

KEPCO POWER SUPPLIES APPLICATION NOTE

Using **Kepco BOP 1KW** for Solar Device Testing

ABSTRACT

The Kepco BOP 1KW provides a one-step solution for test and characterization of solar cells and solar panels. A free LabView subvi allows rapid characterization of the solar device using only the BOP 1KW, eliminating the need for separate DVMs to measure voltage and current. The subvi is designed for both I-V Trace and Dark I-V testing, and can be plugged in or easily adapted to existing LabView test applications, even those previously using two DVMs. This solution relies on an incremental improvement in the proven BOP 1KW to offer lower cost, greater throughput and increased ROI when testing solar devices.

FEATURES AND BENEFITS

- **SOLAR DEVICE TESTING** - Both I-V Trace and Dark I-V Tests supported.
- **FLEXIBILITY** - KEPSCO BOP 1KW LabView Driver allows Solar Device testing while maintaining full functionality of the BOP 1KW Instrument Power Supply features.
- **FASTER THROUGHPUT** - 20mS per point.
- **ROI** - Test setups are quick and easy, require no special programming for synchronization, require no dedicated engineering resources to design and/or maintain components comprising a custom solution.
- **LOWER COST AND SIMPLICITY** - No need to purchase, maintain and calibrate two DVMs - Simplifies calibration, test setup and operation; no trigger connections needed.
- **RELIABILITY** - With all triggering and measurements done within BOP 1KW there are no synchronization or noise issues.
- **PROVEN TECHNOLOGY** - Enhancement of proven BOP 1KW technology.
- **ENERGY CONSERVATION** - Employs energy recuperation as well as active Power Factor Correction (PFC).

BACKGROUND

Solar device testing requires a variable load that can operate in three quadrants: source voltage and current, as well as sink current. The options that a solar device manufacturer has are to:

- 1) design and develop a three- or four-quadrant power supply,
- 2) create a custom three-quadrant solution by combining individual pieces of equipment to form a three-quadrant supply or
- 3) to purchase a true 4 quadrant supply.

Options one and two represent a significant technical challenge. Even most highly successful and competent power supply companies lack the required know-how to design and build such a three- or four-quadrant power supply. Creating a custom solution using various pieces, while less demanding than creating a four-quadrant supply, nevertheless requires an excellent understanding of power supplies and power supply technology in order to make a fault-proof system. If using either option one or two, issues such as component obsolescence, repeatability, etc. must be addressed.

Any manufacturer focused on optimizing resources towards core technology will quickly conclude that the third option is the most cost effective and provides the best ROI. Kepco is the industry leader in test equipment that can operate in four quadrants and has been producing four-quadrant power supplies for over 30 years. BOP power supplies have been used in many solar device test and characterization applications for many years.

TYPICAL TEST SET-UP USING BOP 1KW

The solar device (cell, panel, etc.) is connected to Kepco's BOP power supply functioning as the load, while two DVM's are used to measure output current and voltage (see Figure 1). The BOP is controlled by a computer program which steps through a systematic loading of the solar device in an effort to determine the maximum power point (Pmp) of the device. The DVM measurements are stored in the computer where they are used to form a characteristic I-V curve which defines the solar device.

Each point of the I-V curve requires the BOP output to be changed and measurements taken by the DVMs before the BOP output is advanced to the next point. This setup is relatively costly, requiring purchase, maintenance and calibration of three separate pieces of test equipment. DVM measurements are not synchronized to the BOP output and throughput is relatively slow, requiring at least 100mS for each point of the I-V curve.

