The PV Simulator application for Solar Unmanned Aircraft System Test

Introduction

Recently the unmanned aircraft system (UAS) technology has gained significant development, its application in both military and civil fields has become more and more attractive. With no doubt the UAS technology will further develop to take advantage of solar power, especially to make good use of the fine sunshine condition at high altitude, so as to push the flight endurance time to a high limit, while it's clean energy as well.

Unlike the space satellites which widely adapt the S3R/S4R, nor the terrestrial PV system which adapts pure MPPT, the solar UAS tends to adapt a control method of combining maximum power point tracking (MPPT) and stable voltage power supply. When the battery on the unmanned aerial vehicle or airship is not full and requests to be charged, it uses MPPT to harvest as much energy as possible; then after the battery is full it quits MPPT and keep on a stable voltage. In the laboratories the dedicated PV simulators are used to simulate the electric output of solar arrays, these two different working conditions represent, to some extent, two conflicting requirements on the PV simulator's output characteristics. Also regarding some other features requested by this application, it is necessary to carefully check up what kinds of PV simulator products can fulfill.

Since the shunt regulation switching frequency of the Power Conditioning Unit in the satellite could be as high as dozens of KHz, the solar array simulators for satellite test are always specifically designed linear type current sources, which could provide load shunt switching recovery time performance at micro-second level. Such a source is capable of supporting the MPPT regulation though, it has a relatively big size, low power density, and is quite expensive.

As a benefit from the explosive growth of the terrestrial PV power generation industry, there are much more available choices of PV simulators designed for PV inverters test, which just adapt the MPPT regulation rather than others. The power level of such PV simulators could vary from hundreds of watt for micro-inverter test to mega watt for central inverter test, the performance and price of them also vary a lot.
In this article we take the ETS series from AMETEK Programmable Power, to discuss how those topics, eg. power level, regulation method, multi-channel support, dynamic irradiance simulation at high altitude etc. could make the PV simulator a good choice for solar UAS laboratory test.

Power Level

Most solar UAS adapts large wing span design method, so as to install plenty of solar panels on its back. At the moment the large solar UAS could has a wing span at dozens of meters. Airships have even larger size to install more solar panels.
At the moment the large UAV and airship could already have a power level at higher than 10KW, it will further go high with the development of solar panel technologies. Consistently, the voltage level is steadily increasing, unlike normal satellites whose voltage are usually below 100V, those large UAS could request voltage at 3,400V or even higher.

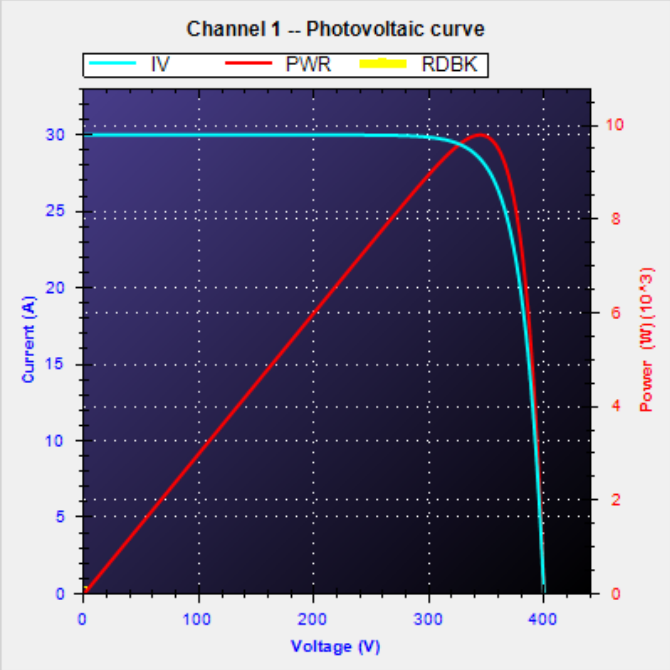

Figure1: An IV curve of Voc=400V,Isc=30A

If we directly implement the power test system at such power level with those satellite-test-oriented solar array simulators, the first obstacle is the lack of suitable high voltage models, secondly the system will have a huge size (may require multiple

cabinets), and very high cost.
Those PV-inverter-test-oriented solar array simulators, a.k.a PV simulators, provide high power density as 15KW single unit in 3U height & standard rack width, voltage levels at 600V~1000V, and parallel capabilities to consist of up to MW level systems. These features make excellent coverage of power and voltage requirement for large UAS test.

Figure2: The AMETEK 5/10/15KW PV Simulator for middle/large power applications

Besides, AMETEK Programmable Power also provides 850W version PV simulator which is 1U height, standard rack width as a single unit, so as to fulfill the test requirement of different electric configurations.

