TerraSAS Proposal

To satisfy

PV Simulator for Micro Inverter Testing

for

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Background

Company Overview

AMETEK Programmable Power, formerly Elgar Electronics Corporation and California Instruments, is comprised of the Elgar, California Instruments, Sorensen and Power Ten brands and is located and headquartered in San Diego, California, with over 360 employees. Within three facilities totaling more than 115,000 square feet (13,000 square meters), all equipment produced by the Programmable Power Division is designed and most are manufactured in our San Diego facilities.

Elgar and California Instruments Brand AC Sources

Since their beginning in the mid-sixties, Elgar and California Instrument's products have been used around the world in a variety of Test & Measurement applications. These programmable AC power sources are designed to meet a wide variety of commercial, industrial and military power requirements and have earned the company a reputation for quality and reliability in programmable power related products.

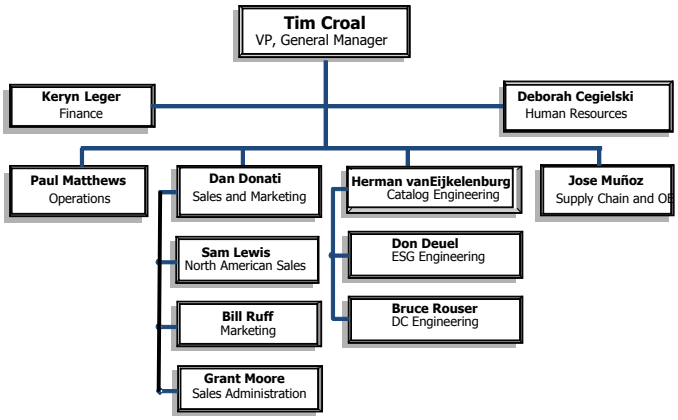
Sorensen and Power Ten Brand Hi Power DC Sources

Sorensen has been a leading manufacturer of high quality power supplies since 1946 and specializes in providing programmable DC power systems for a variety of OEM and test and measurement applications. Power Ten provides bulk power products into the Process Control and Test and Measurement markets.

Engineered Solutions

AMETEK Programmable Power's Engineered Solutions Group (ESG) provides product customization to meet specific customer requirements. The solutions range from modified catalog power supplies to turnkey integrated system solutions like solar array and battery simulators for ground-based satellite testing. In fact, ESG has been selected to supply solar array simulators systems on more satellite programs than any other company worldwide. ESG is especially skilled at providing custom solutions using existing technology and previously developed integration solutions. This approach provides maximum functionality, short lead times and maximum value.

Management Team



AMETEK Programmable Power's management team is responsible for the company's operations and in certain areas has dedicated focus activities, such as the Engineered Solutions Group. The organization chart shown represents the Senior Management of the company.

The nature of the Engineered Solutions business involves a high degree project management involvement with dedicated program management support reporting to the Senior Director of Engineered Solutions. With regard to this project, a Program Manager and Project Engineer and will be responsible for all technical and operational items from contract release to installation.

Design and Procurement

As quoted, this solution is a predominantly a "standard" integration and therefore requires little additional extraordinary design activities. Due to the fact that AMETEK uses common components and subassemblies throughout the Engineered Solutions operations, we have already established a qualified supplier base and constantly work with this select proven base to establish the best value to our customers.

Manufacturing, Assembly and Acceptance Test

AMETEK Programmable Power has invested in the expansion of our Engineered Solutions production facilities to handle the rapid growth of this segment of our business. The final integration and test area is 2080 ft (193 m^2) and can accommodate at least 5 to 10 systems a month depending on the size and type. Other workspace will be made available to facilitate the efficient execution of the contract. A specially trained team from production operations performs production assembly and test of all Engineered Solutions.

Each system will undergo an extensive acceptance test. This acceptance test procedure will be provided.

Documentation and Configuration management

Each solution is uniquely configured to meet the customer's application. The configuration has been established via technical interchange between the customer and AMETEK Programmable Power and is described in this quotation. Each system is identified with a top-level part number and will be under configuration control at AMETEK Programmable Power. Any subsequent change to the configuration of this system will require an Engineering Change. This protects the customer by assuring that any future systems are fabricated identically to the previous delivery.

Additionally, each system will ship with an operator's manual and a top level drawing package.

