Production Line Electrical Safety Testing Solar Panels

Test Methods for Successful Applications

Associated Research Inc.

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Introduction

Over the past two decades, consumer demand for solar electrical energy has increased at a rapid pace. One of the driving factors for this demand is the falling costs of materials and manufacturing. Before any solar panel hits the market, it must be fully tested for electrical safety. These types of tests factor into production costs as they require time and equipment to achieve full compliance with the electrical safety standards. As a result, an efficient system for running the electrical safety tests in a routine production line setting is crucial to maintain low panel costs. Associated Research Inc. has developed various units that allow for full compliance testing via automation. The Associated Research Inc. model 7650 or 8204 along with a scanning matrix system and Autoware software are designed specifically for fully automated electrical safety testing. This paper will detail the electrical safety tests involved with testing solar panels as well as the most efficient methods of testing.

Production Line Vs. Performance Testing

Testing methods for running the electrical safety tests on solar panels vary depending upon whether the test is for performance or production. This is mainly due to the fact that the desired outcome for production line testing is higher throughput. In a performance (often called type testing) testing laboratory environment, panels are tested on a sample basis by engineers that analyze data and results. Thus performance testing is a more time consuming process. Production line testing is designed to allow running multiple tests in a short period of time. As a result, automated testing is more conducive to a production line setting. Minimizing the test time and the degree of operator intervention is the key for maximum testing efficiency.

Electrical Safety Tests and Solar Panels

There are five main types of electrical safety tests involved in testing solar panels for potential shock hazards. These tests are the dielelctric withstand, ground bond, ground continuity, insulation resistance and wet leakage tests. The purpose of these tests are:

"to assess the risk to personnel due to shock or injury because of contact with parts of a module that are electrically energized as a result of design construction or faults caused by environmental operation".[1]

Table 1 below outlines the electrical safety tests and test limits for both production line and performance testing per UL 1703, IEC 610730-1, IEC 61646 and IEC 61215.

Standard / Harmonized Standard	Testing Type	DIELECTRIC WITHSTAND			GROUND BOND/CONTINUITY				WET LEAKAGE			INSULATION RESISTANCE		
		Test Voltage	Max I.	Test Time	Test Current	V Limit	Max. R	Test Time	Test Voltage	Min R.	Test Time	Test Time	V Limit	Min R
IEC 61730-2 UL 1703 Photovoltaic Modules & Panels	Performance	1000 VAC + 2 x rated V or 2000 VAC + 4 x rated V	50 uA	60 s	2.5 x Max Over Current Protection	≤ 12 V	≤ 0.1 Ω	120 s	See IEC 61646/61215			60s	500 VDC or Max rated V	40-400 MΩ
	Production	1000 VAC + 2 x rated V or (1000 VDC + 2 x rated V) X 120%	50 uA	1 or 60 s	Continuity				Not Applicable			Not Applicable		
IEC 61215 - Crystallline Silicon Terrestrial Photovoltaic Modules	Performance	See IEC 61730-2/UL 1703							500 VDC or Max rated V	40-400 MΩ	120s	60s with 500V/s ramp	500 VDC or 1000 VAC + 2 x rated V	40-400 MΩ
	Production	Responsibility of Manufacturer – Production Run Testing Performed on Sampling Basis												
IEC 61646 - Thin Film Terrestrial Photovoltaic Modules	Performance	See IEC 61730-2/UL 1703							500 VDC or Max rated V	40-400 MΩ	60s	120s with 500V/s ramp	500 VDC or 1000 VAC + 2 x rated V	40-400 MΩ
	Production	Responsibility of Manufacturer – Production Run Testing Performed on Sampling Basis												

Table 1: Solar Panel Electrical Safety Tests and Associated Standards

Dielectric Withstand and Insulation Resistance Tests

The dielectric withstand test and insulation resistance test are similar in theory and scope. The dielectric withstand, or hipot (short for high potential) is a test designed to stress the insulation of the solar panel far beyond what it will encounter during normal use. The logic behind this test is that if the panel can withstand high voltage for a short period of time, then the insulation should operate without posing a shock hazard throughout its life cycle. Given the fact that most panels operate with a DC potential, a DC hipot test is generally run on solar panels.