Figure 3: The AMETEK 850W PV Simulator for micro inverter test

Table 1 List of AMETEK PV Simulators

Model(Voltage & Current)	Max. Power	Dimension
ETS 60V 14A	850W	57.4x4.6x48.3cm (WxHxD) Standard rack width, 1U height
ETS 80V 10.5A	850W	
ETS150V 5.6A	850W	
ETS 600V 8.3A	5KW	71.8x13.3x48.3cm(WxHxD) Standard rack width, 3U height
ETS 600V 16.7A	10KW	
ETS 600V 25A	15KW	
ETS 1000V 5A	5KW	
ETS 1000V 10A	10KW	
ETS 1000V 15A	10KW	

Regulation Method

Typically solar UAS adapts MPPT + stable voltage supply regulation method. Those terrestrial PV simulators, as designed and optimized to test inverters with MPPT regulation, are intrinsically current sources, their output capacitance are extremely small so that they could provide fast output response speed, and their built-in high-speed MCU provide fast control loop to make sure the output get maintained on the predefined IV curve. A top-class PV simulator, eg. the AMETEK ETS series, is capable of supporting up to 200Hz MPPT. At present those solar UAS are usually not doing fast MPPT, so most top-brand PV simulators should be fast enough to support their MPPT regulation method.
However, when the craft quits MPPT and get into stable voltage supply mode, the PV simulator could easily get into oscillation due to its weak stabilization capability and conflict caused by its controller trying to maintain output on the IV curve. This is a trial for the design concept of PV simulator to keep balance between high speed MPPT support and steady state working. Considering that the power controller of UAS tends to adapt low speed MPPT, we can simply parallel some external capacitors at PV simulator's output to increases its stability at the compromise of lowering high speed MPPT support.
A simplified method to verify the PV simulator's steady state output capability is to connect an e-load directly to its output, set an IV curve for the PV simulator, set e-load to work under CC mode. By setting the e-load to switch between two different current levels at specific frequency, we can see how the PV simulator responds to different level stable power requirements. Below Figure 4 is the scope capture at PV simulator output that oscillation is happening, Figure 5 is the scope capture at same test set-up except there is a 1410uF capacitor paralleled at the output, we can see the output waveform is significantly improved and stable.

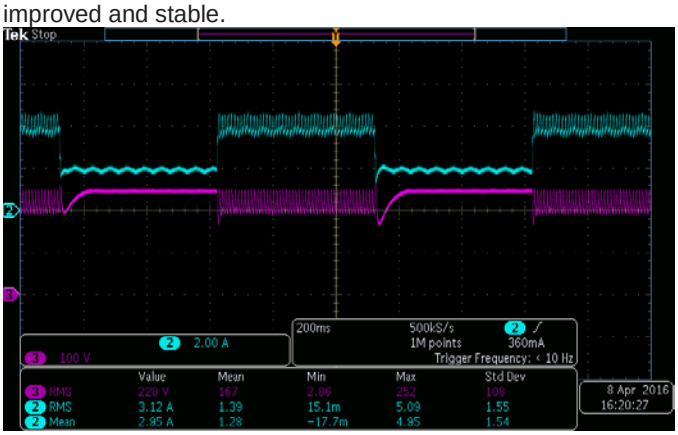

Figure 4: E-load switching between two current levels, PV simulator oscillates

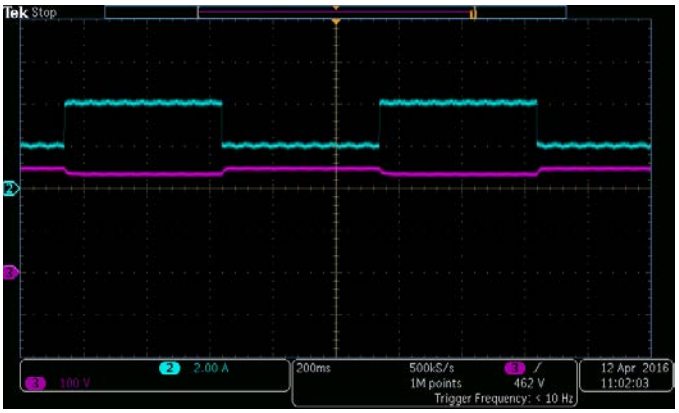

Figure 5: After paralleling 1410uF capacitor, the PV simulator delivers more stable output

Multi-Channel Support

The inverter for terrestrial PV generation system is typically single input (or multiple input but a single MPPT control loop), it's especially true for those string inverters rated at 3~30KW. Some inverters could support multiple input and each input has an independent MPPT control, but the channel number is always limited, typically no more than 4 to 6 channels. As a contrast, the power controller of UAS normally needs to handle high count channels input, eg. 10 channels or tens of channels. It could be a challenge for normal PV simulator system, because its program needs to control plenty of channels simultaneously, and the output of those channels should be synchronized.

The ETS series PV simulator from AMETEK Programmable Power has inherent advantages from this point of view, each ETS unit is controlled via Ethernet communication, the program could control up to 48 channels or even more simultaneously, and the output of each channel is well synchronized. The Figure 6 provides a glimpse of the ETS GUI software, each channel takes a tile in the software, with its output on/off status, present voltage/current/power, error message etc. clearly indicated on the display, all channels can be controlled simultaneously or independently.