Quality System

The administrative infrastructure of Ametek's Quality Assurance Program fully complies with the requirements of MIL-I-45208A that supports high end military, commercial/industrial and space systems requirements. The Quality Assurance Program also is in full compliance with the Code of Federal Regulations, Title 10, Part 50, Appendix B as applies to field service, spares, repair and technical support for ELGAR equipment which was qualified for Class 1E applications in Nuclear Steam Power Electric Generating

Power Stations located domestically and abroad. These core administrative programs coupled with state-of-the-art design, manufacturing technology, such as Demand Flow Technology (DFT), workmanship standards, such as IPC 610, and process controls yield a highly efficient Program that is tailored to meet evolving requirements.

MIL-I-45208A had attained wide acceptance, for both military and commercial programs, over the course of several decades of use. While DoD restricts invoking such standards on new contracts, many military specifications and standards remain viable instruments for commercial use where they have been successfully in place and tailored to compliment more dynamically evolving engineering and manufacturing technologies.

NASA 2005 Quality Award

TerraSAS Technical Approach

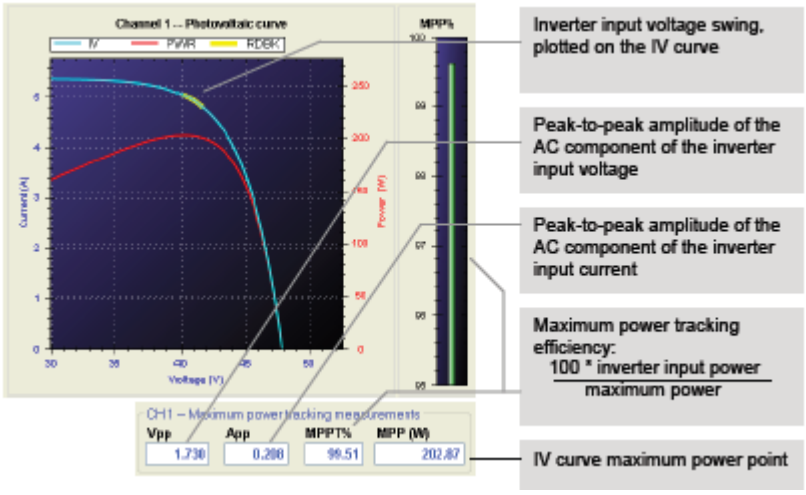
Introduction

The power services we are offering support the test and simulation of a terrestrial solar inverter application. As we understand the requirements, this power simulator will be providing DC stimulus to a micro inverter under test.

System Overview

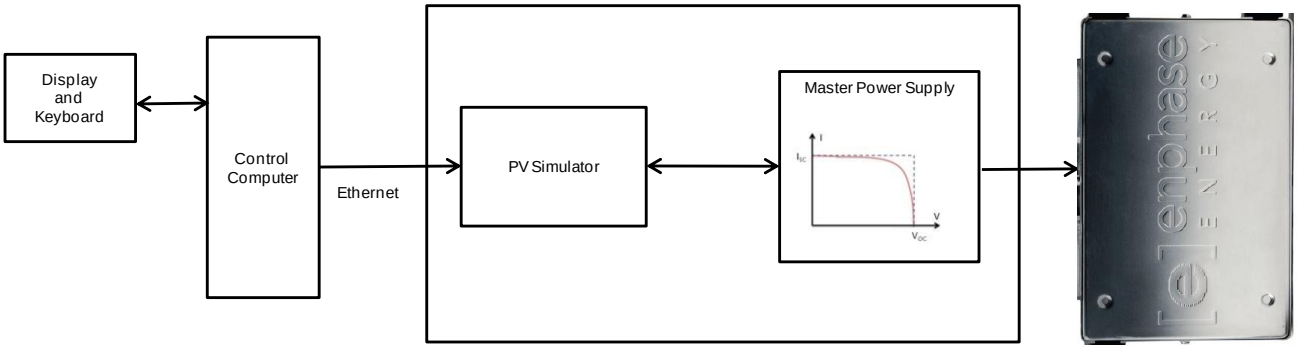
The photo shows a 24 channel TerraSAS consisting of a rack mounted control computer with control software and PV simulation engine that controls each programmable DC power supply. The TerraSAS is a fully integrated system that can simulate an IV curve with programmable open circuit voltage, Voc, and short circuit current Isc, as required for a wide variety of inverters. The system software also allows the user to change the array fill factor by programming the peak power points, Vmpp and Impp to simulate different solar cell characteristics. This combination of hardware allows the TerraSAS to simulate most test protocols and events that a solar installation will be subjected to. The TerraSAS also allows the user to program the following parameters; irradiance level, temperature value, temperature coefficient, and simulation time to ramp the voltage, temperature or irradiance level.
The TerraSAS control computer runs a Windows 7 operating system. Hardware control is accomplished by an application that communicates directly to the PV simulators using Ethernet, which operate as dedicated IV curve generation processors. The local Graphical User Interface (GUI) is accomplished via another application that provides all of the user controls to the TerraSAS system. Imbedded in the application is the Ethernet parser for remote communication and control. All of the functions available locally through the control computer are also available remotely.