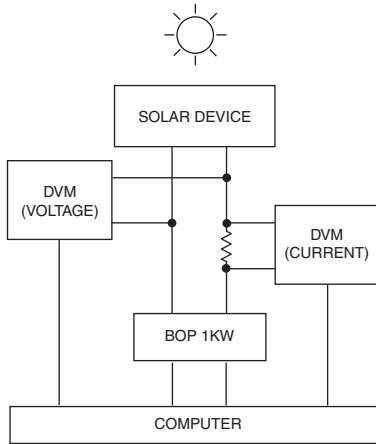


FIGURE 1

Typical Test Set-Up Using BOP 1KW Without Solar Enhancements

IMPROVED TEST SET-UP USING LIST:WAIT AND LIST:TRIGGER COMMANDS

To speed up the process, synchronization was added to the BOP 1KW arbitrary wave form capability with the commands LIST:WAIT and LIST:TRIGger. These provided the ability to connect the BOP 1KW and trigger-capable DVMs together to reduce test time (see Figure 2). This allowed DVM measurements to be synchronized, and greatly increased throughput by decreasing the time required for each point to 36mS (limited by the DVM measurement rate). Triggering could be initiated by either the computer or BOP 1KW.

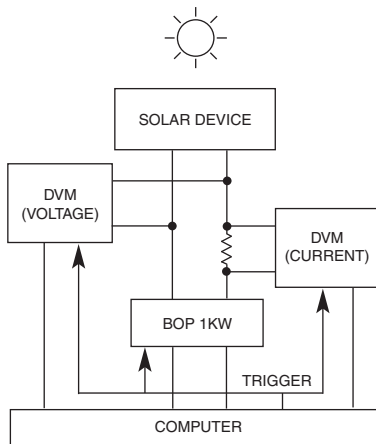


FIGURE 2

Improved Test Set-up Using LIST:WAIT and LIST:TRIGGER Commands

The trigger pulses were created using a USB to Digital output device by a computer program. The BOP 1KW arbitrary wave form function set the output to a level and waited for the trigger to go high or low. First pulse synchronization was accomplished by waiting 200 milliseconds once the initialization commands were sent to both DVMs and the BOP 1KW. A second option allowed the BOP 1KW to generate the trigger

pulses by using the BOP 1KW output on/off signal to provide a low or high pulse to the DVMs, with pulse-width based on the DVM requirements for each step. In both cases, the computer then used the serial poll to determine when to read the accumulated DVM measurements.

This solution greatly improved throughput (from 100mS to 36mS), but the trigger inputs of many measurement devices are susceptible to noise which can result in one of the devices missing a pulse. If one DVM performs a measurement and the other does not, the readback becomes unequal and the entire sample must be retaken, resulting in lost time. The trigger lines must be as short as possible and noise reduction measures must be in place.

KEPCO'S PERFORMANCE ENHANCED SOLUTION

The BOP 1KW has been upgraded to include a faster measurement rate and a faster setting rate. A free, Kepco-developed, Solar Device Tester LabView subvi works with the improved BOP 1KW to use the full capabilities of improved speed of measurement and set operations. This subvi is intended to be used by a programmer to build a LabView application for solar device testing. The subvi can be plugged in or easily adapted to existing LabView test applications, even those that previously used two DVMs for measurement. Because it is a subvi it can be used multiple times within a LabView application without repeating pages and pages of code. The subvi has been integrated into a demonstration standalone test application which can be used as is. Both the subvi and the demonstration application may be downloaded free from the Kepco website at:

www.kepcopower.com/drivers/#bop1k.

The BOP 1KW may now be connected directly to the solar device and controlled by the computer (see Figure 3). Because measurements are done by the BOP itself, the external DVMs are no longer needed (see Figure 4). The BOP 1KW can now change the output and make synchronized measurements, and go on to the next point at a rate of up to 20mS per point. There is no need for triggers or special wiring. Connections are simple (only solar device to BOP 1KW) and only one device to calibrate.