Like the hipot test, the insulation resistance test is also designed to stress the solar panel with high DC potential. The major difference is the results of the test itself. Whereas the result of a hipot test is the leakage current flowing on the surface of or through the insulation (measured in µA), the insulation resistance test displays a value in either MΩ or GΩ. Since both the hipot and insulation resistance tests involve applied

DC potential, the standards dictate that these tests are run in both polarities for both production and performance testing.

In order to perform either of these tests, the insulation of the panel must be placed between the current carrying conductors and the exposed surfaces to the outside world. The most common method for performing this test is to apply high voltage to the shorted positive and negative leads from the panel and place the return circuit to the metal frame of the panel. For panels that do not have a metal frame, the insulated parts must be covered in a conductive material. The voltage is then applied and leakage or resistance values measured by the test equipment.

Since the DC hipot and insulation resistance tests need to be run in both polarities, the easiest method for testing is the use of a hipot tester with a built in high voltage scanning matrix. The Associated Research 7650 with an internal scanning matrix is an all–in-one solution to run these tests:

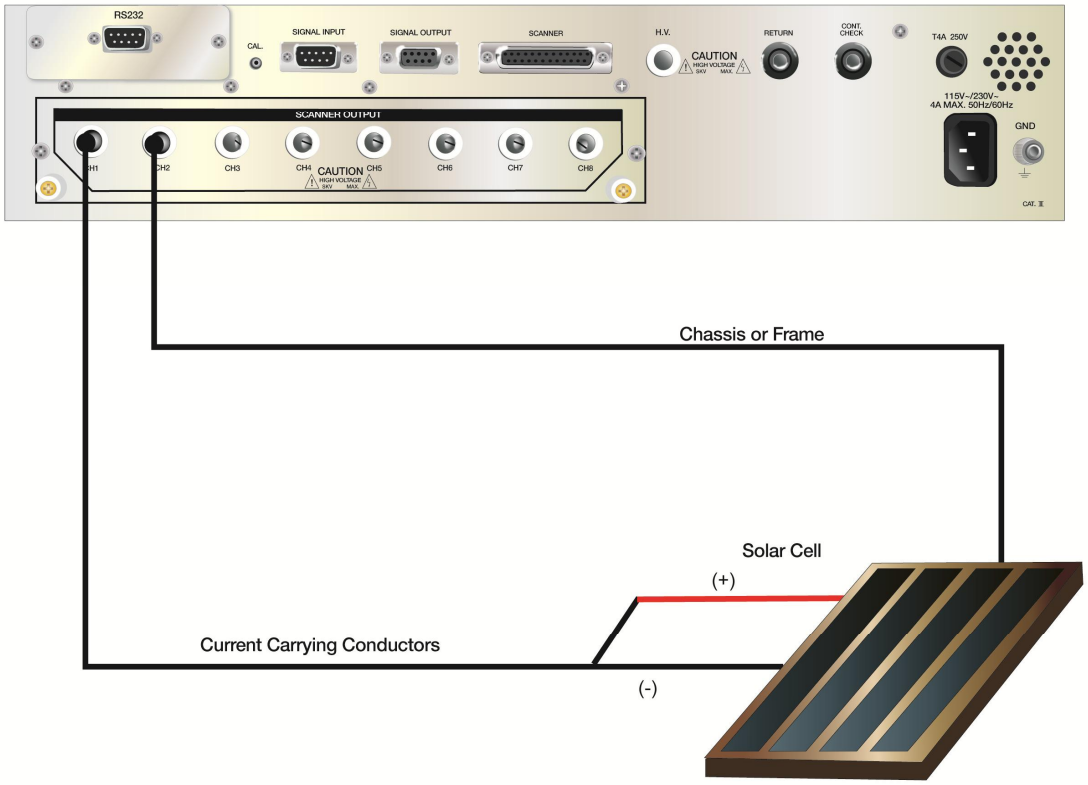

Figure 1: Associated Research 7650 with Internal Scanning Matrix connected to Solar Panel

The scanning matrix channels are three state relays that can be set to high (connects high voltage), low (connects to return point or current sensing) or open (off). For

example, scanner channel 1 can be connected to the solar panel conductors (positive and negative leads) and scanner channel 2 can be connected to the chassis frame or conductive medium. Then the unit can be set for a multi-step test where the first test runs channel 1 = high (high voltage on conductors) and channel 2 = low (return). This can then go right into the next test where the channel settings are reversed for reverse polarity (channel 1 = low and channel 2 = high). This allows for one series of connections to run dielectric withstand and insulation resistance tests in both polarities. Several Nationally Recognized Testing laboratory (NRTL) sites across the United States currently run hipot and insulation resistance tests in this same configuration.

