channel rating also shows the total value.



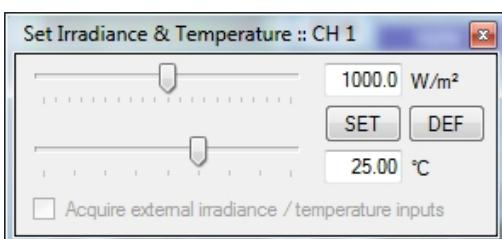
This tile represents a group of series-connected channels. Voltage and power readings show the total value for the group.

Click the PGM button to program the channel.

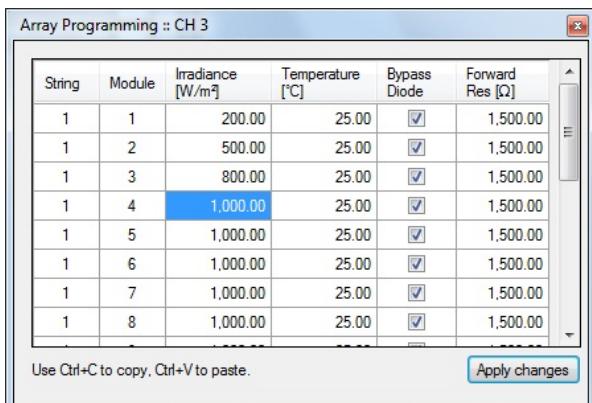
See details below.

**NOTE:** Programming is disabled if the channel is executing a profile.

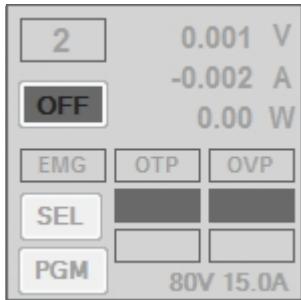
## Channels programming



If a curve is assigned to the channel, enter the desired irradiance and temperature using the sliders or typing their values. Click **[SET]** to transfer the new settings to the PV simulator. Click **[DEF]** to restore the default values and transfer them to the PV simulator.



If an array is assigned to the channel, the spreadsheet programming tool is displayed. This allows entering individual parameters for each module within the array. Click **[Apply changes]** to calculate the array and execute the resulting IV curve. Note that each channel is assigned its own copy of the array. Therefore changes performed on one channel do not affect the others, even when they are executing the same array.

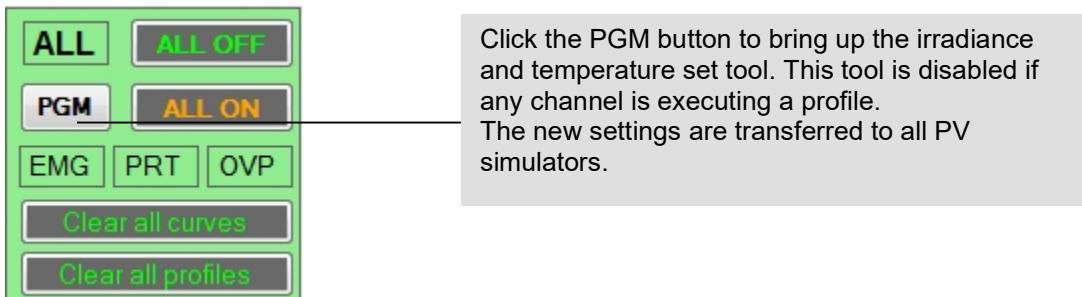
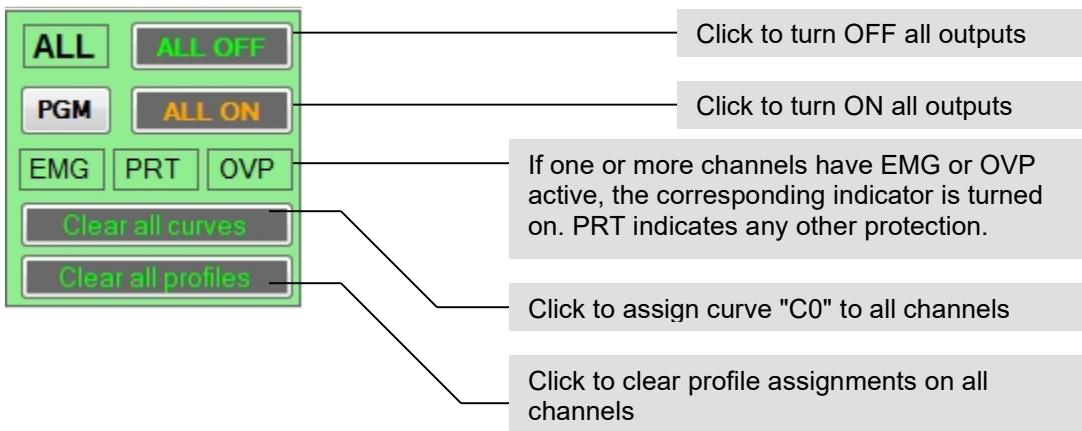


A grayed-out tile indicates a loss of communication, which can be temporary or permanent. If a PV simulator is turned off during operation, its tile becomes gray. It goes back to normal when the simulator is turned back on or its communication issue has been fixed.

If a simulator is down when TerraSAS launches, it is tagged as dead and will not recover if switched back on. The channel will resume operation when TerraSAS is restarted, if the simulator is back online.

### All channels tile description

Curves and profiles dropped on this tile are applied to all channels.



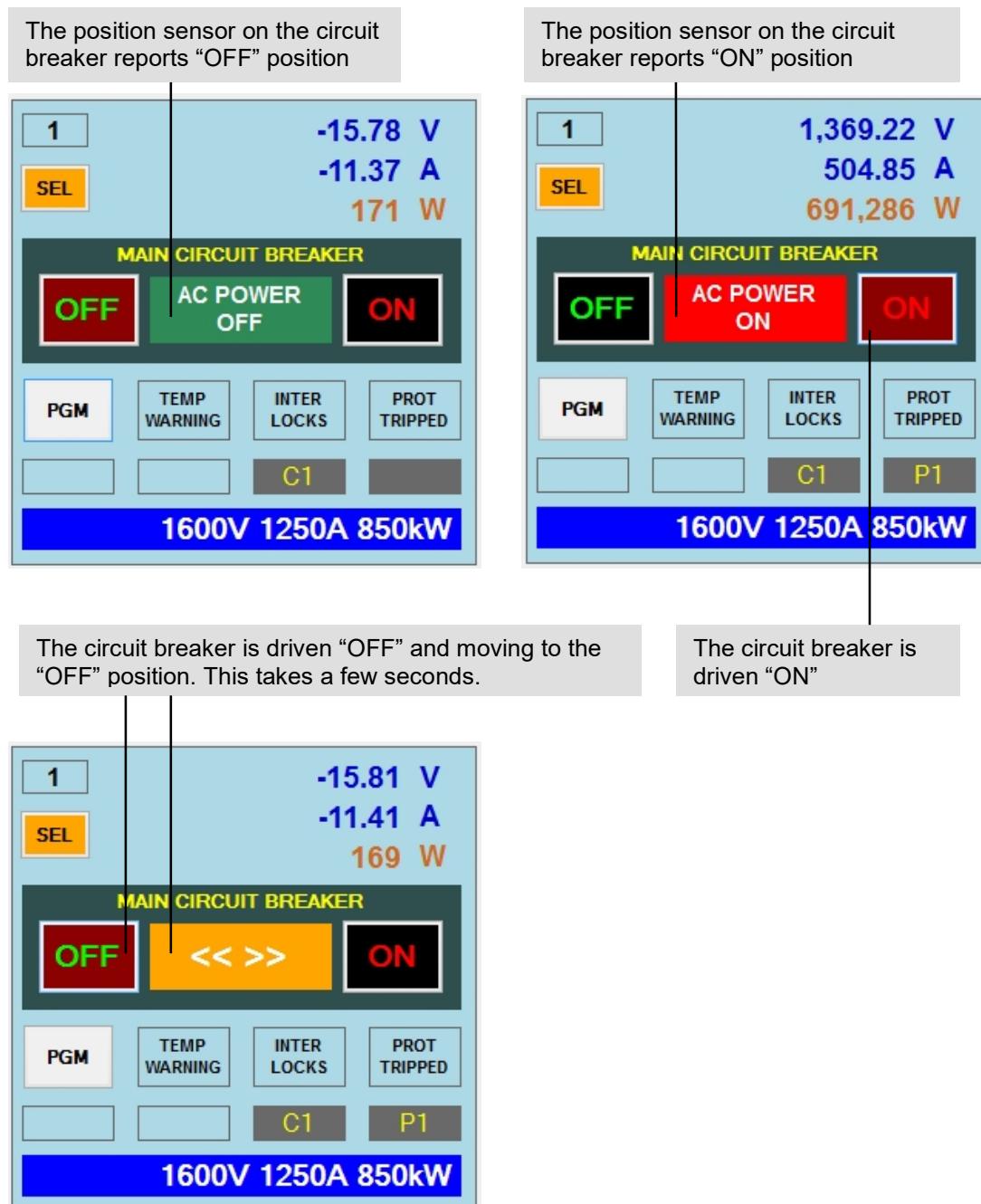
Note: this tile is not displayed on high power systems (large tile) or systems having only one PV simulator.

## **High Power Systems support**

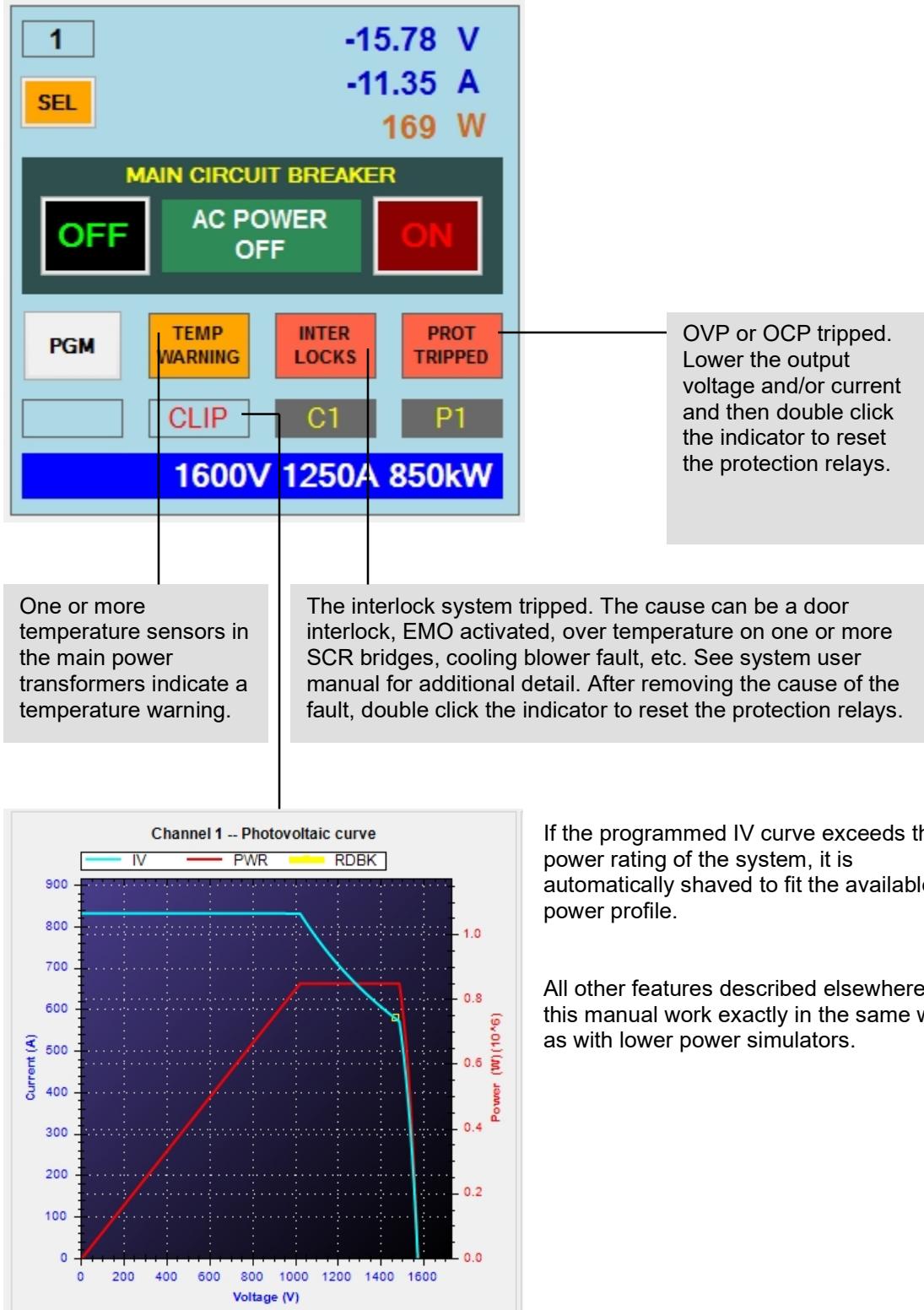
The basic operation of the software, when connected to high power systems, is very similar to the operation with lower power devices.

The tile size has been increased to accommodate the additional items required for a safe operation of these SCR-based, megawatt range PV simulators.

### **Main AC circuit breaker on-off control**



## Warnings and protections



## Advanced programming

### Executing a static simulation

Load or create one or more curves as described in section "TerraSAS main menu items description". Curves in the pool also become listed in the System control tab:

Click here to sort by number

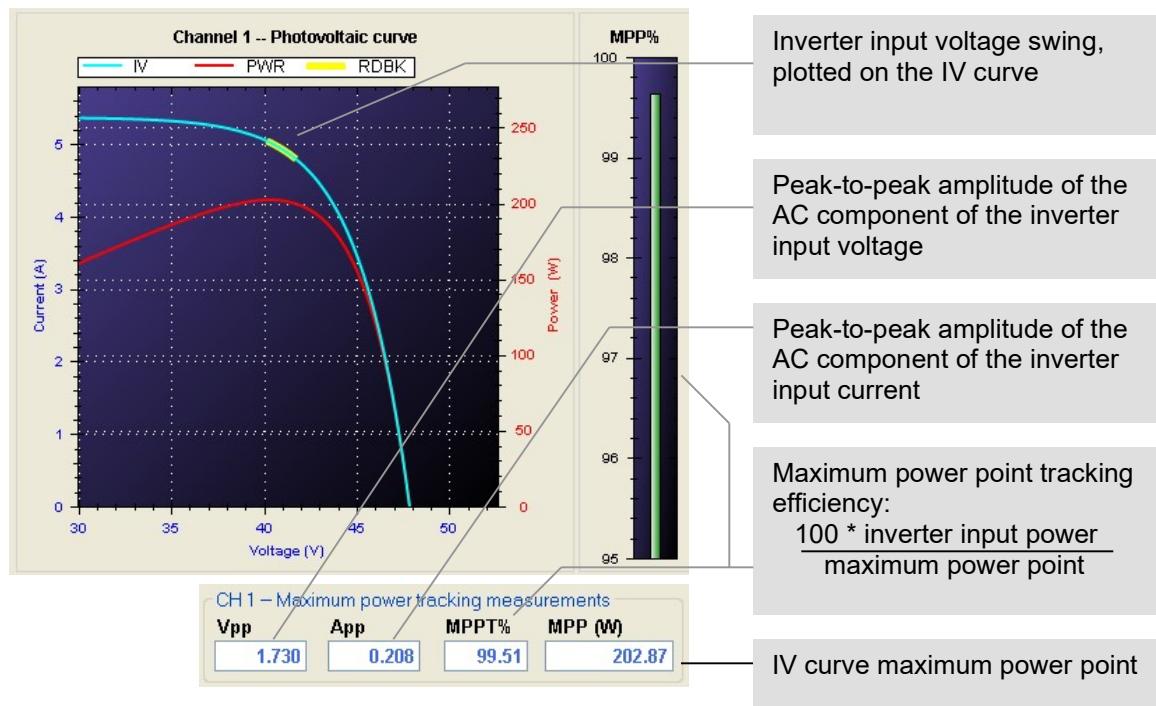
Click here to sort by name

ID	Photovoltaic curve name
1	Sunpower 315 (96 cells)
2	BP Solar - BP 3230T (60 cells)
3	GE Energy - GEPVp-200-M (54 cells)
4	Sunpower 230 (72 cells)

Drag the desired curve name and drop it on one or more tiles to execute.

The curve ID number is displayed on the tile. Power is applied to the output as soon as the output relay is turned ON.

If a curve was already assigned to a channel, the new curve replaces it. Select the tile to display additional data:



### Soft-starting the inverter under test

When the procedure above is followed, voltage is applied to the inverter as soon as the ON/OFF button is toggled. The output voltage reaches  $V_{oc}$  in about 10 ms, depending on the simulator model.

If a softer start is desired, turn on the output before dropping the curve on the tile. In this way, the voltage reaches  $V_{oc}$  in one second. The same applies when turning off the inverter: first switch to curve zero (double click on the tile's curve ID) and then turn off the output. The output voltage will decrease to zero in one second.

## Creating and managing EN 50530 test sessions

Select **Photovoltaic curve > EN 50530:2010 > Create / Update Curve** to display the form below:

The dialog box is titled "Create / Update EN50530 Curve". It has two main sections: "Technology" and "Test type". Under "Technology", "cSi" is selected. Under "Test type", "Static" is selected. The "Test parameters for conversion and static MPPT efficiency" section contains fields for "Rated power" (1,000.000 W), "Maximum Voltage" (120.000 V), "Power level" (1.00), "Rated Voltage" (100.000 V), and "Minimum Voltage" (80.000 V). The "Test parameters for dynamic MPPT efficiency" section contains fields for "Irradiance" (1,000.000 W/m<sup>2</sup>) and "Temperature" (25.000 °C). At the bottom is a "CREATE / UPDATE CURVE" button.

EN 50530 curves are designed to operate the solar inverter under test at specific points in its operating range.

First specify the rated power, maximum operating voltage, rated operating voltage and minimum operating voltage of the inverter (or other MPP tracking device).

Static MPP tracking efficiency tests are always executed at 1000 W/m<sup>2</sup> and 25 °C.

**A static test session** evaluates 48 points (two technologies, eight power levels and three voltage levels). Data logging is typically turned on for the duration of each measurement.

The **EN 50530 static MPPT efficiency** can be calculated by applying the equations provided in the standard to the data collected in the log files.

**A dynamic test session** is always executed at full rated power (Power level 1.00) and rated voltage. Select **Dynamic mode** and execute the EN 50530 profiles with data logging turned on. The **EN 50530 dynamic MPPT efficiency** can be calculated by applying the equations provided in the standard to the data collected in the log files.