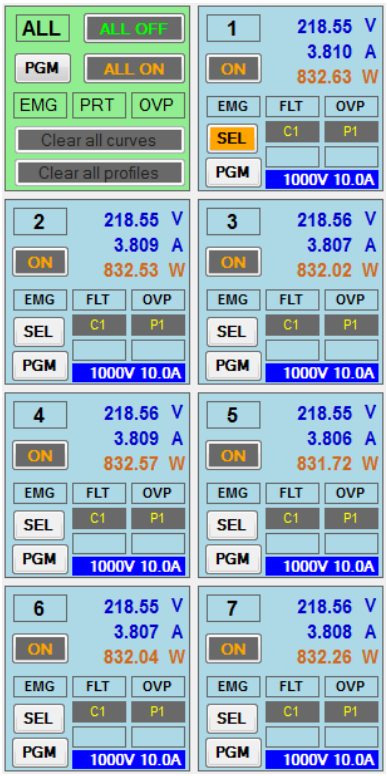

Figure 6: The UI for multi-channel control

Figure 7 shows the output of two of the channels, we can see those two channels are pretty well synchronized when commanded to deliver identical output.

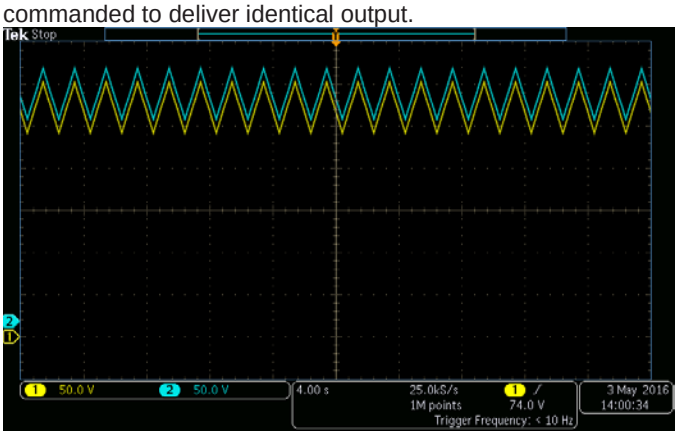

Figure 7: The Synchronized Output of Two Independent Channels

Dynamic Irradiance Process Simulation

At high altitude the air is thin, the irradiance would not vary so drastically like the terrestrial PV system would withstand on ground due to cloud shading, but the irradiance does change with time as well.

The ETS series from AMETEK Programmable Power provides

powerful dynamic irradiance simulation capability, it allows user to create customized irradiance/temperature profiles at 1 second step and unlimited time span, furthermore, it could automatically do linear interpolation to update the IV curves up to 128 times per second. This useful feature enables user to set dynamic irradiance processes eg. for a whole day, a week, a month or even longer, or to simulate eclipse, cloudy/rainy weather etc with convenience, significantly relieve the workload of setting up long time dynamic test environment.

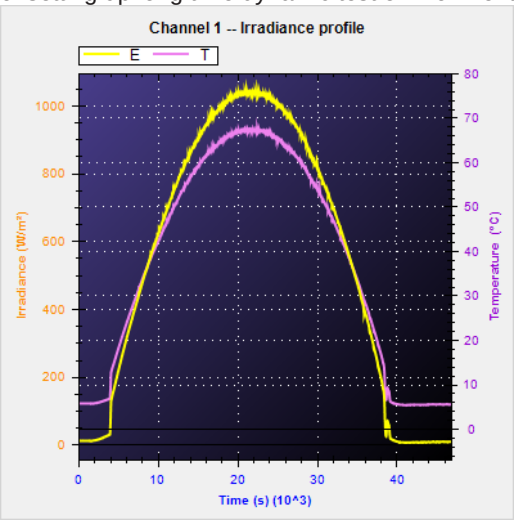

Figure8: Dynamic Irradiance Profile example

Summary

The power conditioning and distributing research of solar UAS is a frontier research topic, no existing test criterion, each research institute is developing their own test items. Based on its premier hardware performance and powerful software features, the ETS series from AMETEK Programmable Power could fulfill all those requirements of power level, regulation method, multi-channel support and dynamic irradiance process simulation, it could no doubt provide great assistance to solar UAS research.

About AMETEK Programmable Power

AMETEK PPD is a division of AMETEK Inc, a multi-billion dollar manufacturer of differentiated technology solutions, and designs and manufactures advanced programmable DC, AC and eLOAD products under the well known and respected Sorensen, California Instruments, Elgar and AMREL brands.

For more than forty years AMETEK has supplied precision programmable power products and systems to diverse industries for test and measurement needs, ATE systems, R&D, process control, power bus simulation and power conditioning. Its products and services are recognized around the world for robust performance, high quality, reliability and economic value.

Contact your AMETEK PPD sales rep for application assistance to optimize a solution for your test needs.

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