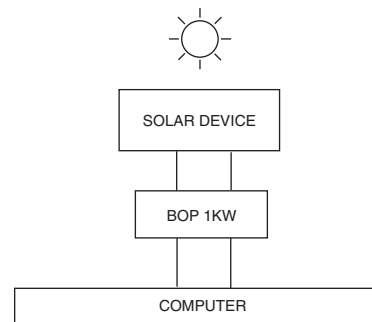


FIGURE 3

Kepco's Performance Enhanced Solution Using the BOP 1KW for Solar Device Testing

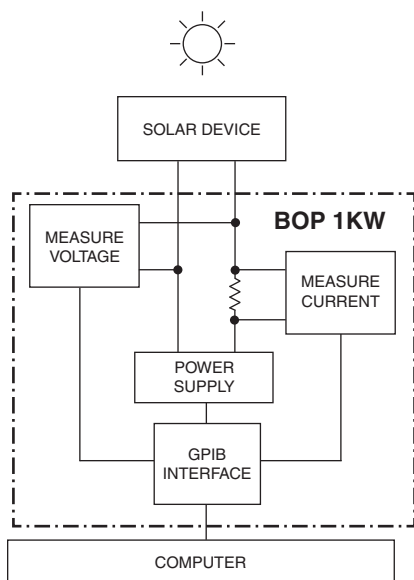


FIGURE 4

BOP 1KW Provides Integral Measurement of Solar Device Output

HOW THE BOP 1KW MEASURES THE SOLAR DEVICE OUTPUT USING THE DEMONSTRATION APPLICATION

The Solar Device Tester demonstration application written in LabView includes a simple user interface (see Figure 5) which may be used as is. This simple standalone application uses the Kepco Solar Device Tester subvi to control the output of the BOP and to take the measurements. The subvi can be adapted to an overall Test application as needed.

The user interface included with the Solar Device Tester demonstration application is illustrated in Figure 5. The bottom of Figure 5 shows a typical I-V curve taken by the subvi. The BOP Parameters display allows the user to select voltage or current mode and enter the start and stop points for the sequence of setpoints that will characterize the device.

The Start and Stop Point units are in Amperes for Current Mode and Volts for Voltage mode. The positive Protection Limit ensures that the BOP output does not exceed the capacity of the solar device. The negative Protection Limit is normally set close to zero to prevent the solar device from overheating.

Once the Start and Stop points are chosen, the user enters Ramp Characteristics: the Number of Points, Milliseconds to Wait and whether to Invert the Data. The number of points determines the resolution or level of detail of the

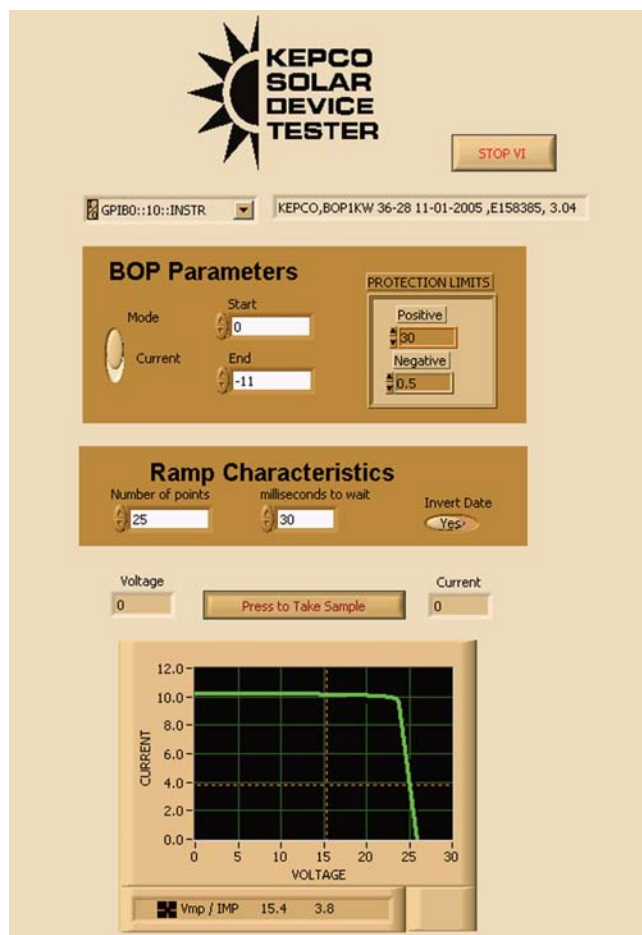


FIGURE 5

Demonstration Application Interface Showing User Inputs and Rendered I-V Curve Output