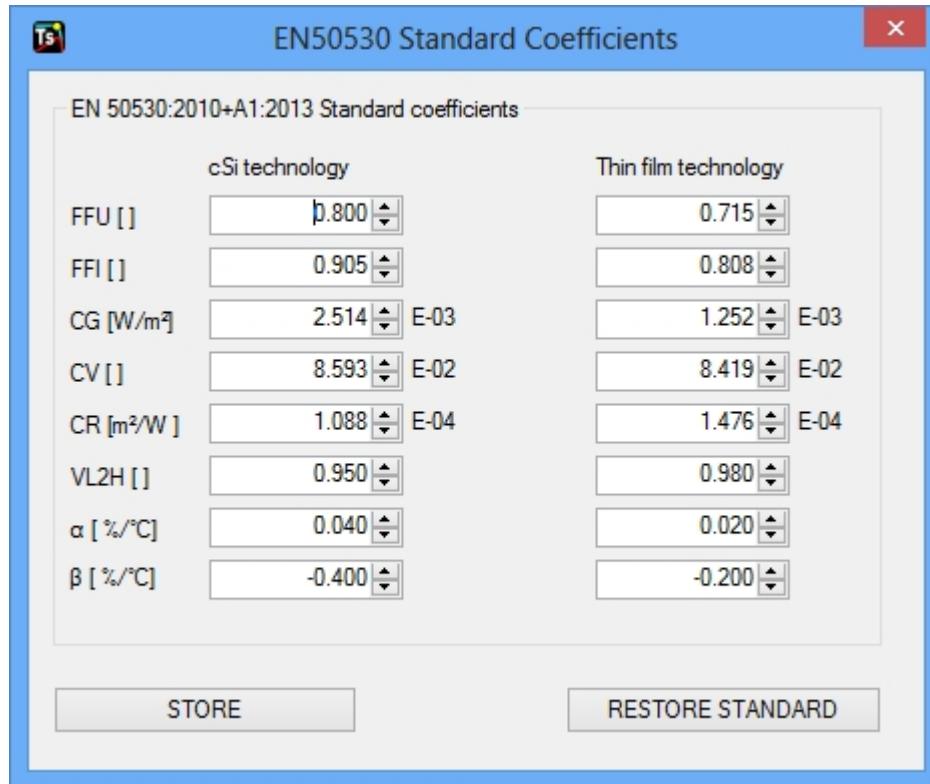
The shape of the curve can be observed in the Photovoltaic simulation tab after the **[CREATE / UPDATE CURVE]** button is clicked.

The name of the curve is "EN 50530 CURVE". This curve can be assigned to output channels and executed as described in the previous section. When an output tile has this curve assigned, click the **[PGM]** button on the tile to bring up the above programming dialog. This allows changing the curve parameters directly on the output channel. Curve changes applied to an output do not affect other outputs or the curve displayed in the Photovoltaic simulation tab.

The name “EN 50530 CURVE” is reserved and cannot be used for SNL curves. Only one curve of this type can be created and it cannot be saved on disk. However, a test session containing an EN 50530 curve can be saved and retrieved using the **Save/Load Test Session** feature.

The EN 50530 curve cannot be assigned to an array element.

The coefficients used in the EN50530 curve equations can be modified by selecting **Photovoltaic curve > EN 50530:2010 > Edit Coefficients**, which brings up the following form:

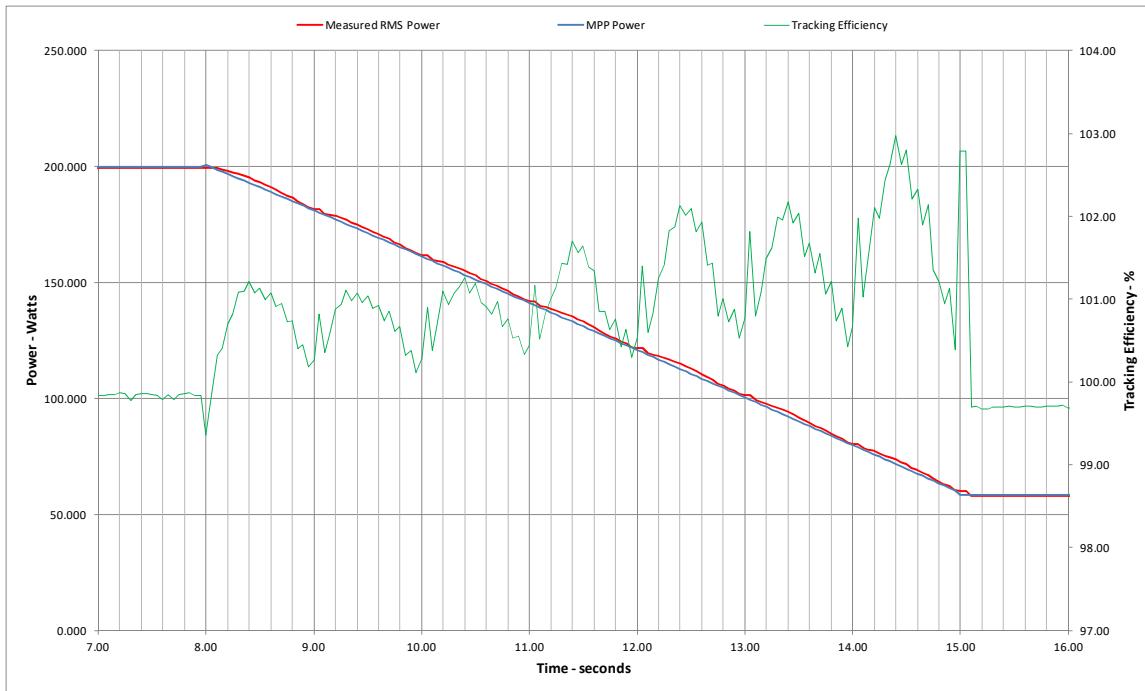


Default coefficients and equations are compliant with the ones published in the EN 50530:2010 standard, including the modifications contained in the A1:2013 amendment.

Once modified coefficients are stored on disk by clicking on the **[STORE]** button, they are used on all subsequent calculations.

### Maximizing measurement accuracy during fast profiles

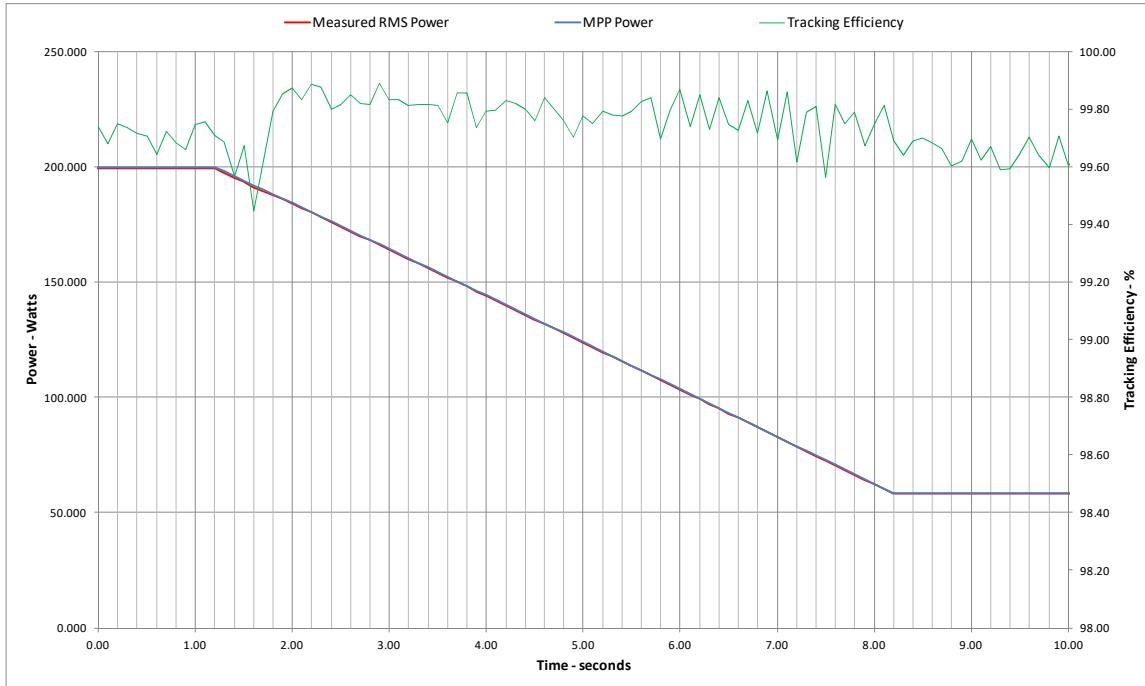
EN50530 profiles include fast irradiance slopes, up to 100 W/m<sup>2</sup>/s. TerraSAS is based on a one-second curve update rate on the PC, while each PV simulator linearly interpolates between curves to provide smooth output waveforms. However, on fast slopes consecutive curves are very different in shape and linear interpolation no longer works acceptably.



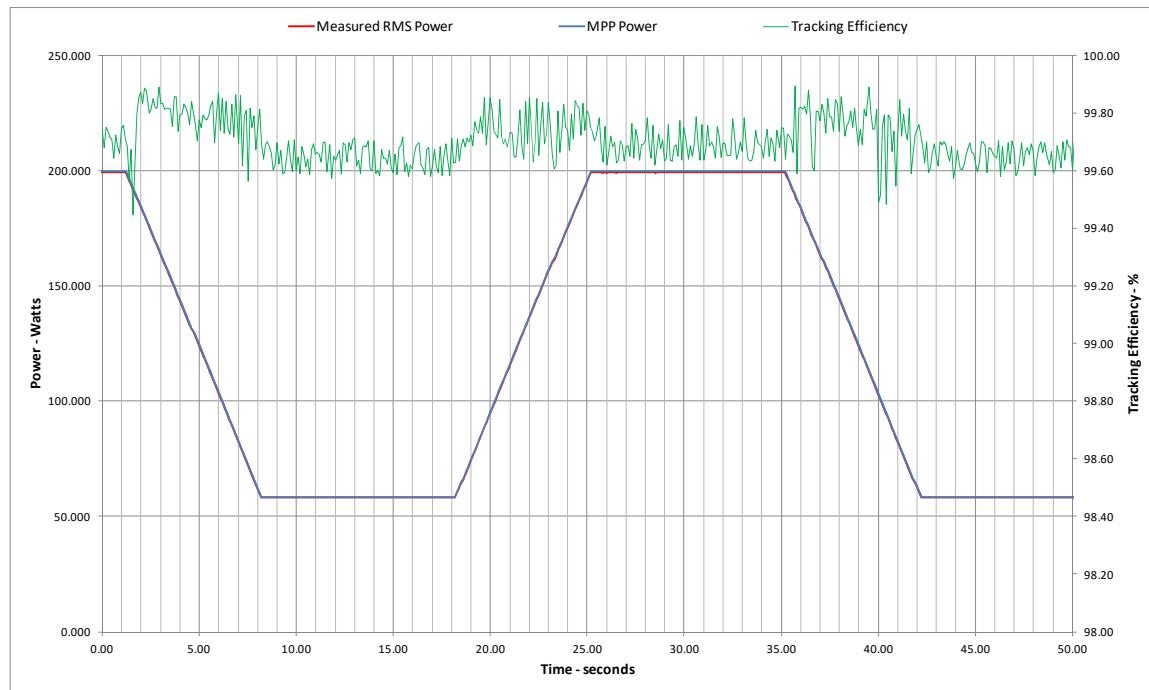
On the chart above it can be seen that the interpolation performed by the simulator is quite good, but the small discrepancy between calculated and actual MPP power produces tracking efficiency measurement errors approaching  $\pm 3\%$ . This is a large number when dealing with modern devices that can track the MPP with nearly 100% efficiency.

Clearly, to improve measurement accuracy on fast slopes linear interpolation must be abandoned and the curve update rate needs to be increased.

When interpolation is disabled in the simulator, the curve update rate on the PC is automatically increased to 10 curves per second. The result is below:



This is the same chart, showing a larger section of the data log:



For best accuracy, select the following settings:

- Check the D/IS checkbox in **System > Configure >Settings** to disable linear interpolation in the simulator
- Set AVG in **System > Configure >Settings** to 4ms or 8ms
- Select a data logging rate of 0.1 seconds

The above settings enable the higher curve update rate and also synchronize RMS power measurements with the curve update cycle, producing remarkably accurate results.

Please note that this feature requires the latest firmware and is therefore only enabled on PV simulators that can be updated in the field. The following legacy models will work with TerraSAS 2.X but will ignore the new D/IS checkbox:

Elgar P/N	Description
5609105-01	DCS80-15 PV Simulator
ETS80X15C-PVE	DCS80-15 PV Simulator
5609158-XX	PV Simulator Chassis (2U)

Running profiles with linear interpolation disabled on many channels can drive the CPU usage upward. Even when using fast computers, only disable linear interpolation when necessary and on as few channels as possible. Windows Task Manager can be used to monitor the CPU load, which should stay below 20% to achieve best results.

## Creating an irradiance / temperature profile

Select **Irradiance profile > Create** to display the form below. This form allows entering a lengthy profile as a table by breaking it down into a sequence of segments. Each segment can be ramping from one irradiance/temperature point to another, or dwell at the specified level for a programmable interval. Each row in the table represents two consecutive segments.

	Line Number	Ramp Time	Ramp to Irradiance	Ramp to Temperature	Dwell Time	Dwell Irradiance	Dwell Temperature	Go to Line	Repeat Cycles
1*	1								

LOAD TABLE    SAVE TABLE    CREATE PROFILE    INSERT ROWS    ADD ROWS

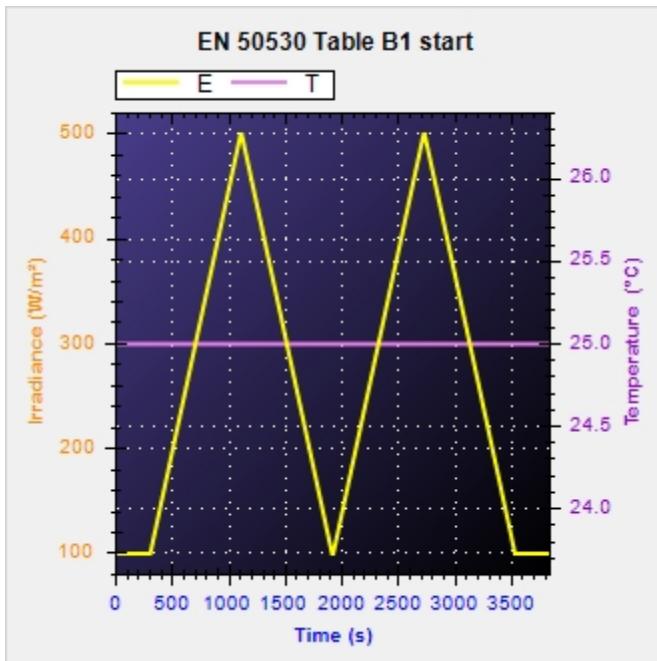
Here are a few simple rules to remember:

- If the desired profile begins with a flat line, program the Ramp Time to zero.
- If there is no flat segment after a ramp, program the Dwell Time to zero.
- If temperature profiling is not desired, enter the same temperature on all segments
- Blocks of rows can be repeated a programmable number of times
- The button **[SAVE TABLE]** saves the entire table as a .irtt text file.
- The button **[LOAD TABLE]** loads a previously saved table for further editing
- The button **[CREATE PROFILE]** processes the entire table and produces a usable profile, which can be saved on disk as a .irtp text file. This file can be executed but not edited within TerraSAS.
- Place the cursor on a row (first column) and press the button **[INSERT ROWS]** to add rows between existing ones
- Highlight a block of rows (select and drag on first column) and then press the **[DEL]** key to delete them
- The button **[ADD ROWS]** adds rows to the end of the table
- Use **[Ctrl+C]** keys to copy blocks of cells and **[Ctrl+V]** to paste their contents.

For example, the table below produces the profile shown in the next page.

	Line Number	Ramp Time	Ramp to Irradiance	Ramp to Temperature	Dwell Time	Dwell Irradiance	Dwell Temperature	Go to Line	Repeat Cycles
1	1	0	0.0	0.00	300	100.0	25.00	0	0
2	2	800	500.0	25.00	10	500.0	25.00	0	0
3	3	800	100.0	25.00	10	100.0	25.00	2	2
4	4	0	0.0	0.00	300	100.0	25.00	0	0
*	5	0	0.0	0.00	0	0.0	0.00	0	0

LOAD TABLE    SAVE TABLE    CREATE PROFILE    INSERT ROWS    ADD ROWS



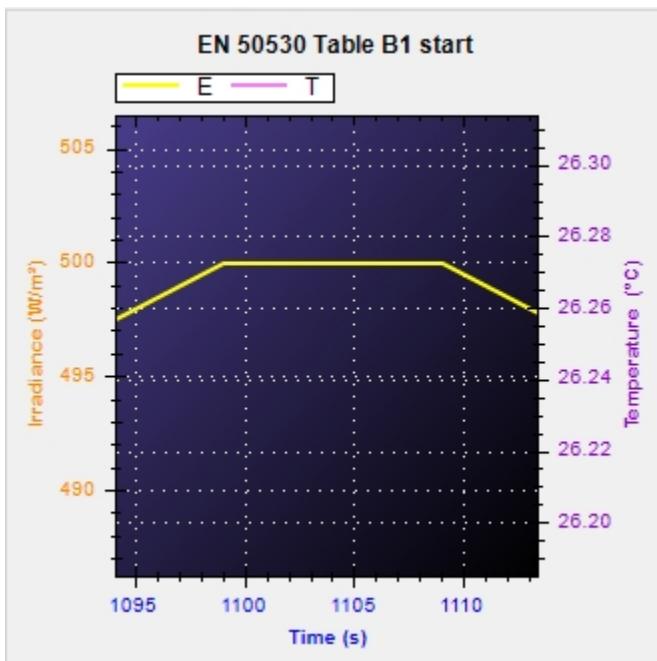
Line 1 programs the first flat segment at  $100 \text{ W/m}^2$ , which lasts for 300 seconds.

Line 2 ramps the irradiance from  $100 \text{ W/m}^2$  to  $500 \text{ W/m}^2$  in 800 seconds and then dwells there for 10 seconds.

Line 3 ramps the irradiance from  $500 \text{ W/m}^2$  to  $100 \text{ W/m}^2$  in 800 seconds and then dwells there for 10 seconds.

At the end of line 3, execution continues to the beginning of line 2, so that lines 2 and 3 are executed twice.

Line 4 programs the last flat segment at  $100 \text{ W/m}^2$  which lasts 300 seconds.



Detail of the dwell segment at the end of each ramp, which lasts 10 seconds.

Standard EN 50530 tables and profiles are provided as examples with the software.

## Executing a dynamic simulation

Load or create one or more curves and load one or more profiles as described in section "TerraSAS main menu items description". Curves and profiles in the pools also become listed in the System control tab:

Curves		Profiles	Arrays
ID	Photovoltaic curve name		
1	Sunpower 315 (96 cells)		
2	BP Solar - BP 3230T (60 cells)		
3	GE Energy - GEPVp-200-M (54 cells)		
4	Sunpower 230 (72 cells)		

Click here to sort by number

Click here to sort by name

Drag the desired curve name and drop it on one or more tiles to execute.  
The curve ID number is displayed on the tile. Power is applied to the output as soon as the output relay is turned ON.