TerraSAS Operation

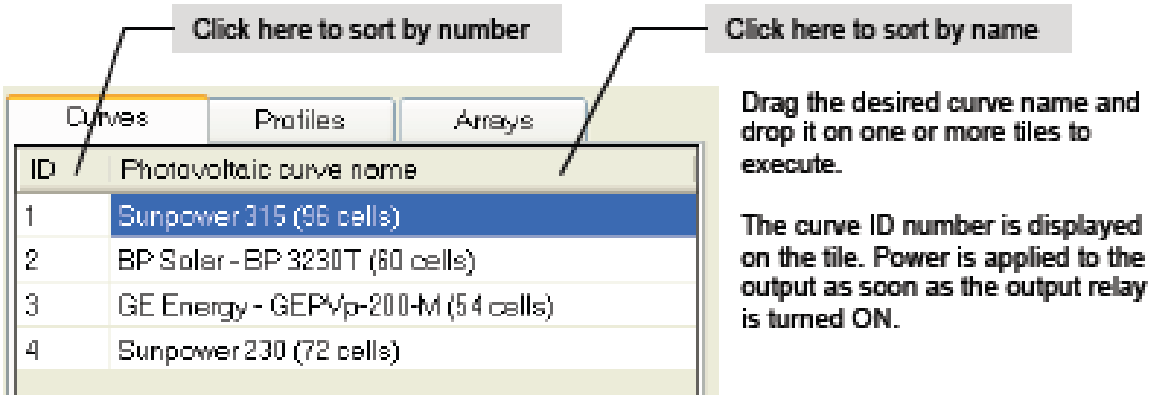


The TerraSAS system provides an easily programmable means of simulating the response of a PV array. The system provides a turn-key approach to testing the maximum peak power tracking (MPPT) characteristics for inverters and charge controllers. The ability to simulate virtually any fill factor allows the system to characterize the MPPT algorithm with a power source that duplicates any IV array slope characteristic. Test software including items based on the Sandia Labs "Performance Test Protocol for Evaluating Inverters Used in Grid-Connected System" is incorporated to allow for ease in programming various test requirements.