characterization and can be set to as few as 10 to as many as 40,000 points per I-V Curve. Data Inversion is convenient for rendering the I-V curve as preferred for I-V Trace and I-V Dark type tests.

Clicking the Press to Take Sample button causes the application to invoke the subvi which changes the BOP output, creating a linear ramp. At each step, the BOP 1KW provides a measured voltage and current value. While the curve is being taken, the voltage and current values change, providing status to the user. When the ramp is completed, these measurements are provided as an array, which the application renders as the I-V curve shown in Figure 5. The subvi also provides measured Vmp and Imp, which is graphically marked on the curve with a cursor formed by intersecting vertical and horizontal lines.

SOLAR DEVICE TESTER SUBVI

The Solar Device Tester subvi, written in LabView, includes an operator panel (see Figure 6). The subvi may be used as is in an overall Test application. The overall application will typically use the measurement data provided by the Solar Device Tester subvi to produce an I-V curve that characterizes the device, and includes the four key device characteristics: Voltage Maximum Power (Vmp), Current Maximum Power (Imp), Voltage Open Collector (Voc) and Current Short Circuit (Isc) as well as Maximum Power Point (Pmp). Figure 5 shows a typical I-V curve characterizing a solar device produced from the data accumulated by the Solar Device Tester subvi.

The Real Time Output, BOP Parameters and Ramp Characteristics, shown in Figure 6, function as described for the demonstration application. When the subvi is invoked by an application, the subvi calculates a Settings Array as shown in Figure 6. The settings array shows the sequential setpoints for the main channel as determined by the start and stop points and the number of points supplied. An arrow to the left of the settings array allows the user to scroll and view each point. To the right of the settings array are the Measured Current and Voltage arrays, showing the measured values at each point from the previous execution of the subvi.

At each point the BOP 1KW main channel is set to a level, and after the user-programmable delay (using the Milliseconds to Wait input under Ramp Characteristics), the subvi requests voltage and current measurements. These requests are made with a single command line to insure the voltage and current measurements are from the same sample. The programmable delay is adjustable from 20 mS to 2 Seconds. If the BOP 1KW is connected to a solar cell, the best timing has been found to be 25 mS.

When all measurements are completed, the Measure Current and Voltage arrays to the right of the Settings array are updated to show the measured values at each point. (In the demonstration application the two arrays of points are used to update the I-V curve. The Imp and Vmp values update the cursor position.)

At the left, under Real Time Output, the user can monitor the test in progress by viewing the instantaneous outputs of the solar device under test: Voltage and Current. Voltage Maximum Power (Vmp), Current Maximum Power (Imp) and the Maximum Power Point (Pmp) are calculated in real time, and are viewable when the characterization is complete.