Curves		Profiles	Arrays
ID	Irradiance profile name		
1	Triangle ramp		
2	Cloudy day		
3	Fast ramp		
4	Heavy clouds day		
5	Irradiance test		

Click here to sort by number

Click here to sort by name

Drag the desired profile name and drop it on one or more tiles to execute.  
The profile ID number is displayed on the tile and also added to the dynamic simulation control panel.

The dynamic simulation control panel allows full control of the simulation:

CH	P/A	Time [s]	Offset [s]	Speed	Run simulation, all channels	Loop mode, toggle all channels	Go to start point, all channels	Stop simulation, all channels
ALL								
1	P1	11,975.00	11,975	1	◀◀	▶	II	◀▶
2	P2	0.00	0	1	◀◀	▶	◀▶	◀▶
3	P3	0.00	0	1	◀◀	▶	◀▶	◀▶

**NOTE:** On ETS...-PVE simulators the simulation can be started from the external trigger input. See the simulator or system user manual for electrical connection details and signal levels.

Simulation timer

Profile ID number

Simulation offset (start point). Zero means start from the beginning. Double click on irradiance chart to set. Pan & zoom the chart to achieve the desired accuracy.

Execution speed. From 1 (normal) to 100x

CH	P/A	Time [s]	Offset [s]	Speed	◀◀	▶	▶▶	II	◀◀	▶▶	■	◀
<b>ALL</b>												
1	P1	11,975.00	11,975	1	◀◀	▶		II	◀◀	▶▶	■	◀
2	P2	0.00	0	1	◀◀	▶		◀◀	▶▶			◀
3	P3	0.00	0	1	◀◀	▶		◀◀	▶▶			◀

Step backward

Step forward

Go to start point

Run simulation

Loop mode, toggle

CH	P/A	Time [s]	Offset [s]	Speed	◀◀	▶	▶▶	II	◀◀	▶▶	■	◀
<b>ALL</b>												
1	P1	11,975.00	11,975	1	◀◀	▶		II	◀◀	▶▶	■	◀
2	P2	0.00	0	1	◀◀	▶		◀◀	▶▶			◀
3	P3	0.00	0	1	◀◀	▶		◀◀	▶▶			◀

When a simulation is running, the channel becomes highlighted in green:

CH	P/A	Time [s]	Offset [s]	Speed	◀◀	▶	▶▶	II	◀◀	▶▶	■	◀
<b>ALL</b>												
1	P1	11,985.40	11,975	1	◀◀	▶	▶▶	II	◀◀	▶▶	■	◀
2	P2	0.00	0	1	◀◀	▶		◀◀	▶▶			◀
3	P3	0.00	0	1	◀◀	▶		◀◀	▶▶			◀

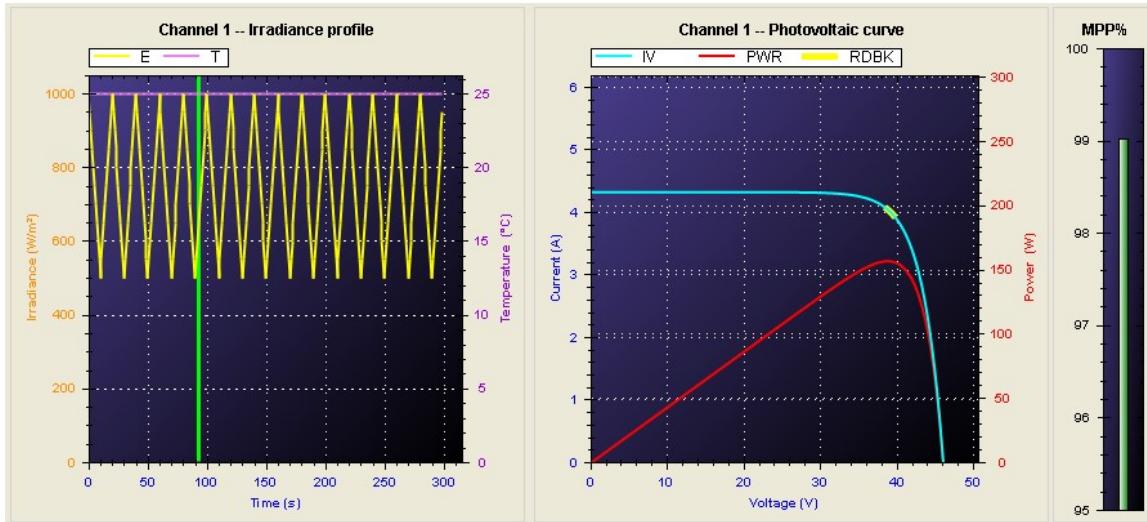
Pause simulation

Stop simulation

When a simulation is running, it can only be paused or stopped. No other parameter can be changed. Loop mode can be toggled while running.

When the simulation reaches the end on a particular channel it stops, unless loop mode is active.

During a dynamic simulation, real time profile and curve data are displayed for the selected channel:

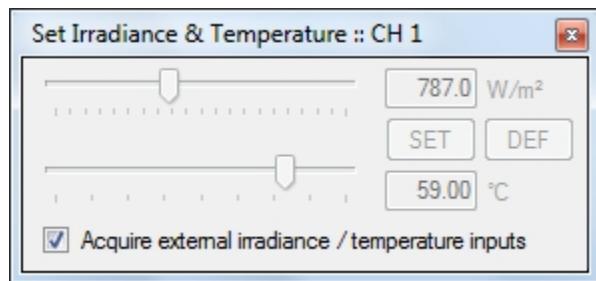


The following features are disabled when one or more channels are executing a dynamic simulation:

- Loading, creating and removing curves
- Loading and removing profiles
- Adding and removing arrays
- Changing curve and profile assignments on any channel running a simulation
- Manually setting irradiance and temperature on any channel running a simulation
- Manually setting irradiance and temperature on tile ALL when one or more channels are running a simulation
- Updating the system configuration table (the table can be displayed, but the START button is unavailable)
- Changing channels grouping configuration

### Executing a dynamic simulation controlled by analog signals

This feature is only available on ETS...-PVE simulators.



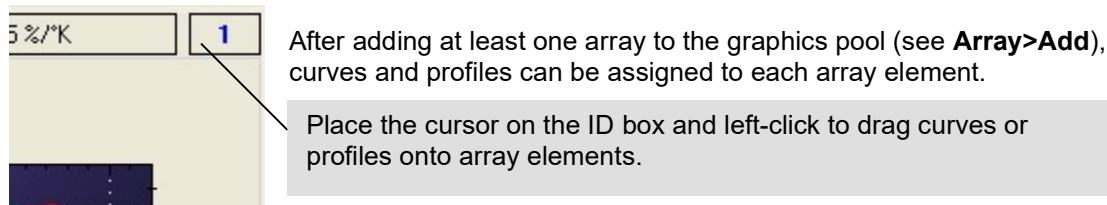
Assign a curve to the desired channel and then click the PGM button on its tile. Check the box to translate the curve in real time based on irradiance and temperature analog inputs.

The maximum power point tracking efficiency measurement becomes inaccurate during the execution of fast irradiance profiles. The purpose of the MPP% bar is to provide a quick visual indication of the approximate performance of the unit under test. Accurate MPPT efficiency measurements can only be obtained by executing EN 50530 test protocols.

## Preparing a static array simulation

The array feature allows simulating the electrical behavior of a solar array by associating IV curves and irradiance profiles to each element in the array. One element usually represents a solar module (also called panel), but can also represent a section of a module for micro-inverter applications. The effects of shading and modules mismatch can be observed and executed on any simulator channel. This often results in IV curves exhibiting two or more peaks in their power curve. The tallest peak is the array's maximum power point, but many solar inverters have troubles finding it. If they do find it during startup, they might switch to a lower peak when irradiance conditions change and the IV curve shape is modified.

### Adding and populating an array



After adding at least one array to the graphics pool (see **Array>Add**), curves and profiles can be assigned to each array element.

Place the cursor on the ID box and left-click to drag curves or profiles onto array elements.

Drop on the array name header to assign the same curve or profile to all elements

Array 1	
1 S1 C0	1 S2 C0
2 S1 C0	2 S2 C0
3 S1 C0	3 S2 C0
4 S1 C0	4 S2 C0

Array element number

Array string number

Bypass diode presence indicator

Press the **[SHIFT]** key while dropping anywhere on any element to assign the same curve or profile to all elements belonging to that string

Drop anywhere on any element to assign a curve or profile to that element

Each array element can only hold one curve and one profile. When dropping a new curve or profile, the existing one is replaced.

Double click on any curve ID to assign curve zero. This can be useful to simulate arrays with strings of different lengths

Double click on any profile ID to remove the association

Array 1	
1 S1 C1 P1	1 S2 C4
2 S1 C1	2 S2 C4
3 S1 C1	3 S2 C4
4 S1 C1	4 S2 C4

## Programming an array

Double click anywhere in this area, on any element, to bring up the array module programming tool

This tool programs **one array module** at a time.

When the **[SET]** or **[DEF]** buttons are clicked, the tool is automatically closed. This is intended to speed up updating many modules manually.

Hold down the **[SHIFT]** key while double-clicking on any element to bring up the string programming tool.

Programmed values will be applied to **all modules** within the selected string.

Drag the sliders or type irradiance and temperature values, and then click on the **[SET]** button to program. Click on the **[DEF]** button to program standard conditions.

Most solar modules on today's market have **bypass diodes** in their junction box, with the exception of thin-film panels. The number of diodes depends on the model. Bypass diodes were introduced to reduce the effects of partial shading. When one or more modules in the string receive less sunlight, their  $I_{sc}$  (short circuit current) is reduced. When the inverter loads the array, the voltage across shaded modules can reverse and potentially damage the module because of overheating (Hot spots). Bypass diodes prevent this inversion and allow the full string current to flow through under-performing modules. To simulate a string or an array without them, uncheck the "bypass diode" checkbox. The electrical behavior of a panel under these conditions is very unstable and usually not specified in the manufacturer's data sheet. Measuring the reverse voltage across a solar module when the current is significantly higher than  $I_{sc}$  at a given irradiance level can approximate the forward resistance value. Calculate as follows:

$$R = -V_o / (I - I_{sc})$$

where:

$V_o$  = negative module voltage

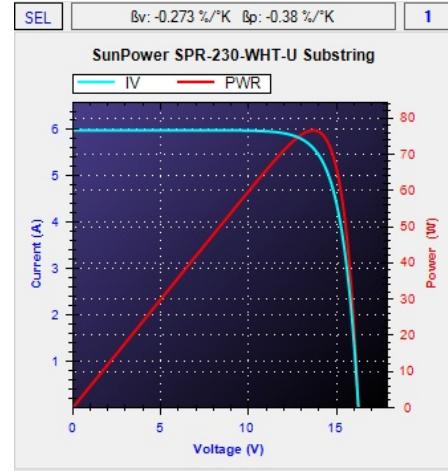
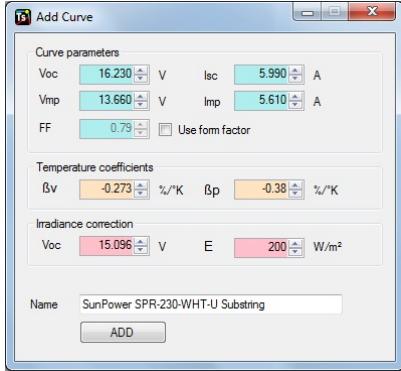
$I$  = module current (supplied by a bench power supply)

$I_{sc}$  = module short circuit current at the desired irradiance and temperature

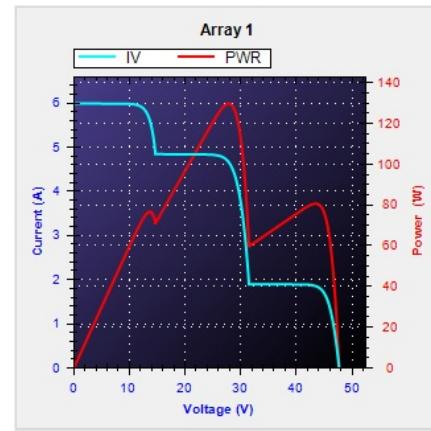
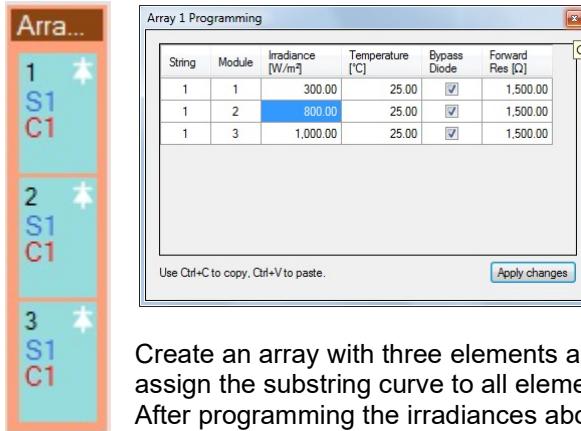
The actual module behavior is non-linear and strongly dependent on its temperature. This method is only providing a simple linear approximation for the purpose of testing solar inverters.

For more details please refer to the document **"Partial shadings on PV arrays: by-pass diode benefits analysis"**, by A. Mermoud and T. Lejeune, University of Geneva, Switzerland. Presented at the 25th European Photovoltaic Solar Energy Conference – Valencia, Spain, 6-10 September 2010.

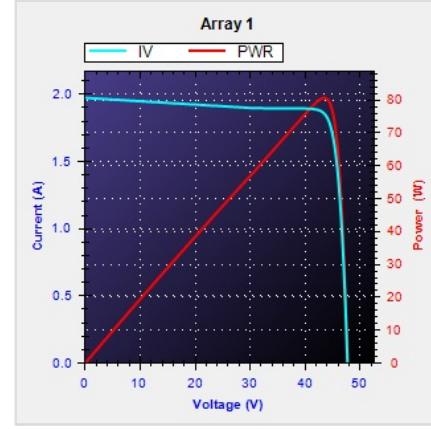
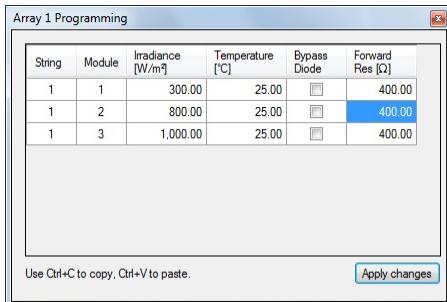
Each simulation element in the array has one bypass diode and is assumed to receive uniform sunlight. To simulate shade at the substring level, as desirable with microinverters, divide the module in substrings, one for each bypass diode. Again, the irradiance is assumed to be uniform on each substring. The example below shows how to program a substring simulation for a microinverter, using module data from the SunPower SPR-230-WHT-U data sheet.



Add a curve as usual, but divide Voc and Vmp from the manufacturer data sheet by the number of bypass diodes in the junction box (three in this case).



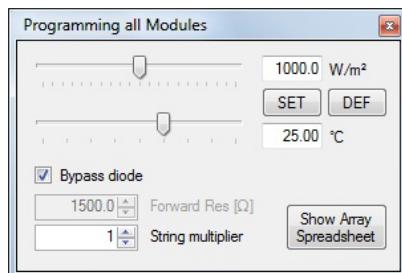
Create an array with three elements and assign the substring curve to all elements. After programming the irradiances above, the string IV curve is calculated and presented.



Same as above, with no bypass diodes. String current and power are strongly affected.

Array 1	
1	1
S1	S2
C1	C4
P1	
2	2
S1	S2
C1	C4
3	3
S1	S2
C1	C4
4	4
S1	S2
C1	C4

Hold down the **[SHIFT]** key while double-clicking on the array name header to bring up the array programming tool



This tool programs the entire array.

Click on the **[Show Array Spreadsheet]** button to bring up the array programming spreadsheet.

Array 1 Programming					
String	Module	Irradiance [W/m²]	Temperature [°C]	Bypass Diode	Forward Res [Ω]
1	1	1,000.00	25.00	<input checked="" type="checkbox"/>	1,500.00
1	2	1,000.00	25.00	<input checked="" type="checkbox"/>	1,500.00
1	3	1,000.00	25.00	<input checked="" type="checkbox"/>	1,500.00
1	4	1,000.00	25.00	<input checked="" type="checkbox"/>	1,500.00
2	1	1,000.00	25.00	<input checked="" type="checkbox"/>	1,500.00
2	2	1,000.00	25.00	<input checked="" type="checkbox"/>	1,500.00
2	3	1,000.00	25.00	<input checked="" type="checkbox"/>	1,500.00
2	4	1,000.00	25.00	<input checked="" type="checkbox"/>	1,500.00

Use **Ctrl+C** to copy, **Ctrl+V** to paste.

**Apply changes**

The spreadsheet tool allows programming the entire array by typing values into a spreadsheet.

Changes are applied when the **[Apply changes]** button is clicked.

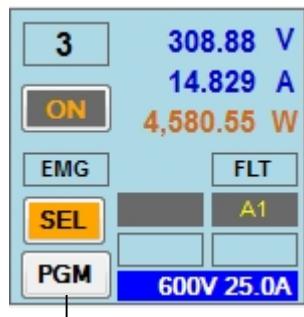
The **Simulation Preview** chart always reflects the IV curve of the array being programmed. If more than one array is present, double-click on the array name (top header) to show its IV curve on the chart.

## Executing a static array simulation

Arrays in the graphics pool become listed in the system control tab, just like curves and profiles.

Curves	Profiles	Arrays
ID	Array name	
1	Array 1	
2	Array 2	

Drag the desired array ID on an output tile to execute the array on one or more channels.



Each channel receives its own copy of the array. Changes applied to the array do not affect other channels, even when assigned the same array. The original array in the **Photovoltaic Simulation** tab is also not affected.

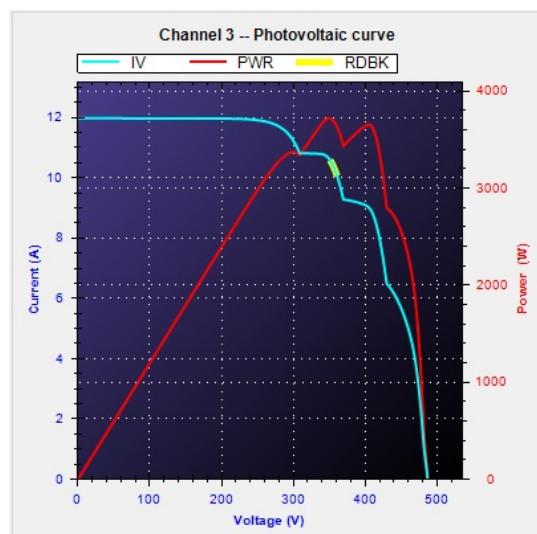
Click the PGM button to bring up the array programming spreadsheet.