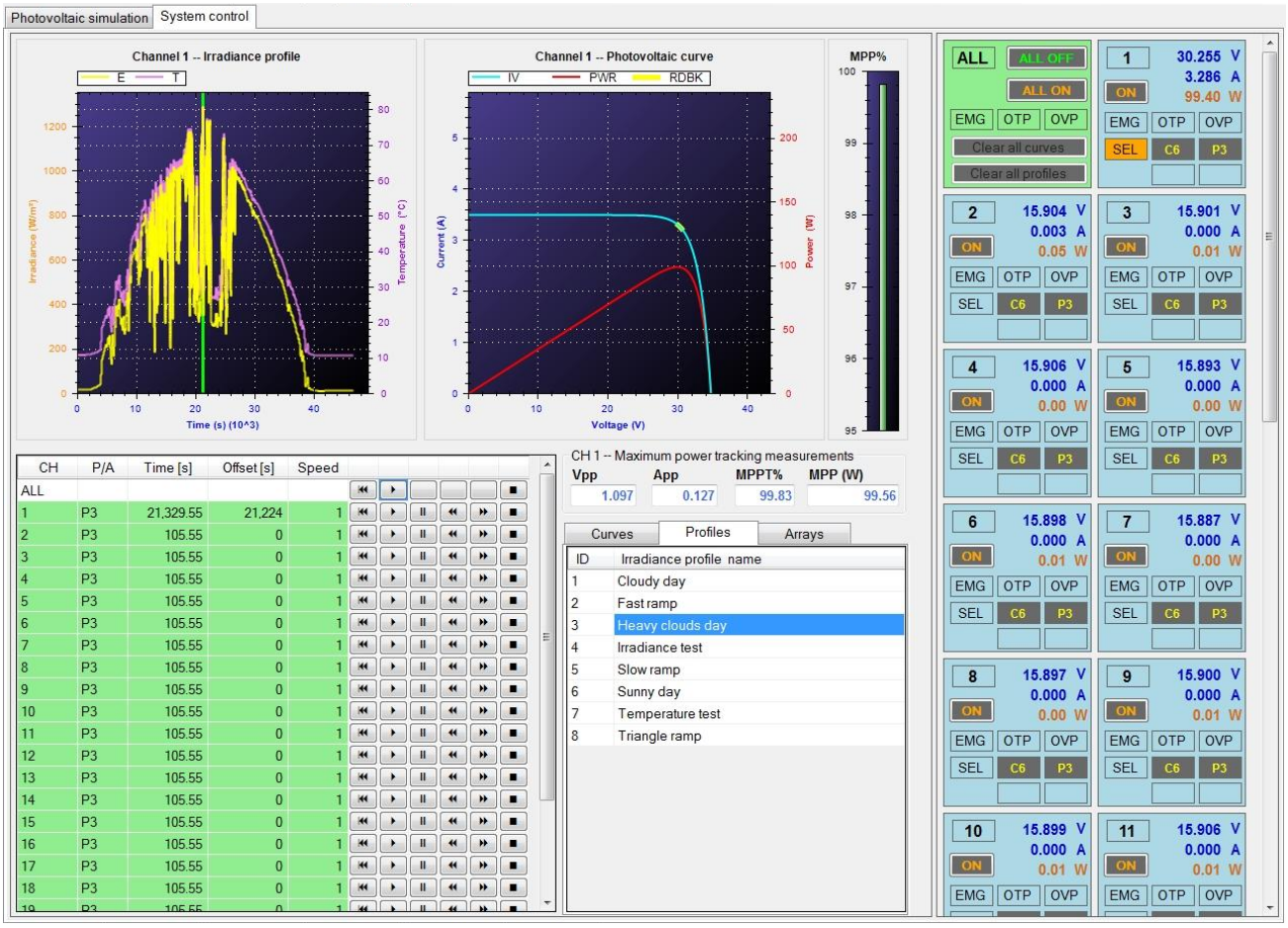
The included software allows modeling of a PV panel without an extensive knowledge of solar array parameters. The main parameters required for a simulation are the open circuit voltage and short circuit current. The software parameters are defined at 25°C and 1000W/m2, so that the resulting IV curve is calculated according to a standard solar cell model. The slope of the IV curve is then modified by the peak power parameters, Vmpp and Impp. Changes to the peak power point parameters allow the shape of the IV curve to be adapted to any fill factor between 0.5 and 0.95.



Once an IV curve has been calculated, changes to the irradiance level or temperature may be changed on the fly so that the behavior of a grid tied inverter can be tested under realistic conditions for cloud shadowing and panel temperature changes. Long-term weather simulations can be run to determine the amount of energy expected in a given situation.



The PV simulator has the ability to simulate ideal IV curves as well as irregular characteristics for peak power tracking that result when solar panels with different output characteristics are paralleled as shown on the two graphs below. The inverter can be optimized for real MPP search modes, because shadowing and temperature changes can be simulated realistically. By programming the changes in irradiance and temperature in a table, dynamic simulation of compressed time profiles of a 24 hour day can be run in a loop to simulate the day and night periods for extended periods of time. The figure below shows a profile with changes in irradiance and temperature.



Simulation Showing Changes in Irradiance over Time

System Power Supplies

The simulator consists of a modified version of the DCS80-15E power supplies, which have an output of 0-80VDC at up to 15A with a maximum power level of 1200W per channel. This will allow for ample derating on the present inverter requirements and will also allow for higher power inverters in the future. Each power supply will be in a separate 1U high full rack width chassis with the PV simulator board and auxiliary components. The power supply will be programmed through the analog interface from the internal PV simulator board, allowing each one to operate like a separate solar panel. This operation will allow a rack to be configured with the required number of channels of separately programmed PV simulator power supplies.