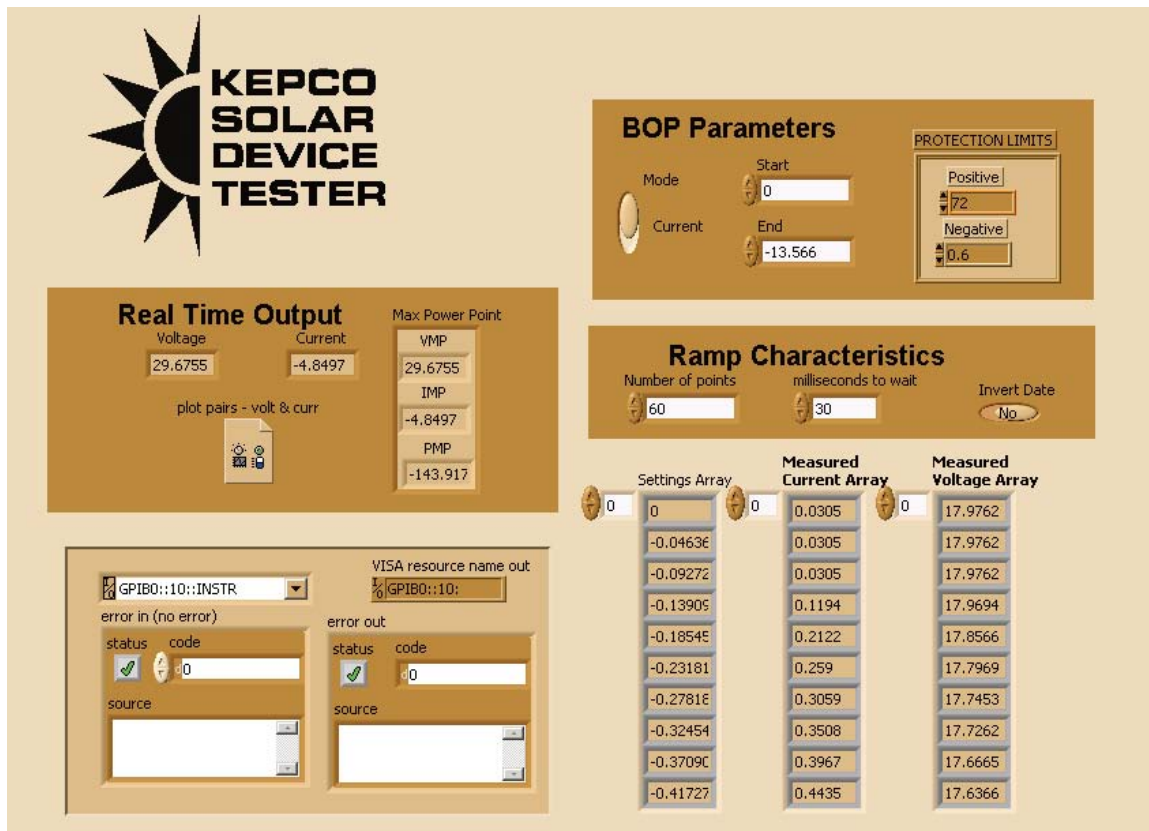


FIGURE 6
Solar Device Subvi Front Panel

AVAILABILITY

The enhancements used for solar device testing are now standard on all BOP 1KW units. The Solar Device Tester subvi is posted on the Kepco website at:

www.kepcopower.com/drivers/#bop1k.

Units shipped prior to October 1, 2009 may be updated by ordering a kit or sending the unit to Kepco for update.

- KIT 219-0533 - Upgrade to BOP 1KW unit.
Customer must calibrate unit after installation.
Cost: \$175.
- KIT 219-0533-n where n = BOP 1KW Serial number.
By including the serial number of the BOP 1KW, the factory calibration constants for that unit will be included and recalibration will not be necessary.
Cost \$375.
- Return unit to Kepco for update, calibration and complete functional testing with certified test data.
Cost \$925.

SPECIFICATIONS

Table 1 lists the specification enhancements to the latest BOP 1KW. For complete specifications of the BOP 1KW refer to Kepco's web site at www.kepcopower.com/bophi.htm.

BOP 1KW SPECIFICATION ENHANCEMENTS		
SPECIFICATION	RATING/DESCRIPTION	CONDITION
Measurement Rate	20mS	Using standard meters display
Setting Rate	5mS	Debug mode disabled
Solar Device Tester Subvi		
Number of points	10 to 40,000	
Programmable delay	20mS to 2 seconds	

TABLE 1