Array Programming :: CH 3					
String	Module	Irradiance [W/m <sup>2</sup> ]	Temperature [°C]	Bypass Diode	Forward Res [Ω]
1	1	200.00	25.00	<input checked="" type="checkbox"/>	1,500.00
1	2	500.00	25.00	<input checked="" type="checkbox"/>	1,500.00
1	3	800.00	25.00	<input checked="" type="checkbox"/>	1,500.00
1	4	1,000.00	25.00	<input checked="" type="checkbox"/>	1,500.00
1	5	1,000.00	25.00	<input checked="" type="checkbox"/>	1,500.00
1	6	1,000.00	25.00	<input checked="" type="checkbox"/>	1,500.00
1	7	1,000.00	25.00	<input checked="" type="checkbox"/>	1,500.00
1	8	1,000.00	25.00	<input checked="" type="checkbox"/>	1,500.00

Use Ctrl+C to copy, Ctrl+V to paste.

Apply changes

Experiment with various irradiance levels to observe the effects on the IV curve and analyze the inverter behavior.



The real-time IV chart shows the inverter tracking behavior as usual.

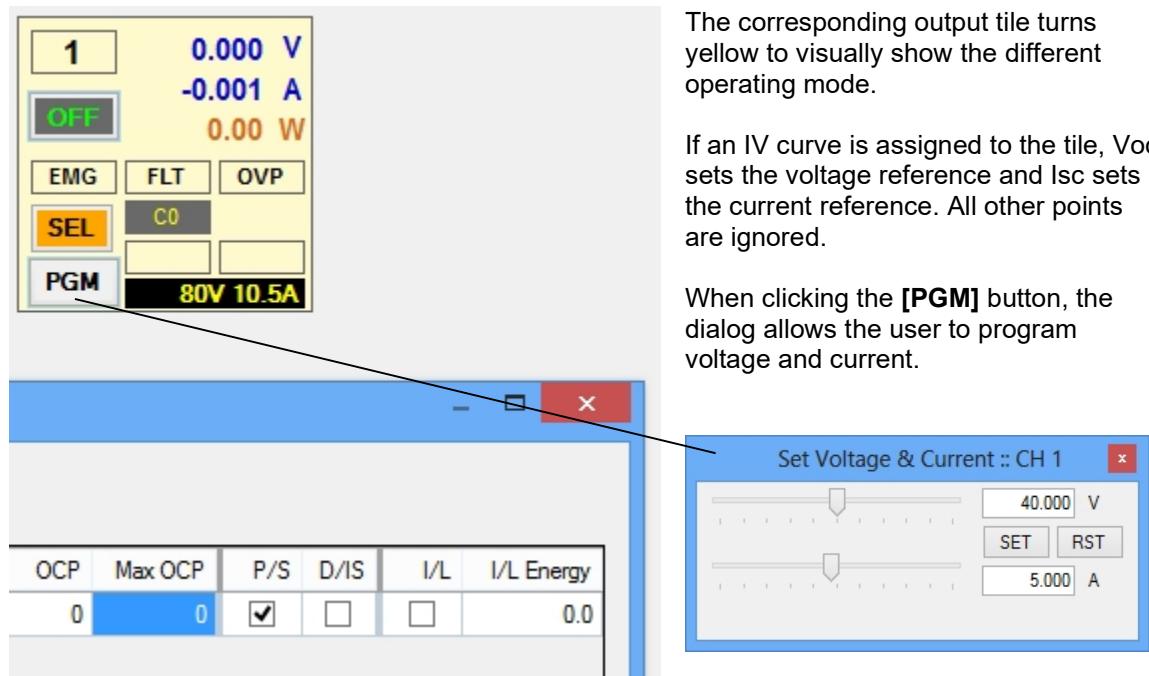
This example was obtained by creating a 2-string array with 10 modules per string. Curve "Sunpower 230 (72 cells)" was assigned to all modules and irradiances were programmed as indicated above.

This array configuration is quite common for small residential installations. This simulated IV curve could be observed when a chimney or a tree casts a shadow on three modules in the first string, reducing their irradiance to 20, 50 and 80% of maximum.

As the chart shows, the MPP went from 4600W to 3718W under shade, a 19.1% power loss caused by a 7.5% loss in irradiance.

## **Operation in Power Supply mode**

Power supply mode allows disabling the IV curve controller and driving the power converter directly with a programmable voltage and current reference. To place one or more channels in P/S mode, check the appropriate box in the **System > Configure > Settings** table.



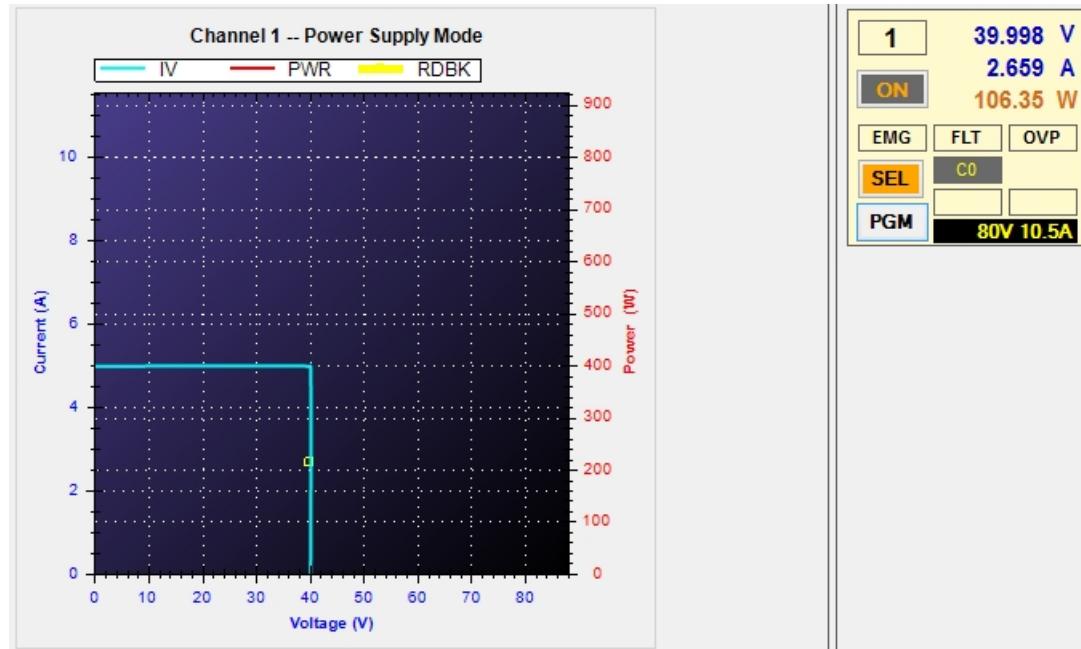
The corresponding output tile turns yellow to visually show the different operating mode.

If an IV curve is assigned to the tile, Voc sets the voltage reference and Isc sets the current reference. All other points are ignored.

When clicking the **[PGM]** button, the dialog allows the user to program voltage and current.

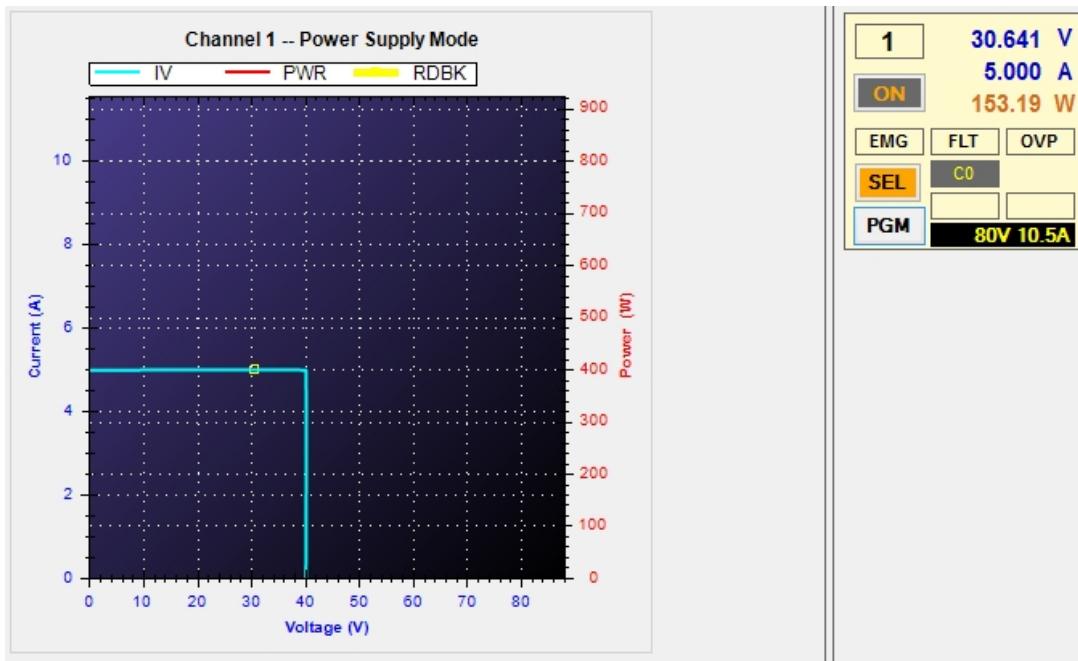
### **Constant Voltage (CV) mode**

The IV profile is displayed as a rectangle. Constant Voltage operation is shown below.



## Constant Current (CC) mode

The power converter automatically switches to Constant Current operation when the reference current is reached.

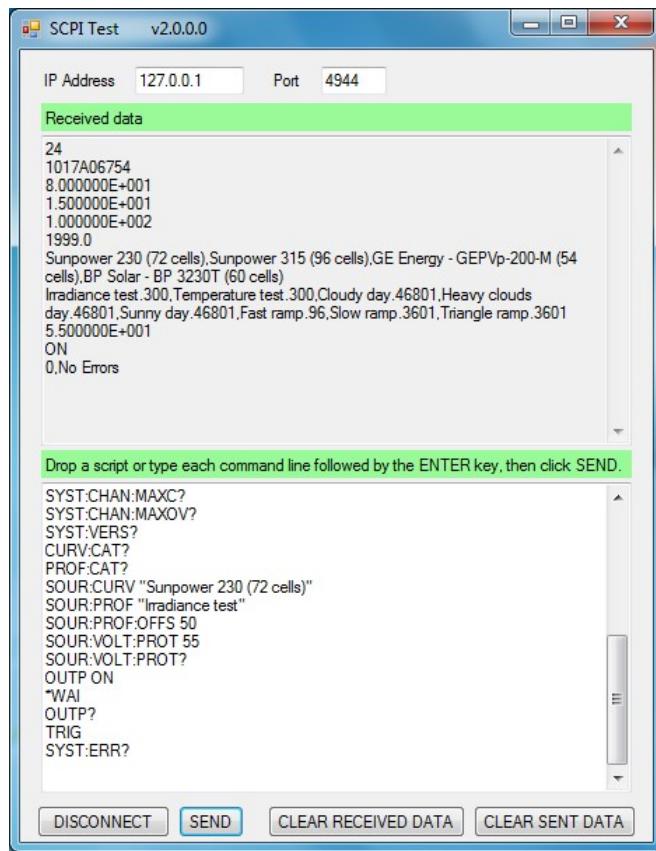


As usual when testing power supplies, CV operation was shown above when using an electronic load in CC mode. CC operation was monitored while the electronic load was placed in CV mode.

## Remote interface operation

### Using the SCPI Test utility

The enclosed SCPI Test utility can help you establish a remote connection to TerraSAS for evaluation or test purposes.



In order to connect, you need to know the IP address of the machine running TerraSAS. On that machine, click on START / Control Panel / Network and Internet Connections / Network Connections. Right click on the connection of interest, and then select Status. Select the Support tab. The IP address is displayed in the format xxx.xxx.xxx.xxx (Example: 192.168.0.1).

Enter the IP address into SCPI Test and leave the default port number: 4944. If SCPI Test is running on the same machine where TerraSAS is running, you can simplify the above process by leaving the default local host address 127.0.0.1.

**Important:** the network adapter must be connected to a network. If the network cable is unplugged, the local host address will become unreachable.

Click on the CONNECT button and confirm it becomes the DISCONNECT button. This means that a connection was established successfully.

On the TerraSAS status line (bottom of the user interface) the OFFLINE status should change to ONLINE :



### Sending and receiving commands

Now you are ready to type commands (lower text window) and see the responses (upper window). To monitor what TerraSAS is receiving, click on System > Debug > Show SCPI traffic.

Command lines need to conform to the following specifications:

- Up to 255 characters long
- Line terminator is <CR> or <CR><LF>

Returned data lines are terminated with <CR><LF>

You can also copy and paste the example scripts provided in the install disk into the SEND window. Click SEND to send the entire script and verify correct operation.

For a detailed description of all supported SCPI commands and their syntax, please refer to the SCPI Commands Reference section.

### **Connecting to TerraSAS using third party applications**

TerraSAS is always listening for TCP/IP connections on all Ethernet adapters, port 4944.

The supported connection type is known as TCP socket, which allows text-based communication using the ASCII character encoding.

**IMPORTANT:** Telnet and other terminal emulation protocols are not supported and can cause malfunctions.

## **Release notes**

### **TerraSAS 1.7.5.0 changes and improvements**

- Added support for the Inrush Limiter option module. See the ETS1000 user manual for details.
- Fixed bug on previous release, which caused a crash after extended profiles execution.

### **TerraSAS 1.7.8.0 changes and improvements**

- Added test session storage and retrieval (save / load test setup)
- Added ability to run PV simulators in power supply mode
- Added support for new SCR-controlled High Power PV Systems
- Updated SAM libraries to latest NREL release 2013.9.20
- Fixed bug preventing OVP settings above 999V

### **TerraSAS 2.0.0.0 changes and improvements**

- Tool to create and edit complex irradiance profiles (see **Irradiance profile > Create**)
- EN50530 support (static and dynamic MPP tracking efficiency)
- Ability to disable linear interpolation on profiles execution
- Longer timeout on PV firmware to allow operation on slow computers
- Other minor improvements
- Enhanced remote interface. See SCPI reference section for details.
- Updated SAM libraries to latest NREL release 2014.1.14

**Note:** existing SCPI automation scripts will need minor changes to run with TerraSAS release 2.0.0.0 and above. See SCPI reference section for details.

### **Features for future release**

The following new features are planned for release 3.0.0.0:

- Execution of complex profiles on array models
- IEC61683 support (static and dynamic power conversion efficiency)

## **Reporting software bugs**

If you find a bug please report it as soon as possible via e-mail to:

[PPSupport.PPD@ametek.com](mailto:PPSupport.PPD@ametek.com)

Please include as much detail as possible, such as:

- Application name: TerraSAS
- Software version you are running (e.g: 1.7.8.0), as reported by Help>About TerraSAS
- Description of the malfunction and its adverse effects
- Conditions that trigger the malfunction
- Curve and profile files used during the malfunctioning simulation
- SCPI script that triggers the malfunction, if one was in use
- Model of all connected PV simulators

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## **File formats**

Tab-separated text formats were chosen for the following reasons:

- Import and export compatibility with Microsoft Excel and Microsoft Access
- Small file size (about 1/6 of the corresponding Excel file)
- Fast loading
- Human readable

The decimal separator for all numeric values is "." (period), regardless of localized versions of the operating system and/or computer system regional settings. This was preferred for the following reasons:

- Example and configuration files were created on a US computer
- Module and inverter libraries are published in US format
- The SCPI Language standard is incompatible with numbers using "," (comma) as the decimal separator.

### **Curves**

Line 1: <max voltage> <tab> <min current> <CR><LF>

Line 2: < voltage> <tab> < current> <CR><LF>

....

Line 1024: <min voltage> <tab> <max current> <CR><LF>

Line 1025: <Beta voltage> <tab> <Beta power> <tab> <K factor> <CR><LF>

Beta parameters represent the voltage and power temperature coefficients, expressed in %/°C.  
The K factor is expressed as:

$$k = \left( \frac{V_1 - V_0}{V_0} \right) * \frac{\ln(E_0)}{\ln(E_1) - \ln(E_0)}$$

Where:

$V_0$  = Open circuit voltage at reference conditions

$V_1$  = Open circuit voltage at lowest known irradiance point

$E_0$  = Irradiance at reference conditions (1000 W/m<sup>2</sup>)

$E_1$  = Irradiance at lowest known irradiance point (e.g: 200 W/m<sup>2</sup>)

The suggested number of decimals is 6, which gives 1 uV and 1 uA of resolution. The application converts these values to double precision floating point (64 bits), which is used for all calculations. The number of decimals can be changed with no restrictions. The file format is text ("txt") and the file extension must be changed to ".crv"

### **Irradiance profiles**

Line 1: <irradiance> <tab> <temperature> <CR><LF>

...

Line n: <irradiance> <tab> <temperature> <CR><LF>

Irradiance is in Watts/m<sup>2</sup>, temperature is in degrees Celsius. Data is in text ("txt") form. The suggested number of decimals is 3, but any other number can be used.

There is no limit to the size of the file. Each line represents a fixed one second interval. This matches the hardware simulation and real time interpolation clock, which is crystal controlled. However, file translation to and from other intervals could be accommodated in future releases. The file extension must be changed to ".irtp".

## Irradiance profile tables

This file stores an irradiance profile table in text format. This file should only be created and edited using TerraSAS software. The file extension is ".irtt".

## Session files

Session files store an entire test session setup for quick retrieval. They include all curves, profiles, arrays, system configuration, channels grouping and settings. The file format is XML.

## Data logging files

Line 1 (column headers):

```
<TIME STAMP><t><CHa measx><t>...<CHa measy><t>...<CHn measx><t>...<CHn measy><CR><LF>
```

Line 2 (data):

```
<time stamp><t><CHa measx><t>...<CHa measy><t>...<CHn measx><t>...<CHn measy><CR><LF>
```

.....

Line n (data):

```
<time stamp><t><CHa measx><t>...<CHa measy><t>...<CHn measx><t>...<CHn measy><CR><LF>
```

where:

<t> the Tab character

<CR> the carriage return character

<LF> the line feed character

<time stamp> date, time and milliseconds in the format MM/DD/YYYY hh:mm:ss.mmm

<CHa measx> first selected measurement on the first selected channel

<CHa measy> last selected measurement on the first selected channel

<CHn measx> first selected measurement on the last selected channel

<CHn meas y> last selected measurement on the last selected channel

The file format is Windows text with the standard .txt file extension.

Example with time stamp, channel 1, channel 2, DC voltage and DC current selected:

TIME STAMP	CH1 DCV	CH1 DCI	CH2 DCV	CH2 DCI
8/13/2010 14:09:35.707	4.408666E+001	4.587487E+000	4.408829E+001	4.589466E+000
8/13/2010 14:09:36.689	4.408985E+001	4.585021E+000	4.408901E+001	4.593165E+000
8/13/2010 14:09:37.686	4.408746E+001	4.589313E+000	4.408727E+001	4.584248E+000
8/13/2010 14:09:38.684	4.408948E+001	4.590363E+000	4.408307E+001	4.592713E+000
8/13/2010 14:09:39.681	4.408591E+001	4.588170E+000	4.408640E+001	4.588562E+000
8/13/2010 14:09:40.679	4.408676E+001	4.592735E+000	4.408728E+001	4.591793E+000
8/13/2010 14:09:41.676	4.408202E+001	4.584058E+000	4.408569E+001	4.592407E+000
8/13/2010 14:09:42.674	4.408170E+001	4.592139E+000	4.408165E+001	4.590404E+000

**Note:** Time stamp and number formats **do not follow** localized versions of the operating system and/or computer system regional settings.