TerraSAS Specifications

DC Output

Open circuit voltage, Voc: 0 - 80VDC
Short circuit current, Isc: 0 – 15A
Maximum output power at MPP: 1020W max at fill factor of 0.85

Number of Channels

28 maximum in a single bay rack

Accuracy

Voltage: ±1% of full scale value for calculated curve formula at E>250
Current: ±2% of full scale value for calculated curve formula at E>250
Voltage Readback: 0.2% of max voltage
Current Readback: 1% of max current

Curve Formula

The PV curves for the simulator are derived from the formula shown below.
Io as a function of Vo:
Io=Isc (1-C1 (exp (V/(C2 x Voc))-1))
C1=(1-(Imp/Isc)) (exp(-Vmp/(C2 x Voc)))
C2=((Vmp/Voc)-1)/(ln(1-Imp/Isc))

Where the Reference Irradiance conditions for the simulated arrays is 1000W/m^2 and the Reference Array Temperature is 25°C

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

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

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

$$\mathrm{P} = V \times I$$

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

Where:

$\beta =$ Array temperature Coefficient, %/°C
T= Cell temperature, °C
V= Voltage, V
I= Current, A
FF= Fill Factor
Subscripts:
Ref= Reference (i.e., at reference or rated conditions)
MP= Maximum Power
OC= Open Circuit
SC= Short Circuit

PV Array Parameters

IV Curve resolution: 1024 data points with 16 point interpolation between each point
Irradiance level: 0 to 1500 W/m²
Temperature value: -40 to 90°C
Voltage level: 0 to 80VDC
Current level from 0 to rated output current
Voltage temperature coefficient: 0 to -2%/°C

Communication

The supplies will be connected to the control computer through an Ethernet hub with an RJ-45 connector on the rear panels. The system can then be externally controlled via TCP/IP Ethernet using standard SCPI commands. All functions available locally through the Graphical User Interface (GUI) can be implemented remotely from the host computer.

AC Input Power

The AC input to the power supplies is 200-250VAC, single phase with a maximum AC current of 9A per unit. The input connector is a two position terminal block which accepts spade lugs. A single point ground screw is provided.

DC Output Connections

Molex connectors are used on the power supply rear panels.

Mechanical

Power Supplies are 1U high rack mount by using rack mounting "L" brackets (not included)
Computer is 2U high rack mount
LCD display / keyboard assembly are 1U high rack mount
Ethernet hub and external power supply are not rack mount type and will need to be secured to a panel or rack rail

Pricing Proposal

The current 80V PV power supplies will be configured to operate in series to allow twice the maximum output voltage to the load.

Contract Line Item	Shanghai Jiaotong University	Qty.		
1	**560XXXX-01 - One Channel TerraSAS with Control Computer** **Consisting of the following:**	1		
	Rack configured to hold up to ten 1U power supplies			
	Rackmount Control Computer and Ethernet hub	1		
	TerraSAS Control Software fully loaded and tested	1		
	Rack mount 17" LCD display and keyboard	1		
	1U Full Rack Power Supply with PV Simulator Controller **1200W per Channel; Voc=80V max, Isc=15A max**	2		
	Two supplies will be operated in series configuration for **Voc=160V max, Isc=15A max**			

Terms and Conditions

The terms and conditions of sale are as follows:

1. Delivery Lead times are based upon engineering resource availability at the time of order placement where the allocation of engineering resources are on a first-come, first-served basis. Typical lead time for a project as described in the technical section above is 14 weeks assuming immediate resource availability, however, firm commitments for delivery dates can only be provided upon receipt of a purchase order.
2. This quotation covers the system described in the technical section of this proposal
3. This quotation is valid for thirty (30) days from the date of this memo.
4. All products will be manufactured in accordance with Ametek's Best Commercial Quality (MIL-I-45208A) and Workmanship Standards (MIL-STD-454, Requirement 9).
5. Payment terms are net 30 days from date of shipment.
6. All shipments will be made Ex-Works, San Diego, CA, collect, unless otherwise negotiated.
7. Standard Warranty of one (1) year shall apply to the entire system.
8. No other terms and conditions apply to this quotation or resulting order unless they are reviewed and approved by Ametek.