When exporting log files on computers using ","(comma) as the decimal separator, custom import settings need to be used to avoid data corruption.

The example below shows how to correctly import logged data in Microsoft Excel:



A similar dialog is available in Microsoft Access when importing text files.

This setting is only needed when running TerraSAS on computers using "," (comma) as the decimal separator, as in most European and South American Countries.

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# TerraSAS SCPI Commands Reference

## Overview

The SCPI interface allows performing most functions available to the local user from a remote computer.

Incoming commands are placed into a memory buffer and executed in the order they are received. Compound commands are processed left to right. While the vast majority of the commands are sequential (they must complete before the next command is processed), some are overlapped. Operations that require time to complete are typically overlapped, to avoid blocking the interface.

The following commands initiate an overlapped operation and are included in the pending operation flags:

- OUTPut[:STATe] {ON|OFF} [,(@chanlist)]
- OUTPut:PROTection:CLEar [(@chanlist)]
- ABORT:DLOG
- ABORT[:TRANSient] [(@chanlist)]
- ABORT:MPPTRecovery

The following commands initiate an overlapped operation and are **not** included in the pending operation flags:

- TRIGger:DLOG[:IMMEDIATE]
- TRIGger[:TRANSient][:IMMEDIATE] [(@chanlist)]
- TRIGger[:TRANSient][:IMMEDIATE]:PAUse [(@chanlist)]
- TRIGger[:TRANSient][:IMMEDIATE]:RESet [(@chanlist)]
- TRIGger:MPPTRecovery[:IMMEDIATE]

To synchronize script execution with triggered operations, poll the status word (see the STATus subsystem)

Please refer to the SCPI Language standard for complete details about the commands below, with particular regard to syntax, commands structure and sequential/overlapped commands operation. The standard can be downloaded free of charge from this web page:

<http://www.ivifoundation.org/specifications/default.aspx>

Or click below to directly download the .PDF document.

<http://www.ivifoundation.org/docs/scpi-99.pdf>

A brief SCPI Language tutorial is also provided at the end of this section.

## **Release 2.X SCPI commands update**

The commands and queries listed below were added. The documentation provided in this manual now includes all 168 commands that are currently supported (132 from software releases 1.X and 36 new ones).

```
SYSTem:CHANnel:MAXPower? [(@chanlist)]
SYSTem:CHANnel:MAXOVCurrent? [(@chanlist)]
CURVe:EN50530:MPPparms <Pmp>, <Vmp>
CURVe:EN50530:MPPparms?
CURVe:EN50530:SIMtype {CSI|TF},{STA|DYN}
CURVe:EN50530:SIMtype?
CURVe:EN50530:ADD
[SOURce:]VOLTage <volts> [,(@chanlist)]
[SOURce:]VOLTage? [,(@chanlist)]
[SOURce:]CURREnt <amps> [,(@chanlist)]
[SOURce:]CURREnt? [,(@chanlist)]
[SOURce:]EN50530:VOLTage <volts> [,(@chanlist)]
[SOURce:]EN50530:VOLTage? [,(@chanlist)]
[SOURce:]EN50530:POWER <watts> [,(@chanlist)]
[SOURce:]EN50530:POWER? [,(@chanlist)]
[SOURce:]EN50530:TECHnology {CSI|TF} [,(@chanlist)]
[SOURce:]EN50530:TECHnology? [,(@chanlist)]
[SOURce:]EN50530:SIMtype {STA|DYN} [,(@chanlist)]
[SOURce:]EN50530:SIMtype? [,(@chanlist)]
[SOURce:]EXECute [,(@chanlist)]
[SOURce:]CURREnt:PROTection[:LEVel] <value> [,(@chanlist)]
[SOURce:]CURREnt:PROTection[:LEVel]? [,(@chanlist)]
SENSe:VPgain <value> [,(@chanlist)]
SENSe:VPgain? [,(@chanlist)]
SENSe:Vlgain <value> [,(@chanlist)]
SENSe:Vlgain? [,(@chanlist)]
SENSe:VDgain <value> [,(@chanlist)]
SENSe:VDgain? [,(@chanlist)]
SENSe:MODe {PS|PV} [,(@chanlist)]
SENSe:MODe? [,(@chanlist)]
SENSe:INLimiter {ON|OFF} [,(@chanlist)]
SENSe:INLimiter? [,(@chanlist)]
SENSe:ILEnergy <energy> [,(@chanlist)]
SENSe:ILEnergy? [,(@chanlist)]
SENSe:DIslope {ON|OFF} [,(@chanlist)]
SENSe:DIslope? [,(@chanlist)]
```

The commands listed below were modified to improve performance or support new features.  
Changes are **highlighted**.

### **SYSTem:REMote**

Places the system in remote mode, disabling local user interaction with the graphical interface. It also minimizes the user interface and removes the icon from the Windows taskbar.

### **SYSTem:LOCal**

Places the system in local mode, enabling local user interaction with the graphical interface. It also maximizes the user interface (full screen) and restores the icon in the Windows taskbar.

**CURVe:ADD <name>**

&lt;...&gt;

17, Invalid characters in name or file name

If the reserved name "EN 50530 CURVE" or invalid characters are entered

**ARRAy:MODULE#:STRing#:CURVe <name>**

&lt;...&gt;

16, Operation not allowed in this context

If one or more channels are executing a profile.

If the EN50530 curve is assigned.

**[SOURce:]CURVe <name> [,(@chanlist)]**

The indicated curve is applied on the selected channels. If the name is blank, curve 0 is applied.

Specify name "EN 50530 CURVE" to execute the EN50530 curve.

**[SOURce:]IRRadiance <irradiance> [,(@chanlist)]**The programmed irradiance is applied to the selected channels. Acceptable range is 0 to 1999 W/m<sup>2</sup>. This command applies to SNL and EN50530 curves.

&lt;...&gt;

16, Operation not allowed in this context

If one or more selected channels are executing a profile

If one or more selected channels are set in power supply (PS) mode

**[SOURce:]TEMPerature <temperature> [,(@chanlist)]**

The programmed temperature is executed on the selected channels. Acceptable range is -100 to +100 °C. This command applies to SNL and EN50530 curves.

&lt;...&gt;

16, Operation not allowed in this context

If one or more selected channels are executing a profile

If one or more selected channels are set in power supply (PS) mode

**SENSe:DLOG:DATA (numlist)**

Selects the data items that will be logged, according to the table below.

Parameter	Description
1	Time stamp
2	DC Voltage
3	DC Current
4	RMS Power
5	AC Voltage
6	AC Current
7	MPP Accuracy
8	Energy
9	MPP Power
10	MPP Voltage
11	MPP Current

Example:

SENS:DLOG:DATA (1:11) will log all parameters for each enabled channel

SENS:DLOG:DATA (1,4) will log time stamp and rms power for each enabled channel

**OUTPut:PROTection:CLEar [(@chanlist)]**

Resets the overvoltage or overcurrent protection latch on the selected channels

## Backward compatibility with TerraSAS 1.X SCPI scripts

Existing scripts will require the change described below to continue working.

The new command [SOURce:]EXECute [,(@chanlist)] must be added to existing scripts after command sequences that alter :

- Irradiance setting
- Temperature setting
- Curve assignment (curve executed on an output channel)
- EN 50530 curve parameters

This is because each of the above commands requires the updated curve to be transferred to the PV simulator. This process was previously transparent to the user, but unfortunately causing execution troubles. Consider the script below:

```
Line 1: sour:curv "Sunpower 230 (72 cells)",(@1:3)
Line 2: sour:irr 800,(@1:3)
Line 3: temp 50,(@1:3)
Line 4: sour:irr 1000,(@1:3)
```

On line 1 the selected curve is assigned and executed on channels 1, 2 and 3. This triggered asynchronous internal processes that transmit the curve to each PV simulator. When line 2 is executed, the curve is recalculated and transferred while the previous transfer may still be in progress. This can produce inconsistent results (wrong output voltage / current).

Correct results are now obtained by adding one line at the end of the script:

```
Line 1: sour:curv "Sunpower 230 (72 cells)",(@1:3)
Line 2: sour:irr 800,(@1:3)
Line 3: temp 50,(@1:3)
Line 4: sour:irr 1000,(@1:3)
Line 5: sour:exec (@1:3)
```

TerraSAS 2.X no longer transfers any curves until the new command in Line 5 is executed. This allows transmitting the updated curve only once, which avoids wasting communication resources and corrupting or dropping curves when overlapped transfers occurred.

Scripts written for TerraSAS 1.X will no longer transfer curves when running on TerraSAS 2.X until the new command is added.

## **IEEE-488.2 commands and queries**

### **\*CLS**

Clears the error queue, the Standard Events Register and all No Operation Pending flags.

**Possible errors:**

1-12 Syntax and parameter mismatch errors

### **\*ESR?**

Returns the contents of the Standard Events Register in decimal format. The ESR is an unsigned 32-bit word with the following meaning:

ERROR CODE	DECIMAL VALUE	DESCRIPTION
	1	Operation Complete Flag
1	2	Numeric suffix is an invalid value
2	4	Invalid value in numeric or channel list, e.g. out of range
3	8	Invalid number of dimensions in a channel list
4	16	Parameter of type numeric value overflowed its storage
5	32	Wrong units for parameter
6	64	Wrong type of parameter(s)
7	128	Wrong number of parameters
8	256	Unmatched quotation mark (single/double) in parameters
9	512	Unmatched bracket
10	1024	Command keywords were not recognized
11	2048	No entry in list to retrieve (number list or channel list)
12	4096	Too many dimensions in entry to be returned in parameters
13	8192	File name or name not found
14	16384	File name or name already exists
15	32768	Out of range in one or more numeric values
16	65536	Operation not allowed in this context
17	131072	Invalid characters in name or file name
18	262144	Missing pre-condition, cannot execute command
19	524288	Invalid channel
20	1048576	Invalid channel group
21	2097152	Future use
22	4194304	Future use
23	8388608	Future use
24	16777216	Future use
25	33554432	Future use
26	67108864	Future use
27	134217728	Future use
28	268435456	Future use
29	536870912	Future use
30	1073741824	Future use
31	2147483648	Future use

**Possible errors:**

1-12 Syntax and parameter mismatch errors

**\*IDN?**

Returns product and version information.

Possible errors:

1-12 Syntax and parameter mismatch errors

Example:

\*IDN?

Ametek PPD,TerraSAS,<serial number>,<revision number>

**\*OPC**

Sets the Operation Complete Flag in the Standard Events Register when all pending operations are completed. This is an overlapped command, the parser will continue processing commands without waiting for pending operations to complete.

Possible errors:

1-12 Syntax and parameter mismatch errors

**\*OPC?**

Suspends processing further commands until all pending operations are completed, then returns "1".

Possible errors:

1-12 Syntax and parameter mismatch errors

**\*RST**

Resets the system. The following tasks are performed:

- Suspends processing further commands until the system is reset and ready to accept commands
- Stops all dynamic simulations
- Terminates datalogging and closes the file
- Terminates triggered measurements
- Terminates all pending operations
- Deletes all curves, profiles and arrays
- Resets all channels to curve zero, no profile
- Opens all output relays
- Resets all channels to default irradiance and temperature
- Clears the error queue, the Standard Events Register and all No Operation Pending flags.

System Configuration, System Settings and Channels Grouping are not affected.

Possible errors:

1-12 Syntax and parameter mismatch errors

**\*WAI**

Suspends processing further commands until all pending operations are completed.

Possible errors:

1-12 Syntax and parameter mismatch errors

## **SYSTem commands and queries**

### **SYSTem:ERRor[:NEXT]?**

Returns the next error code and error message in the queue. If the queue is empty, returns "0, No errors".

Possible errors:

1-12 Syntax and parameter mismatch errors

### **SYSTem:REMote**

Places the system in remote mode, disabling local user interaction with the graphical interface. It also minimizes the user interface and removes the icon from the Windows taskbar.

Possible errors:

1-12 Syntax and parameter mismatch errors

### **SYSTem:REMote?**

Returns "1" if the system is in remote mode, "0" otherwise

Possible errors:

1-12 Syntax and parameter mismatch errors

### **SYSTem:LOCal**

Places the system in local mode, enabling local user interaction with the graphical interface. It also maximizes the user interface (full screen) and restores the icon in the Windows taskbar.

Possible errors:

1-12 Syntax and parameter mismatch errors

### **SYSTem:CHANnel[:COUNT]?**

Returns the number of PV simulators in the system. Note that channel and PV simulators count may differ when channels are grouped. See "System>Channels grouping setup" for details.

Possible errors:

1-12 Syntax and parameter mismatch errors

### **SYSTem:CHANnel:SERial? [(@chanlist)]**

Returns the serial number of the PV simulators for the selected channels. Multiple entries are separated by a comma. A dead channel reports "0".

Possible errors:

1-12 Syntax and parameter mismatch errors

15, Out of range in one or more numeric values

**SYSTem:CHANnel:MAXPower? [(@chanlist)]**

Returns the maximum power capability of the selected channels. Multiple entries are separated by a comma.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

**SYSTem:CHANnel:MAXVoltage? [(@chanlist)]**

Returns the maximum voltage capability of the selected channels. Multiple entries are separated by a comma.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

**SYSTem:CHANnel:MAXCurrent? [(@chanlist)]**

Returns the maximum current capability of the selected channels. Multiple entries are separated by a comma.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

**SYSTem:CHANnel:MAXOVoltage? [(@chanlist)]**

Returns the maximum voltage protection setting of the selected channels. Multiple entries are separated by a comma.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

**SYSTem:CHANnel:MAXOVCurrent? [(@chanlist)]**

Returns the maximum current protection setting of the selected channels. Multiple entries are separated by a comma.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

## **SYSTem:VERSion?**

Returns the SCPI language version number.

Possible errors:

1-12 Syntax and parameter mismatch errors

## **SYSTem:GROup:CATalog?**

Returns output channel groups configuration, in the format

<ID>,<Mchan>,< MaxVoc >,< MaxIsc >, ... , <ID>,<Mchan>,< MaxVoc >,< MaxIsc >

where:

<ID> "S" for series or "P" for parallel followed by group number

<Mchan> master channel number (the first channel in the group)

<MaxVoc> Maximum group voltage

<MaxIsc> Maximum group current

If there are no groups configured, "G.0" is returned. Please note that groups are actually created when valid groups are first defined and then configured by executing the SYSTem:GROup:SETup command.

Possible errors:

1-12 Syntax and parameter mismatch errors

Example:

Two series groups and two parallel groups, assuming a 24 channels system with 80V

15A PV simulators:

SYST:GRO:DELE:ALL

SYST:GRO:DEF:SER 1,(@5,10)

SYST:GRO:DEF:PAR 1,(@8:9)

SYST:GRO:DEF:PAR 2,(@21:24)

SYST:GRO:DEF:SER 2,(@12,14,15)

SYST:GRO:SET

SYST:GRO:CAT?

S1,5,160,15,P1,8,80,30,S2,12,240,15,P2,21,80,60

## **SYSTem:GROup:DELEte:ALL**

Deletes all previously entered group definitions. Should be sent first when redefining groups.

Possible errors:

1-12 Syntax and parameter mismatch errors

## **SYSTem:GROup:DEFine:PARallel <group>, (@chanlist)**

Defines a group of channels wired in parallel. The maximum group number is half the number of PV simulators in the system.

Possible errors:

1-12 Syntax and parameter mismatch errors

15,Out of range in one or more numeric values

**SYSTem:GROup:PARallel? <group>**

Returns the channel list associated with the group definition. Multiple entries are separated by a comma. If the group does not exist, "G.0" is returned.

**Possible errors:**

1-12 Syntax and parameter mismatch errors  
15,Out of range in one or more numeric values

**Example:**

```
SYST:GRO:DELE:ALL
SYST:GRO:DEF:PAR 1,(@1:3)
SYST:GRO:PAR? 1
    1,2,3
SYST:GRO:PAR? 2
    G.0
```

**SYSTem:GROup:DEFine:SERies <group>, (@chanlist)**

Defines a group of channels wired in series. The maximum group number is half the number of PV simulators in the system.

**Possible errors:**

1-12 Syntax and parameter mismatch errors  
15,Out of range in one or more numeric values

**SYSTem:GROup:SERies? <group>**

Returns the channel list associated with the group definition. Multiple entries are separated by a comma. If the group does not exist, "G.0" is returned.

**Possible errors:**

1-12 Syntax and parameter mismatch errors  
15,Out of range in one or more numeric values

**Example:**

```
SYST:GRO:DELE:ALL
SYST:GRO:DEF:SER 1,(@1:3)
SYST:GRO:SER? 1
    1,2,3
SYST:GRO:SER? 2
    G.0
```

## **SYSTem:GROup:SETup**

Configures all output channels with all previously defined groups, after validating all entries. None of the groups are actually configured if the validation fails.

Upon successful execution, new channel group configurations become effective. All channels are turned off, assigned curve zero, no profile and reset to default irradiance and temperature settings.

### Possible errors:

1-12 Syntax and parameter mismatch errors

16,Operation not allowed in this context

Profile execution, datalogging or triggered measurements are active on one or more channels

20,Invalid channel group

- One or more groups with only one channel assigned had been defined
- One or more series groups with more than three members were defined
- Channels have incompatible electrical ratings (see "System>Channels grouping setup" for details)
- One or more dead channels were included in group definitions

### Example:

```
SYST:GRO:DELE:ALL
SYST:GRO:DEF:SER 1,(@5,10)
SYST:GRO:DEF:PAR 1,(@8:9)
SYST:GRO:DEF:PAR 2,(@21:24)
SYST:GRO:DEF:SER 2,(@12,14,15)
SYST:GRO:CAT?
          G.0
SYST:GRO:SET
SYST:GRO:CAT?
          S1,5,160,15,P1,8,80,30,S2,12,240,15,P2,21,80,60
SYST:GRO:DELE:ALL
SYST:GRO:CAT?
          S1,5,160,15,P1,8,80,30,S2,12,240,15,P2,21,80,60
SYST:GRO:SET
SYST:GRO:CAT?
          G.0
```

## **CURVe subsystem**

### **CURVe:READFile <file name>**

Loads a photovoltaic curve from a disk file. The file name must be enclosed in double quotes. The file extension is automatically added.

#### Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 13,File name or name not found
- 14,File name or name already exists
- 16,Operation not allowed in this context
  - If one or more channels are executing a profile
- 17,Invalid characters in name or file name

#### Example:

CURV:READF "Sunpower 230 (72 cells)" will load the curve file <Sunpower 230 (72 cells).crv> from the \\root\TerraSas\Curves folder.

### **CURVe:Vlparms <Voc>, <lsc>**

Sets Voc and lsc for the curve being added to the graphic pool, at standard test conditions (1000 W/m<sup>2</sup>, 25.0 °C). This parameter pair **must** be sent before any other when creating a new curve.

#### Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context
  - If one or more channels are executing a profile

### **CURVe:Vlparms?**

Returns the last Voc and lsc parameters that were entered, formatted as <Voc>,<lsc>

#### Possible errors:

- 1-12 Syntax and parameter mismatch errors

### **CURVe:MPPparms <Vmp>,<Imp>**

Sets Vmp and Imp for the curve being added to the graphic pool, at standard test conditions (1000 W/m<sup>2</sup>, 25.0 °C). This overwrites any previously entered form factor. The resulting form factor must be between 0.5 and 0.95.

#### Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context
  - If one or more channels are executing a profile

### **CURVe:MPPparms?**

Returns the last Vmp and Imp parameters that were entered, formatted as <Vmp>,<Imp>

#### Possible errors:

- 1-12 Syntax and parameter mismatch errors

### **CURVe:FORMfactor <form factor>**

Computes Vmp and Imp from the supplied form factor. The allowed range is 0.5 to 0.95. This overwrites any previously entered Vmp, Imp parameters.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context

If one or more channels are executing a profile

### **CURVe:FORMfactor?**

Returns the last form factor that was entered

Possible errors:

- 1-12 Syntax and parameter mismatch errors

### **CURVe:BETAprms <Beta V>,<Beta P>**

Sets the voltage and power temperature coefficients, expressed in percent values per degree Kelvin. Some manufacturers report the voltage coefficient in mV/°K. Divide by Voc to obtain a percentage. Allowed range is +1.99 to -1.99.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context

If one or more channels are executing a profile.

### **CURVe:BETAprms?**

Returns the last Beta V and Beta P parameters that were entered, formatted as <Beta V>,<Beta P>.

Possible errors:

- 1-12 Syntax and parameter mismatch errors

### **CURVe:KFactor <voltage>,<irradiance>**

Sets the irradiance correction factor by entering parameters V<sub>1</sub> and E<sub>1</sub>. See "Photovoltaic curve > Create" for more details. The voltage must be equal to or less than Voc. The irradiance must be between 100 and 800 W/m<sup>2</sup>.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context

If one or more channels are executing a profile.

### **CURVe:KFactor?**

Returns the last voltage and irradiance parameters that were entered, formatted as <voltage>,<irradiance>.

Possible errors:

- 1-12 Syntax and parameter mismatch errors

### **CURVe:ADD <name>**

Adds a previously characterized photovoltaic curve to the graphic pool and creates a disk file into the \\root\TerraSas\Curves folder, with file name <name>.crv. The curve is digitized to 1,024 points using the equations from Appendix A1, page 37 of the document "Performance Test Protocol for Evaluating Inverters Used in Grid-Connected Photovoltaic Systems", October 2004, Sandia National Laboratories.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 13,File name or name not found
- 14,File name or name already exists
- 15,Out of range in one or more numeric values
  - If previously entered numerical parameters are out of range
- 16,Operation not allowed in this context
  - If one or more channels are executing a profile.
- 17,Invalid characters in name or file name
  - If the reserved name "EN 50530 CURVE" or invalid characters are entered

### **CURVe:DELEte <name>**

Removes the indicated curve from the graphic pool. The corresponding disk file is **not** deleted. Disk files can only be deleted manually, using Windows Explorer.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 13,File name or name not found
- 16,Operation not allowed in this context
  - If one or more channels are executing a profile.

### **CURVe:CATalog?**

Returns the list of curve names currently loaded in the graphic pool. If there are no curves loaded, "C.0" is returned. Multiple entries are separated by a comma.

Possible errors:

- 1-12 Syntax and parameter mismatch errors

### **CURVe:EN50530:MPPparms <Pmp>, <Vmp>**

Sets maximum power point parameters Pmp (power) and Vmp (voltage) for the EN50530 curve.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 16,Operation not allowed in this context
  - If one or more channels are executing a profile

### **CURVe:EN50530:MPPparms?**

Returns the last Pmp and Vmp parameters that were entered, formatted as <Pmp>,<Vmp>

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 18,Missing pre-condition, cannot execute command
  - If no parameters were previously entered

### **CURVe:EN50530:SIMtype {CSI|TF},{STA|DYN}**

Sets the technology (crystalline silicon or thin film) and simulation type (static or dynamic) for the EN50530 curve. Irradiance and temperature are set to their default (1000 W/m<sup>2</sup> and 25°C). For static simulations, the power level is fixed at 1.00. Power and voltage levels are controlled remotely by programming Pmp and Vmp.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 16,Operation not allowed in this context
- If one or more channels are executing a profile

### **CURVe:EN50530:SIMtype?**

Returns the last simulation type parameters that were entered, formatted as {CSI|TF},{STA|DYN}

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 18,Missing pre-condition, cannot execute command
- If no parameters were previously entered

### **CURVe:EN50530:ADD**

Adds a previously characterized EN50530 photovoltaic curve to the graphic pool. The curve is digitized to 1,024 points using the equations provided in the EN50530 standard. Coefficients can be edited on the console but cannot be programmed remotely. The curve name is "EN 50530 CURVE". This name is reserved and cannot be used for SNL curves. If the curve already exists, it is updated.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 18,Missing pre-condition, cannot execute command
- If no parameters were previously entered

## **PROFile subsystem**

### **PROFile:READFile <file name>**

Loads an irradiance profile from a disk file. The file name must be enclosed in double quotes. The file extension is automatically added.

#### Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 13,File name or name not found
- 14,File name or name already exists
- 16,Operation not allowed in this context
  - If one or more channels are executing a profile.
- 17,Invalid characters in name or file name

#### Example:

PROF:READF "Sunny day" will load the profile file <Sunny day.irtp> from the \\root\TerraSas\Profiles folder

### **PROFile:DELEte <name>**

Removes the indicated irradiance profile from the graphic pool. The corresponding disk file is not affected.

#### Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 13,File name or name not found
- 16,Operation not allowed in this context
  - If one or more channels are executing a profile.

### **PROFile:CATalog?**

Returns the list of profile names currently loaded in the graphic pool and their duration. The format returned is <profile name>.<length in seconds>. Multiple entries are separated by a comma. If there are no profiles loaded, "P.0" is returned.

#### Possible errors:

- 1-12 Syntax and parameter mismatch errors

## **ARRAy subsystem**

### **ARRAy:SIZE <modules>,<strings>**

Defines an array size. The maximum number of modules in an array is 100.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values

### **ARRAy:SIZE?**

Returns the last defined array size, in the form <modules>,<strings>.

Possible errors:

- 1-12 Syntax and parameter mismatch errors

### **ARRAy:ADD <name>**

Creates an array and adds it to the graphic pool. The array size must have been previously defined. After creation, the new array is selected and ready to be assigned curves and profiles.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 14,File name or name already exists
- 16,Operation not allowed in this context
  - If one or more channels are executing a profile.
- 17,Invalid characters in name or file name
  - If the array name is blank

### **ARRAy:SElect <name>**

Selects the indicated array. All subsequent curve and profile assignments refer to the currently selected array.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 13,File name or name not found

### **ARRAy:SElect?**

Returns the name of the currently selected array. If no array is selected, "A.0" is returned.

Possible errors:

- 1-12 Syntax and parameter mismatch errors

### **ARRAy:MODULE#:STRING#:CURVe <name>**

Assigns a curve to the selected array module(s). If the curve name is blank, curve zero is assigned. If the module number is zero, all modules in the string are assigned the same curve. If the string number is zero, the curve is assigned to the selected module on all strings. If both numbers are zero, the curve is assigned to all modules within the array.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 13,File name or name not found
  - If the specified curve does not exist in the graphic pool
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context
  - If one or more channels are executing a profile.
  - If the EN50530 curve is assigned.
- 18,Missing pre-condition, cannot execute command
  - If no array is selected

### **ARRAy:MODULE#:STRING#:CURVe?**

Returns the curve name assigned to the selected array module. If no curve was assigned "C.0" is returned.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 18,Missing pre-condition, cannot execute command
  - If no array is selected

### **ARRAy:MODULE#:STRING#:PROFILE <name>**

Assigns a profile to the selected array module(s). If the profile name is blank, no profile is assigned. If the module number is zero, all modules in the string are assigned the same profile. If the string number is zero, the profile is assigned to the selected module on all strings. If both numbers are zero, the profile is assigned to all modules within the array.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 13,File name or name not found
  - If the specified profile does not exist in the graphic pool
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context
  - If one or more channels are executing a profile.
  - 18,Missing pre-condition, cannot execute command
    - If no array is selected

### **ARRAy:MODULE#:STRING#:PROFILE?**

Returns the profile name assigned to the selected array module. If no profile was assigned "P.0" is returned.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 18,Missing pre-condition, cannot execute command
  - If no array is selected

## **ARRAy:MULTiplier <value>**

Programs the currently selected array with the specified current multiplier. Accepted range is an integer between 1 and 1000. The default value is 1, which is assigned when a new array is created.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 18,Missing pre-condition, cannot execute command

If no array is selected

## **ARRAy:MULTiplier?**

Returns the array multiplier for the currently selected array.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 18,Missing pre-condition, cannot execute command

If no array is selected

## **ARRAy:DELEte <name>**

Removes the indicated array from the graphic pool. If the array was selected, the selection is cancelled (ARRAy:SElect? returns "A.0"). If the array was assigned to one or more output channels, assignment is cleared and curve zero is executed.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 13,File name or name not found
- 16,Operation not allowed in this context

If one or more channels are executing a profile.

## **ARRAy:CATalog?**

Returns the list of array names currently loaded in the graphic pool and their size. The format returned is <array name>.<modules>.<strings>. Multiple entries are separated by a comma. If there are no arrays loaded, "A.0" is returned.

Possible errors:

- 1-12 Syntax and parameter mismatch errors

Example:

```
ARRA:SIZE 3,1
ARRA:ADD "Test 1"
ARRA:SIZE 4,2
ARRA:ADD "Test 2"
ARRA:CAT?
Test 1.3.1,Test 2.4.2
```

## **SOURce subsystem**

### **[SOURce:]CURVe <name> [,(@chanlist)]**

The indicated curve is applied on the selected channels. If the name is blank, curve 0 is applied. Specify name “EN 50530 CURVE” to execute the EN50530 curve.

#### Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 13,File name or name not found
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context
  - If one or more selected channels are executing a profile
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

### **[SOURce:]CURVe? [(@chanlist)]**

Returns the curve name for the selected channels. If no curve was assigned, returns "C.0". Multiple entries are separated by a comma.

#### Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

### **[SOURce:]IRRadiance <irradiance> [,(@chanlist)]**

The programmed irradiance is applied to the selected channels. Acceptable range is 0 to 1999 W/m<sup>2</sup>. This command applies to SNL and EN50530 curves.

#### Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context
  - If one or more selected channels are executing a profile
  - If one or more selected channels are set in power supply (PS) mode
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

### **[SOURce:]IRRadiance? [(@chanlist)]**

Returns the irradiance setpoint for the selected channels. Multiple entries are separated by a comma.

#### Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**[SOURce:]TEMPerature <temperature> [,(@chanlist)]**

The programmed temperature is executed on the selected channels. Acceptable range is -100 to +100 °C. This command applies to SNL and EN50530 curves.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context
  - If one or more selected channels are executing a profile
  - If one or more selected channels are set in power supply (PS) mode
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**[SOURce:]TEMPerature? [(@chanlist)]**

Returns the temperature setpoint for the selected channels. Multiple entries are separated by a comma.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**[SOURce:]VOLTage <volts> [,(@chanlist)]**

The specified voltage setpoint is applied to the selected channels. This setpoint is only valid in power supply (PS) mode.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context
  - If one or more selected channels are set in photovoltaic (PV) mode
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**[SOURce:]VOLTage? [(@chanlist)]**

Returns the voltage setpoint for the selected channels. Multiple entries are separated by a comma.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**[SOURce:]CURREnt <amps> [,(@chanlist)]**

The specified current setpoint is applied to the selected channels. This setpoint is only valid in power supply (PS) mode.

**Possible errors:**

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context
  - If one or more selected channels are set in photovoltaic (PV) mode
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**[SOURce:]CURREnt? [(@chanlist)]**

Returns the current setpoint for the selected channels. Multiple entries are separated by a comma.

**Possible errors:**

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**[SOURce:]EN50530:VOLTage <volts> [,(@chanlist)]**

The specified EN50530 maximum power point voltage is applied to the selected channels.

**Possible errors:**

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context
  - If one or more selected channels are set in power supply (PS) mode
  - If one or more selected channels are not executing an EN50530 curve
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**[SOURce:]EN50530:VOLTage? [(@chanlist)]**

Returns the EN50530 maximum power point voltage for the selected channels. Multiple entries are separated by a comma.

**Possible errors:**

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**[SOURce:]EN50530:POWer <watts> [,(@chanlist)]**

The specified EN50530 maximum power point power is applied to the selected channels.

**Possible errors:**

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context
  - If one or more selected channels are set in power supply (PS) mode
  - If one or more selected channels are not executing an EN50530 curve
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**[SOURce:]EN50530:POWer? [(@chanlist)]**

Returns the EN50530 maximum power point power for the selected channels. Multiple entries are separated by a comma.

**Possible errors:**

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**[SOURce:]EN50530:TECHnology {CSI|TF} [,(@chanlist)]**

The specified EN50530 technology type (crystalline silicon or thin film) is applied to the selected channels.

**Possible errors:**

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context
  - If one or more selected channels are set in power supply (PS) mode
  - If one or more selected channels are not executing an EN50530 curve
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**[SOURce:]EN50530:TECHnology? [(@chanlist)]**

Returns the EN50530 technology type formatted as {CSI|TF}. Multiple entries are separated by a comma.

**Possible errors:**

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**[SOURce:]EN50530:SIMtype {STA|DYN} [,(@chanlist)]**

The specified EN50530 simulation type (static or dynamic) is applied to the selected channels.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context
  - If one or more selected channels are set in power supply (PS) mode
  - If one or more selected channels are not executing an EN50530 curve
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**[SOURce:]EN50530:SIMtype? [(@chanlist)]**

Returns the EN50530 simulation type formatted as {STA|DYN}. Multiple entries are separated by a comma.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**[SOURce:]EXECute [,(@chanlist)]**

All previously programmed curve parameters are calculated and transferred to the PV simulator(s). This command applies to SNL and EN50530 curves.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context
  - If one or more selected channels are executing a profile
  - If one or more selected channels are set in power supply (PS) mode
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**[SOURce:]PROFile <name> [,(@chanlist)]**

The indicated profile is sent to the selected channels. Execution starts when a trigger command is received. If one or more channels in the list are executing a profile, error 16 is generated.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 13,File name or name not found
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context
  - If one or more selected channels are executing a profile
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**[SOURce:]PROFile? [(@chanlist)]**

Returns the profile name for the selected channels. If no profile is assigned, returns "P.0".  
Multiple entries are separated by a comma.

**Possible errors:**

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
  - If one or more selected channels are executing a profile
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**[SOURce:]PROFile:OFFSet <value> [,(@chanlist)]**

Sets the starting time (offset) of the profile for the selected channels.

**Possible errors:**

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
  - If the offset value falls outside the profile time span on one or more selected channels
- 16,Operation not allowed in this context
  - If one or more selected channels are executing a profile
- 18,Missing pre-condition, cannot execute command
  - If one or more channels do not have a profile assigned
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**[SOURce:]PROFile:OFFSet? [(@chanlist)]**

Returns the profile offset for the selected channels. Multiple entries are separated by a comma.

**Possible errors:**

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**[SOURce:]VOLTage:PROTection[:LEVel] <value> [,(@chanlist)]**

Sets the overvoltage protection threshold on the selected channels

**Possible errors:**

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**[SOURce:]VOLTage:PROTection[:LEVel]? [(@chanlist)]**

Returns the overvoltage protection threshold on the selected channels. Multiple entries are separated by a comma.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

**[SOURce:]CURRent:PROTection[:LEVel] <value> [,(@chanlist)]**

Sets the overcurrent protection threshold on the selected channels

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

**[SOURce:]CURRent:PROTection[:LEVel]? [(@chanlist)]**

Returns the overcurrent protection threshold on the selected channels. Multiple entries are separated by a comma.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

**[SOURce:]ARRAy <name> [,(@chanlist)]**

The indicated array is executed on the selected channels. If the name is blank, array execution is terminated and curve 0 is executed.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 13,File name or name not found
- 16,Operation not allowed in this context
  - If one or more selected channels are executing a profile
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

**[SOURce:]ARRAy? [(@chanlist)]**

Returns the array name for the selected channels. If no array was assigned, returns "A.0". Multiple entries are separated by a comma.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

### **SOURce#:ARRAy:MODULE#:STRing#:IRRadiance <irradiance>**

The indicated array module(s) on the selected channel are programmed with the specified irradiance level. If the module number is zero, all modules in the string are programmed. If the string number is zero, the selected module is programmed on all strings. If both numbers are zero, all modules within the array are programmed. Acceptable range is 0 to 1999 W/m<sup>2</sup>.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context
  - If the selected channel is executing a profile
- 18,Missing pre-condition, cannot execute command
  - If the channel does not have an array assigned
- 19,Invalid channel
  - If the selected channel is hidden (group slaves)

### **SOURce#:ARRAy:MODULE#:STRing#:IRRadiance?**

Returns the irradiance level for the selected array module and channel

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 18,Missing pre-condition, cannot execute command
  - If the selected channel does not have an array assigned
- 19,Invalid channel
  - If the selected channel is hidden (group slaves)

### **SOURce#:ARRAy:MODULE#:STRing#:TEMPerature <temperature>**

The indicated array module(s) on the selected channel are programmed with the specified temperature level. If the module number is zero, all modules in the string are programmed. If the string number is zero, the selected module is programmed on all strings. If both numbers are zero, all modules within the array are programmed. Acceptable range is -100 to +100 °C.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context
  - If the selected channel is executing a profile
- 18,Missing pre-condition, cannot execute command
  - If the channel does not have an array assigned
- 19,Invalid channel
  - If the selected channel is hidden (group slaves)

### **SOURce#:ARRAy:MODULE#:STRing#:TEMPerature?**

Returns the temperature level for the selected channel and array module.

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 18,Missing pre-condition, cannot execute command
  - If the selected channel does not have an array assigned
- 19,Invalid channel
  - If the selected channel is hidden (group slaves)

## **SOURce#:ARRAy:MODULE#:STRing#:DIOde {YES|NO}**

The indicated array module(s) on the selected channel are programmed with the specified bypass diode option. If the module number is zero, all modules in the string are programmed. If the string number is zero, the selected module is programmed on all strings. If both numbers are zero, all modules within the array are programmed.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context
  - If the selected channel is executing a profile
- 18,Missing pre-condition, cannot execute command
  - If the channel does not have an array assigned
- 19,Invalid channel
  - If the selected channel is hidden (group slaves)

## **SOURce#:ARRAy:MODULE#:STRing#:DIOde?**

Returns the diode option state (YES or NO) for the selected channel and array module.

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 18,Missing pre-condition, cannot execute command
  - If the selected channel does not have an array assigned
- 19,Invalid channel
  - If the selected channel is hidden (group slaves)

## **SOURce#:ARRAy:MODULE#:STRing#:RESistance <resistance>**

The indicated array module(s) on the selected channel are programmed with the specified forward resistance. If the module number is zero, all modules in the string are programmed. If the string number is zero, the selected module is programmed on all strings. If both numbers are zero, all modules within the array are programmed.

Acceptable range is 0 to 100 kohms.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context
  - If the selected channel is executing a profile
- 18,Missing pre-condition, cannot execute command
  - If the channel does not have an array assigned
- 19,Invalid channel
  - If the selected channel is hidden (group slaves)

## **SOURce#:ARRAy:MODULE#:STRing#:RESistance?**

Returns the forward resistance for the selected channel and array module.

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 18,Missing pre-condition, cannot execute command
  - If the selected channel does not have an array assigned
- 19,Invalid channel
  - If the selected channel is hidden (group slaves)

## **SOURce#:ARRAy:EXECute**

The array is calculated and the resulting IV curve is executed on the selected channel.

### Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context
  - If the selected channel is executing a profile
- 18,Missing pre-condition, cannot execute command
  - If the channel does not have an array assigned
- 19,Invalid channel
  - If the selected channel is hidden (group slaves)

## **STATus subsystem**

### **STATus:OPERation:CONDition? [(@chanlist)]**

Returns the operating status of the selected channels. If the channel list is omitted, bit positions marked with X are reported for the system level status. For example, if one or more channels are executing a profile, bit 6 will be set. Multiple entries are separated by a comma.

<b>BIT POSITION</b>	<b>DECIMAL VALUE</b>	<b>SYST</b>	<b>DESCRIPTION</b>
0	1	X	Interlock or emergency switch active
1	2	X	Overvoltage protection tripped
2	4	X	Overtemperature protection active
3	8	X	Communication loss (offline)
4	16	X	Dead channel (offline when TerraSAS started)
5	32	X	Clipping (voltage or current exceeds maximum)
6	64	X	Profile execution is running
7	128		Profile execution is paused
8	256		Channel is a member of a parallel-wired group
9	512		Channel is a member of a series-wired group
10	1024	X	Datalogging in progress
11	2048	X	Triggered measurement in progress
12	4096		Future use
13	8192		Future use
14	16384		Future use
15	32768		Future use

#### Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

## **SENSe subsystem**

### **SENSe:DLOG:TINTerval <value>**

Sets the datalogging interval. Acceptable values are between 0.05 and 3600 seconds.  
Values are rounded to the nearest 0.05s multiple.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values

### **SENSe:DLOG:TINTerval?**

Returns the datalogging interval.

Possible errors:

- 1-12 Syntax and parameter mismatch errors

### **SENSe:DLOG:NAME <name>**

Sets the datalogging file name. If left blank, a name is automatically generated as follows:  
<Data log YYYY-MM-DD-HH-MM-SS-mmm>. The disk file is created and data logging  
will start when a trigger command is received. If the selected file name already exists on  
disk, its contents are replaced with the new data. After this command is executed,  
datalogging is placed into an "armed" condition that can only be triggered or aborted. No  
other changes are allowed.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context
  - If datalogging is already active or the datalogging file is already open
- 17,Invalid characters in name or file name

### **SENSe:DLOG:NAME?**

Returns the active datalog file name. If no open file exists, returns "D.0"

Possible errors:

- 1-12 Syntax and parameter mismatch errors

### **SENSe:DLOG:ENABLE [(@chanlist)]**

Enables datalogging on the selected channels.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context
  - If the log file is open or datalogging is active.
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

### **SENSe:DLOG:ENABLE? [(@chanlist)]**

Returns the datalogging state of the selected channels. Multiple entries are separated by a comma.

Possible errors:

1-12 Syntax and parameter mismatch errors  
15,Out of range in one or more numeric values  
19,Invalid channel

If one or more selected channels are hidden (group slaves)

### **SENSe:DLOG:DATA (numlist)**

Selects the data items that will be logged, according to the table below.

Parameter	Description
1	Time stamp
2	DC Voltage
3	DC Current
4	RMS Power
5	AC Voltage
6	AC Current
7	MPP Accuracy
8	Energy
9	MPP voltage
10	MPP current
11	MPP power

Possible errors:

1-12 Syntax and parameter mismatch errors  
15,Out of range in one or more numeric values  
16,Operation not allowed in this context

If the log file is open or datalogging is active.

Example:

SENS:DLOG:DATA (1:11) will log all parameters for each enabled channel  
SENS:DLOG:DATA (1,4) will log time stamp and rms power for each enabled channel

### **SENSe:DLOG:DATA?**

Returns the data items that are selected for datalogging.

Possible errors:

1-12 Syntax and parameter mismatch errors

Example:

SENS:DLOG:DATA (1:8)

SENS:DLOG:DATA?

1,2,3,4,5,6,7,8

If no parameter is selected, "0" is returned.

**SENSe:PROFile:SPeD <value> [,(@chanlist)]**

Sets the irradiance profile execution speed for the selected channels. Accepted range is 1 to 100.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context
  - If one or more selected channels are executing a profile
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**SENSe:PROFile:SPeD? [(@chanlist)]**

Returns the irradiance profile execution speed for the selected channels. Multiple entries are separated by a comma.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**SENSe:PROFile:LOOP {ON|OFF} [,(@chanlist)]**

Sets profile execution in loop mode on the selected channels. When the end of the profile is reached, execution restarts from the offset time index.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**SENSe:PROFile:LOOP? [(@chanlist)]**

Returns the loop mode state for the selected channels: ON if active, OFF if inactive. Multiple entries are separated by a comma.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**SENSe:AVERage {OFF|4|8|20|40|80|200|400} [,(@chanlist)]**

Sets the measurement averaging period for the selected channels, in milliseconds. Low voltage (80V) PV simulators are limited to 80ms, high voltage (600/1000V) accept the full range.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**SENSe:AVERage? [(@chanlist)]**

Returns the measurement averaging period for the selected channels. Multiple entries are separated by a comma.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

**SENSe:Pgain <value> [,(@chanlist)]**

Sets the proportional gain coefficient for the selected channels. Acceptable values are 0 to 0.9999.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

**SENSe:Pgain? [(@chanlist)]**

Returns the proportional gain coefficient for the selected channels. Multiple entries are separated by a comma.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

**SENSe:Pgain? [,(@chanlist)]**

Sets the integral gain coefficient for the selected channels. Acceptable values are 0 to 0.9999.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

**SENSe:Pgain? [(@chanlist)]**

Returns the integral gain coefficient for the selected channels. Multiple entries are separated by a comma.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

**SENSe:Dgain <value> [,(@chanlist)]**

Sets the derivative gain coefficient for the selected channels. Acceptable values are 0 to 0.9999.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

**SENSe:Dgain? [(@chanlist)]**

Returns the derivative gain coefficient for the selected channels. Multiple entries are separated by a comma.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

**SENSe:VPgain <value> [,(@chanlist)]**

Sets the proportional voltage gain coefficient for the selected channels. Acceptable values are 0 to 0.9999.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

**SENSe:VPgain? [(@chanlist)]**

Returns the proportional voltage gain coefficient for the selected channels. Multiple entries are separated by a comma.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

**SENSe:Vlgain <value> [,(@chanlist)]**

Sets the integral voltage gain coefficient for the selected channels. Acceptable values are 0 to 0.9999.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

**SENSe:V<sub>I</sub>gain? [(@chanlist)]**

Returns the integral voltage gain coefficient for the selected channels. Multiple entries are separated by a comma.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**SENSe:V<sub>D</sub>gain <value> [,(@chanlist)]**

Sets the derivative voltage gain coefficient for the selected channels. Acceptable values are 0 to 0.9999.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**SENSe:V<sub>D</sub>gain? [(@chanlist)]**

Returns the derivative voltage gain coefficient for the selected channels. Multiple entries are separated by a comma.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**SENSe:MODe {PS|PV} [,(@chanlist)]**

Sets the operating mode of the selected channels. PS sets the channel in power supply mode (voltage and current programming), PV sets the channel in photovoltaic simulation mode (irradiance and temperature programming).

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**SENSe:MODe? [(@chanlist)]**

Returns the operating mode of the selected channels, formatted as {PS|PV}. Multiple entries are separated by a comma.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

**SENSe:INLimiter {ON|OFF} [,(@chanlist)]**

Enables or disables the inrush limiter option. If this optional module is not installed on the PV simulator, this command has no effect.

**Possible errors:**

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

**SENSe:INLimiter? [(@chanlist)]**

Returns the status of the inrush limiter option of the selected channels, formatted as {ON|OFF}. Multiple entries are separated by a comma.

**Possible errors:**

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

**SENSe:ILEnergy <energy> [,(@chanlist)]**

Sets the energy threshold of the inrush limiter option. If this optional module is not installed on the PV simulator, this command has no effect.

**Possible errors:**

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

**SENSe:ILEnergy? [(@chanlist)]**

Returns the status of the inrush limiter option of the selected channels, formatted as {ON|OFF}. Multiple entries are separated by a comma.

**Possible errors:**

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

**SENSe:Dislope {ON|OFF} [,(@chanlist)]**

Disables the 1-second linear interpolation slope during profiles execution.

**Possible errors:**

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

**SENSe:Dislope? [(@chanlist)]**

Returns the status of the profile interpolation feature, formatted as {ON|OFF}. Multiple entries are separated by a comma.

**Possible errors:**

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

**SENSe:MPPTRecovery:CURVe <name>**

Sets the curve name to be used for the maximum power point recovery time measurement. Name validation performed at the time the measurement is started (see TRIGger:MPPTRecovery[:IMMEDIATE] command). This command does not load the curve file from disk.

**Possible errors:**

- 1-12 Syntax and parameter mismatch errors
- 16,Operation not allowed in this context

If the measurement is already in progress

**SENSe:MPPTRecovery:CURVe?**

Returns the curve name to be used for the maximum power point recovery time measurement.

**Possible errors:**

- 1-12 Syntax and parameter mismatch errors

**SENSe:MPPTRecovery:PROFle <name>**

Sets the profile name to be used for the maximum power point recovery time measurement. Name validation performed at the time the measurement is started (see TRIGger:MPPTRecovery[:IMMEDIATE] command). This command does not load the profile file from disk.

**Possible errors:**

- 1-12 Syntax and parameter mismatch errors
- 16,Operation not allowed in this context

If the measurement is already in progress

**SENSe:MPPTRecovery:PROFle?**

Returns the profile name to be used for the maximum power point recovery time measurement.

**Possible errors:**

- 1-12 Syntax and parameter mismatch errors

### **SENSe:MPPTRecovery:TRIGger <leading edge>,<trailing edge>**

Sets the trigger point for leading and trailing edge measurements, referred to the irradiance profile timing scale. Acceptable values are 0 to 100,000. Additional validation performed at the time the measurement is started (see TRIGger:MPPTRecovery[:IMMEDIATE] command)

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context

If the measurement is already in progress

### **SENSe:MPPTRecovery:TRIGger?**

Returns the trigger point for leading and trailing edge measurements, referred to the irradiance profile timing scale

Possible errors:

- 1-12 Syntax and parameter mismatch errors

### **SENSe:MPPTRecovery:MAXimum <leading edge>,<trailing edge>**

Sets the maximum recovery time expected for leading and trailing edge measurements. Acceptable values are 0 to 100,000. Additional validation performed at the time the measurement is started (see TRIGger:MPPTRecovery[:IMMEDIATE] command)

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context

If the measurement is already in progress

### **SENSe:MPPTRecovery:MAXimum?**

Returns the maximum recovery time expected for leading and trailing edge measurements

Possible errors:

- 1-12 Syntax and parameter mismatch errors

### **SENSe:MPPTRecovery:VALue <leading edge>,<trailing edge>**

Sets the desired MPP accuracy after recovery for leading and trailing edge measurements. Acceptable values are 50 to 100.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context

If the measurement is already in progress

**SENSe:MPPTRecovery:VALue?**

Returns the desired MPP accuracy after recovery for leading and trailing edge measurements

Possible errors:

1-12 Syntax and parameter mismatch errors

**SENSe:MPPTRecovery:TOlerance <leading edge>,<trailing edge>**

Sets the desired MPP accuracy tolerance after recovery for leading and trailing edge measurements. Acceptable values are 0.1 to 20.

Possible errors:

1-12 Syntax and parameter mismatch errors

15,Out of range in one or more numeric values

16,Operation not allowed in this context

If the measurement is already in progress

**SENSe:MPPTRecovery:TOlerance?**

Returns the desired MPP accuracy tolerance after recovery for leading and trailing edge measurements.

Possible errors:

1-12 Syntax and parameter mismatch errors

**SENSe:MPPTRecovery:ENABLE [(@chanlist)]**

Enables maximum power point recovery time measurement on the selected channels.

Possible errors:

1-12 Syntax and parameter mismatch errors

15,Out of range in one or more numeric values

16,Operation not allowed in this context

If the measurement is already in progress or any channels are executing a profile

19,Invalid channel

If one or more selected channels are hidden (group slaves)

**SENSe:MPPTRecovery:ENABLE? [(@chanlist)]**

Returns the maximum power point recovery time measurement state of the selected channels. Multiple entries are separated by a comma.

Possible errors:

1-12 Syntax and parameter mismatch errors

15,Out of range in one or more numeric values

19,Invalid channel

If one or more selected channels are hidden (group slaves)

**SENSe:ENERgy:RESET [(@chanlist)]**

Resets the energy reading of each selected channel.

**Possible errors:**

1-12 Syntax and parameter mismatch errors

15,Out of range in one or more numeric values

19,Invalid channel

If one or more selected channels are hidden (group slaves)

## **MEASure subsystem**

### **MEASure[:SCALar]:CURRent[:DC]? [(@chanlist)]**

Returns the average DC current present on the selected channels. Multiple entries are separated by a comma.

Possible errors:

1-12 Syntax and parameter mismatch errors  
15,Out of range in one or more numeric values  
19,Invalid channel

If one or more selected channels are hidden (group slaves)

### **MEASure[:SCALar]:CURRent:AC? [(@chanlist)]**

Returns the peak-to-peak AC current component present on the selected channels. Multiple entries are separated by a comma.

Possible errors:

1-12 Syntax and parameter mismatch errors  
15,Out of range in one or more numeric values  
19,Invalid channel

If one or more selected channels are hidden (group slaves)

### **MEASure[:SCALar]:VOLTage[:DC]? [(@chanlist)]**

Returns the average DC voltage present on the selected channels. Multiple entries are separated by a comma.

Possible errors:

1-12 Syntax and parameter mismatch errors  
15,Out of range in one or more numeric values  
19,Invalid channel

If one or more selected channels are hidden (group slaves)

### **MEASure[:SCALar]:VOLTage:AC? [(@chanlist)]**

Returns the peak-to-peak AC voltage component present on the selected channels. Multiple entries are separated by a comma.

Possible errors:

1-12 Syntax and parameter mismatch errors  
15,Out of range in one or more numeric values  
19,Invalid channel

If one or more selected channels are hidden (group slaves)

### **MEASure[:SCALar]:POWER[:DC]? [(@chanlist)]**

Returns the True RMS power delivered by the selected channels. Multiple entries are separated by a comma.

Possible errors:

1-12 Syntax and parameter mismatch errors  
15,Out of range in one or more numeric values  
19,Invalid channel

If one or more selected channels are hidden (group slaves)

### **MEASure[:SCALar]:MPPaccuracy? [(@chanlist)]**

Returns the Maximum Power Point tracking accuracy, expressed as the ratio between the True RMS power and the Maximum Power Point, in percent value. Multiple entries are separated by a comma.

#### Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

### **MEASure[:SCALar]:MPPTRecovery?**

Returns the last measured MPPT recovery time on all enabled channels in the format: <leading chan a>,<trailing chan a>,<leading chan b>,< trailing chan b>,...,<leading channel n>,< trailing chan n>. All values are in seconds.

#### Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 18,Missing pre-condition, cannot execute command

If one or more channels did not complete the measurement cycle

### **MEASure[:SCALar]:ENERgy[:DC]? [(@chanlist)]**

Returns the energy delivered by each selected channel since the last reset, in kWh.

See command SENSe:ENERgy:RESet [(@chanlist)] to reset the reading.

Multiple entries are separated by a comma.

#### Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

## ***TRIGger subsystem***

### **TRIGger:DLOG[:IMMEDIATE]**

Starts datalogging on all previously enabled channels.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 16,Operation not allowed in this context
  - If datalogging is already active
- 18,Missing pre-condition, cannot execute command
  - If the log file is not open

### **TRIGger[:TRANSient][:IMMEDIATE] [(@chanlist)]**

Starts executing a profile on the selected channels.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 18,Missing pre-condition, cannot execute command
  - If one or more selected channels do not have a profile assigned
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

### **TRIGger[:TRANSient][:IMMEDIATE]:PAUSE [(@chanlist)]**

Pauses profile execution on the selected channels.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context
  - If one or more channels in the list are **not** executing a profile
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

### **TRIGger[:TRANSient][:IMMEDIATE]:RESET [(@chanlist)]**

Resets profile execution on the selected channels to the offset time index.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context
  - If one or more channels in the list are executing a profile
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

## **TRIGger:MPPTRecovery[:IMMEDIATE]**

Starts the maximum power point recovery time measurement on all previously enabled channels. The measurement is actually started only after all previously entered parameters are validated.

### Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 13,File name or name not found
  - Curve or profile names were not found
- 15,Out of range in one or more numeric values
  - Leading or trailing trigger positions fall outside the profile time span
  - Leading or trailing trigger positions added to the maximum recovery time fall outside the profile time span
- 16,Operation not allowed in this context
  - One or more selected channels are executing a profile
- 18,Missing pre-condition, cannot execute command
  - No channels were selected for measurement
- 19,Invalid channel
  - If one or more selected channels are dead.

## **ABORt commands**

### **ABORt:DLOG**

Stops datalogging on all channels and closes the disk file.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 13,File name or name not found
  - An error occurred when closing the log file.
- 16,Operation not allowed in this context
  - If the log file is not open

### **ABORt[:TRANsient] [(@chanlist)]**

Stops execution of the irradiance profile on the selected channels

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 16,Operation not allowed in this context
  - One or more selected channels are **not** executing a profile
- 19,Invalid channel
  - If one or more selected channels are hidden (group slaves)

### **ABORt:MPPTRecovery**

Stops the maximum power point recovery time measurement.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 18,Missing pre-condition, cannot execute command
  - If the triggered measurement is not running

## **OUTPut subsystem**

### **OUTPut[:STATe] {ON|OFF} [,(@chanlist)]**

Turns on or off the output on the selected channels

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

### **OUTPut[:STATe]? [,(@chanlist)]**

Returns the output state of the selected channels. Multiple entries are separated by a comma.

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

### **OUTPut:PROTection:CLEar [(@chanlist)]**

Resets the overvoltage or overcurrent protection latch on the selected channels

Possible errors:

- 1-12 Syntax and parameter mismatch errors
- 15,Out of range in one or more numeric values
- 19,Invalid channel

If one or more selected channels are hidden (group slaves)

## Units of Measure

### Units of Measure

#### Volts

"NV"	NanoVolt
"UV"	MicroVolt
"MV"	MilliVolt
"V"	Volt
"KV"	KiloVolt
"MAV"	MegaVolt

#### Amperes

"NA"	NanoAmp
"UA"	MicroAmp
"MA"	MilliAmp
"A"	Amp

#### Ohms

"UR"	MicroOhm
"UOHM"	MicroOhm
"R"	Ohm
"OHM"	Ohm
"KR"	KiloOhm
"KOHM"	KiloOhm
"MR"	MegaOhm
"MAR"	MegaOhm
"MOHM"	MegaOhm
"MAOHM"	MegaOhm
"GR"	GigaOhm
"GOHM"	GigaOhm

(Note: no MilliOhms in SCPI - see MegaOhm)

(in SCPI, MR=MAR=MegaOhm)

#### Watts

"NW"	NanoWatt
"UW"	MicroWatt
"MW"	MilliWatt
"W"	Watt
"KW"	KiloWatt
"MAW"	MegaWatt
"GW"	GigaWatt

#### Decibel Watts

"DBNW"	Decibel NanoWatt
"DBUW"	Decibel MicroWatt
"DBM"	Decibel MilliWatt
"DBMW"	Decibel MilliWatt
"DBW"	Decibel Watt

#### Joules

"UJ"	MicroJoule
"MJ"	MilliJoule
"J"	Joule
"KJ"	KiloJoule

#### Farads

"PF"	PicoFarad
"NF"	NanoFarad
"UF"	MicroFarad
"MF"	MilliFarad
"F"	Farad

**Henrys**

"UH"	MicroHenry
"MH"	MilliHenry
"H"	Henry

**Hertz**

"HZ"	Hertz
"KHZ"	KiloHertz
"MHZ"	MegaHertz
"MAHZ"	MegaHertz
"GHZ"	GigaHertz

(in SCPI, MHZ=MAHZ=MegaHertz)

**Seconds**

"PS"	PicoSecond
"NS"	NanoSecond
"US"	MicroSecond
"MS"	MilliSecond
"S"	Second

**Temperature**

"K"	Degree Kelvin
"CEL"	Degree Celsius
"FAR"	Degree Fahrenheit

# **SCPI Language Tutorial**



# Appendix A – An Introduction to SCPI

## A.1 Benefits of SCPI

The SCPI Standard was defined in order to provide a consistent command language for all types of remotely programmable instruments. In doing so, SCPI aims to reduce significantly the learning curve required by a technician to be able to program a particular instrument.

In addition, SCPI defines specific ‘core’ command sets for some types of instrument, such as digital meters, signal switchers, etc. By defining a set of commands that must be supported by certain types of equipment, it means that equipment from different manufacturers should be almost interchangeable in an ATE system, for instance.

As well as saving time for the customer’s technicians to learn to control a new piece of equipment, SCPI also has benefits for the instrument manufacturer too. It provides a framework for defining the command set of an instrument and therefore saves time designing a proprietary command structure and syntax. It may also save time supporting the instrument, since many technicians are now familiar with SCPI and so will be able to grasp the command syntax straight away.

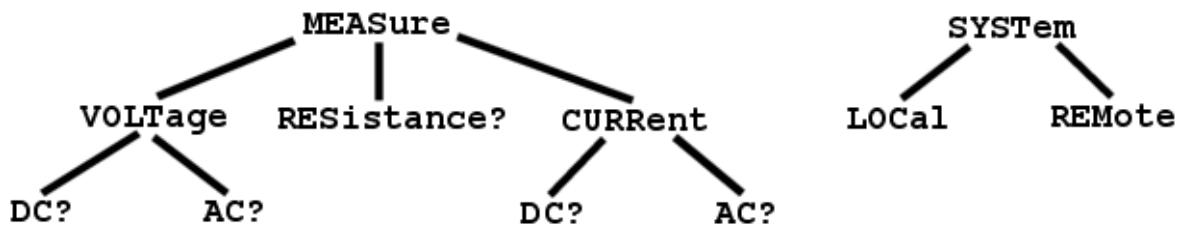
In practice, many manufacturers choose to support a *SCPI-like* interface, rather than implementing all of the features required by SCPI to claim SCPI compliancy. This is a valid approach, since the look-and-feel of SCPI will again reduce the technician’s time spent learning the instrument. Either approach, SCPI-like or full SCPI compliancy, is possible using JPA-SCPI Parser.

## A.2 Background to SCPI

SCPI was developed, and is still being expanded, by the SCPI Consortium (<http://www.scpicconsortium.org>). It uses another standard IEEE488.2 as its basis, except that SCPI is usable whatever the physical interface used (e.g. GPIB, RS232, USB, etc.), whereas IEEE488.2 only applies to the GPIB (IEEE488.1) interface.

## A.3 Command Structure

SCPI commands are hierarchical, being based on a *tree system*, for example:



The *nodes* of the tree represent *command keywords*, e.g. **MEASure**, **VOLtage**, **DC?**, **RESistance**.

At the top of the trees are the *root nodes*, i.e. **MEASure** and **SYSTEM**. Under each root node is what is known as a *subsystem*.

A command is formed by traversing the tree from a root node downwards until a node is reached with no further nodes below it.

Instead of drawing command trees, SCPI uses a *notation* to represent command specifications. When writing a command, the root node is written first, followed by the keywords on the lower levels. Colons (:) are used to separate keywords on different levels of the tree. For example:

```
MEASure:VOLTage:DC?
```

or:

```
SYSTem:LOCAL
```

In addition, SCPI notation represents the levels of the tree by the horizontal indentation of the keywords. The root node is in the leftmost position and so on. The commands represented by the diagram above would be written as:

```
MEASure
  :VOLTage
    :DC?
    :AC?
  :RESistance?
  :CURRent
    :DC?
    :AC?

SYSTem
  :LOCAL
  :REMote
```

### A.3.1 Long and Short Form Keywords

You will see that many of the keywords above have upper and lowercase letters. This system is used to represent the *long form* and *short form* of each keyword. The long form of the keyword comprises all the characters of the keyword. The short form is made up of just the characters in uppercase.

For instance, for **MEASure** above:

- Long Form is **MEASURE**
- Short Form is **MEAS**

Usually, the short form of a keyword comprises the first four letters. However, if the fourth letter is a vowel, then the short form normally only uses the first 3 letters (e.g. **CALibration**).

Commands sent to a SCPI instrument can include any combination of long and short form keywords. For the command set above, all of these commands are valid:

```
MEASURE:VOLTAGE:DC?
```

```
MEAS:VOLT:DC?
```

```
MEASURE:VOLT:DC?
```

```
MEAS:VOLTAGE:DC?
```

Note, that commands sent to a SCPI instrument are case-insensitive, for example, all of these are also valid commands:

```
Meas:Volt:DC?  
measure:Voltage:dc?
```

By convention, however, example SCPI commands are usually shown in uppercase form. This is what we use in this manual.

### A.3.2 Query Commands

Any SCPI commands that expect data to be sent back over the remote interface are termed *query commands*. Such commands might request the voltage reading from a digital voltmeter, or request the identity of the instrument.

All query commands end in a question mark. In the command set above, query commands include:

```
MEASure:VOLTage:DC?  
MEASure:RESistance?  
etc.
```

### A.3.3 Default Keywords

To shorten command entry, SCPI allows the use of *default keywords* (also known as *default nodes*). These are keywords that can be left out of commands without affecting the meaning of the command.

Default keywords are shown in command specifications by enclosing them in square brackets. For example, the keywords of a command specification might be:

```
APPLy:[SOURce:]CURRent[:LEVEL[:IMMEDIATE]:AMPLitude
```

In this case, valid forms of the command include:

```
APPLY:SOURCE:CURRENT:LEVEL:IMMEDIATE:AMPLITUDE  
APP:CURR:AMPL  
APP:CURRENT:LEV:AMPLITUDE  
etc.
```

Notice how a colon can be included within the square brackets, in order that all possible command constructs will contain keywords separated by a single colon.

### A.3.4 Numeric Suffixes

An instrument may have more than one outputs, trigger sources, etc. In order to specify which of these channels a command is referring to, a numeric suffix can be added to the command. For instance, a command to set the voltage range on a multi-channel oscilloscope might be specified as:

```
[SENSe:]VOLTage[:DC]<channel#>:RANGE {<voltage>|MIN|MAX}
```

To set channel 1 to 200mV range, the user might enter this command as:

```
VOLT1:RANG 200MV
```

To set channel 2 to 10V range, the user could enter this command:

```
SENS:VOLT2:RANG 10V
```

In addition, if the user does not enter a numeric suffix, then the value 1 is assumed. So in this case, these two commands are equivalent, both setting channel 1 to the 2V range:

`VOLT1:DC:RANG 2V`

`VOLT:DC:RANG 2V`

Note, a command may have more than one numeric suffix. For example, this command might be used to set the 2nd FM signal component of the 3rd output channel:

`OUTP3:FM2`

### A.3.5 Compound Commands

It is possible to send compound commands to a SCPI instrument. Commands are separated within a command line by a semi-colon (;). For example:

`MEAS:VOLT:DC?;AC?`

Note that the second command is not the full command but rather it uses the command tree that was reached by the command before it. This shorthand is used by SCPI to reduce the length of command lines.

If you need to use a command higher up the tree, then the second command must be prefixed by a colon (:). This has the effect of resetting the command tree to the root. The next command must therefore be in its full form, for example:

`MEAS:VOLT:DC?;:MEAS:CURR:DC?`

or:

`MEAS:VOLT:DC?;:SYST:LOC`

### A.3.6 IEEE488.2 Common Commands

SCPI-compliant instruments must support a small set of *IEEE488.2 common commands* defined in the IEEE488.2 standard. These include:

`*RST`

`*CLS`

IEEE488.2 common commands are used to reset the device, query its status registers, reset the interface etc. For more information on these commands, refer to the SCPI Standard and/or the IEEE488.2 Standard.

### A.3.7 Parameters

Many commands take one or more parameters in order to provide the instrument with more information, for example, the voltage level to set on a programmable power supply, or the resolution to use on a digital resistance meter.

Parameters appear after the command keywords, separated from the keywords by a space (no spaces are allowed within the command keywords).

If more than one parameter is allowed by the command, each parameter is separated by a comma.

For example, a command might be sent as:

`MEAS:VOLT? 1KV, 10MV`

This would take a measurement from a digital voltmeter using a range of 1 kilovolts, and with a resolution of 10 millivolts. The parameters are `1KV` and `10MV`.

## A.3.8 Types of Parameter

The different types of parameter allowed are:

### A.3.8.1 Numeric Value

This is a number with or without units. It could represent a voltage, a frequency, a count – anything that can be represented numerically.

Numeric Values can also include units after the number. These are usually optional.

In the example above, both `1KV` and `10MV` are Numeric Values.

#### A.3.8.1.1 Number Bases

SCPI allows Numeric Values to be entered in some number bases other than decimal: binary, octal and hexadecimal.

When entering a number in one of these other bases, the number must be prefixed to indicate the base.

Base	Prefix	Example
Binary	#B	#B11001010 = 202 <sub>10</sub>
Octal	#Q	#Q107 = 71 <sub>10</sub>
Hexadecimal	#H	#H10FF = 4351 <sub>10</sub>

Note: Negative and real (non-integer) numbers are only allowable in decimal.

### A.3.8.2 Boolean

Sometimes, a parameter is required to set a state to on or off, e.g. auto-ranging on a digital meter can either be on or off. Parameters that just require two states are known as *Booleans*. Boolean parameters can be entered in a number of ways:

```
ON  
OFF  
1           // same as entering ON  
0           // same as entering OFF
```

In addition, SCPI allows entry of a number where a Boolean parameter is permitted. The number is converted to `ON` (1) or `OFF` (0) according to these rules:

- The sign of the number is ignored
- The number is rounded to the nearest integer, where .5 and above is rounded upwards
- If the resulting number is zero, the Boolean parameter is `OFF` (0). Otherwise the Boolean parameter is `ON` (1).

Boolean parameters can be specified with a *default value*, i.e. if the parameter is not entered it is equivalent to the parameter being entered with the default value. In SCPI notation, default values are shown in bold type (or you can use underline if bold type is not available). For example:

```
{ON|OFF}
```

Here, the default value is `ON`.

### A.3.8.3 Character Data

SCPI also allows mnemonics to be entered as parameters. These are called *Character Data* parameters. For example, the command specification:

```
TRIGger:SOURce {BUS|IMMEDIATE|EXTernal}
```

The possible values of the Character Data parameter are: **BUS**, **IMM**, **IMMEDIATE**, **EXT** or **EXTERNAL**.

In addition, Character Data choices are often combined with another type of parameter, e.g. a Numeric Value or Boolean parameter.

For example, the specification of a command to set the resistance range of an ohmmeter might be:

```
SENSe:RESistance:RANGe {<range>|MINimum|MAXimum}
```

This command allows entries such as:

```
SENS:RES:RANG 1000  
SENS:RES:RANG 1GOHM  
SENS:RES:RANG MAX  
SENS:RES:RANG MINIMUM
```

As with Boolean parameters, Character Data parameters can have a default value. For example:

```
{BUS|IMMEDIATE|EXTernal}
```

Here, **IMMEDIATE** is the default value used if the parameter is not entered.

### A.3.8.4 String

Occasionally, an instrument may wish to accept a parameter made up of a string of characters. For example, a command to display a text message on the instrument's readout.

Strings in SCPI must be delimited by quotes (either double or single). For instance, a command specification such as:

```
DISPlay:TEXT <message string>
```

would accept commands such as:

```
DISP:TEXT "hello world"
```

```
DISP:TEXT 'Set function to "Volts".'
```

In addition, JPA-SCPI Parser also supports a type we call *Unquoted Strings*. These function exactly the same as normal strings except that they do not require quotes to delimit them. Instead they are delimited by the commas (if any) that surround any parameter.

Unquoted Strings are useful for entry of passwords, for instance, to allow access to calibration factors or maintenance functions.

For example, the command specification:

```
CALibration:SECure:CODE <code>
```

would accept entries such as:

```
CAL:SEC:CODE ABC123
```

### A.3.8.5 Expression

SCPI defines various other types of parameter as expressions. These types include:

- Numeric Expressions, e.g. (15\*5+4)
- Numeric Lists, e.g. (1,2,3:7,9)
- Channel Lists, e.g. (@1!3,2!4:5!5)
- DIF (Data Interchange Format) Expressions

All these types of expression start with an opening bracket ('(' and end with a closing bracket (')).

Support for expressions is optional in SCPI. In fact most instrument do not support them. DIF, for instance, is used for transferring large amounts of data from an instrument to a computer, so is useful for logging instruments etc.

Numeric Lists and Channel Lists are amongst the most useful of the expressions, and these are explained further below.

### A.3.8.6 Numeric List

A numeric list is used to allow entry of a variable number of numeric values and ranges of numeric values.

The format of a numeric list is:

`(<entry>[,<entry>[,<entry>....]]])`

where `<entry>` has the format:

`<numeric value>|<numeric value>:<numeric value>`

Ranges are indicated by the first number in the range and last number in the range separated by a colon (:).

For example, a numeric list could be:

`(5,7:17,20.5)`

This numeric list has 3 entries: the value 5, the range 7 through to 17, and the value 20.5.

Note, the order of entries in a numeric list does not matter – there is no order implied by the ordering of the entries in the numeric list.

### A.3.8.7 Channel List

A channel list is used to specify a set of electrical ports on an instrument. The most common use is for specifying signal routing and switching.

The format of a channel list is:

`(@<entry>[,<entry>[,<entry>....]]])`

where `<entry>` has the format:

`<channel spec>|<channel spec>:<channel spec>`

Ranges are indicated by the first number in the range and last number in the range separated by a colon (:).

In addition to allowing ranges of values just like numerical lists, channel list entries can have more than one dimension. A two dimensional entry comprises the value of the first dimension followed by a '!' symbol followed by the value of the second dimension.

The specification for `<channel spec>` is:

`<numeric value>[!<numeric value>[!<numeric value>....]]]`

For example, a channel spec could be:

3

or 5!6

or 4!7!9

The number of ! symbols is one less than the number of dimensions, so the last example above has 3 dimensions.

Dimensions are useful for representing a matrix of switches, for example. Say you have 10 rows and 12 columns of switches. The 1st dimension represents the row number and the 2nd dimension represents the column number:

Row	Column											
	1	2	3	4	5	6	7	8	9	10	11	12
1	1!1	1!2	1!3	1!4	1!5	1!6	1!7	1!8	1!9	1!10	1!11	1!12
2	2!1	2!2	2!3	2!4	2!5	2!6	2!7	2!8	2!9	2!10	2!11	2!12
3	3!1	3!2	3!3	3!4	3!5	3!6	3!7	3!8	3!9	3!10	3!11	3!12
4	4!1	4!2	4!3	4!4	4!5	4!6	4!7	4!8	4!9	4!10	4!11	4!12
5	5!1	5!2	5!3	5!4	5!5	5!6	5!7	5!8	5!9	5!10	5!11	5!12
6	6!1	6!2	6!3	6!4	6!5	6!6	6!7	6!8	6!9	6!10	6!11	6!12
7	7!1	7!2	7!3	7!4	7!5	7!6	7!7	7!8	7!9	7!10	7!11	7!12
8	8!1	8!2	8!3	8!4	8!5	8!6	8!7	8!8	8!9	8!10	8!11	8!12
9	9!1	9!2	9!3	9!4	9!5	9!6	9!7	9!8	9!9	9!10	9!11	9!12
10	10!1	10!2	10!3	10!4	10!5	10!6	10!7	10!8	10!9	10!10	10!11	10!12

A channel list to specify the switch at row 2, column 3 and row 9, column 11 would be:

(@2!3,9!11)

As mentioned above you can also specify ranges in a channel list. For a single dimensional channel list, this is exactly the same as a numeric list, e.g. for the range 5 through to 11, then channel list would be:

(@5:11)

But what happens when you want to specify a range of values in a 2 dimensional, or multi-dimensional channel list?

For instance, say we wanted to specify the switches in the table below that are shown with the grey background. We pick the first element in the group (3!3) and the last element (7!11) and separate them with a colon (:), i.e.:

3!3:7!11

This tells the instrument to operate on all the switches in the area marked. Not only that, but the order of operation is also implied by the order of the values in the range. In that example it means start at 3!3, then 3!4 and so on until 3!11. Now continue with 4!3 through to 4!11, and so on until 7!3 through to 7!11.

If we wanted to operate in reverse order then we would simply reverse the order of the numbers, i.e.:

7!11:3!3

Unlike a numeric list, the order of operation with entries in a channel list is implied by the order of the entries. For example:

`(@1!3,2!5:3!1,4!4)`

means operate in the following order:

`1!3, 2!5, 2!4, 2!3, 2!2, 2!1, 3!5, 3!4, 3!3, 3!2, 3!1, 4!4`

As well as numeric entries, SCPI allows channel lists to include alphanumeric entries such as module specifiers and path names. These are not very common in use and are beyond the scope of this introduction to SCPI. You may wish to refer to the SCPI Standard for more information.