Protective Bonding/Continuity Test

Protective bonding and continuity tests are designed to test the resistance of the grounding circuit on a solar panel. Such a test only applies to solar panels that are built with a metallic frame or other grounding point. The protective bonding or ground bond test actually tests the integrity of the ground circuit by running high current from the ground terminal or lead to any accessible conductive parts. Per UL 1703, the test current is 2X the fuse rating. The ground continuity test also measures resistance of the same circuit but in this case the current is low amperage (generally on the order to 100mA DC or less).

The protective bonding test is a performance test only while the continuity test is run as a 100% production line electrical safety test. The 7650 mentioned in the previous section also has the capability to run a continuity test to meet this specification. However, the ground bond test can be added as a routine production line test for safety reasons. The ground bond test is a more robust test for analyzing a ground path because not only does prove there is continuity on the circuit but also loads the ground circuit down to ensure that it can handle any fault current likely to be imposed upon it. The Associated Research Omnia 8204 with built in high current and high voltage scanning matrix will allow the user to run hipot, insulation resistance and ground bond tests with a single set of connections:

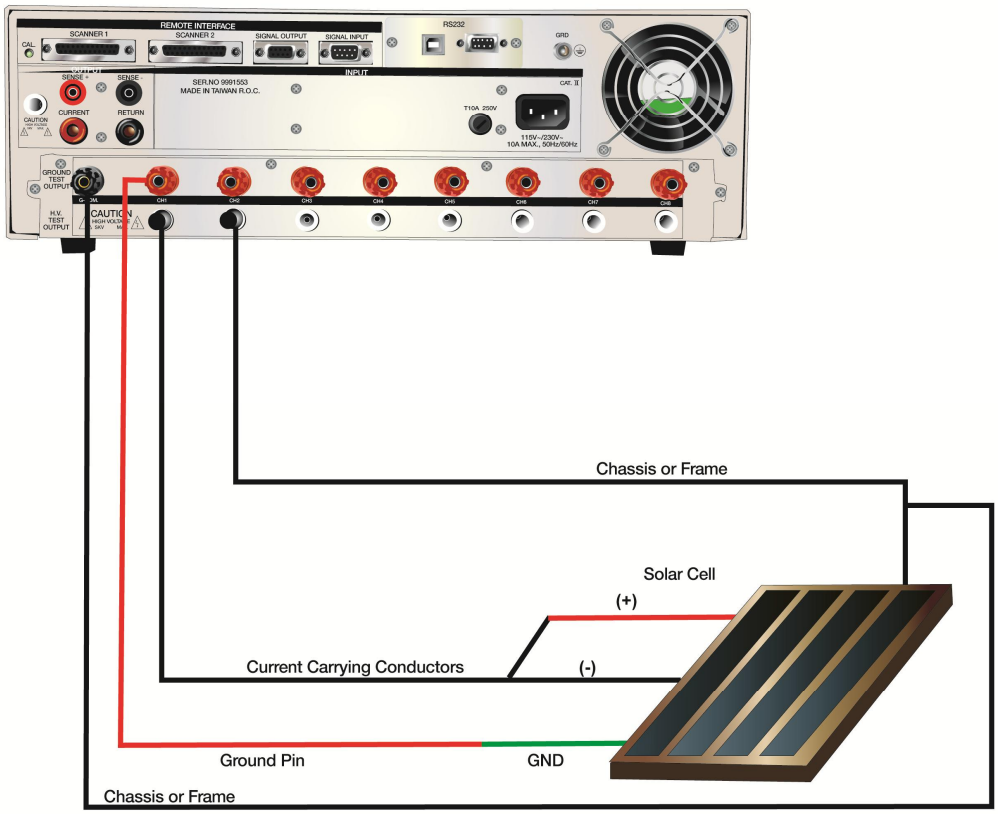

Figure 2: Associated Research 8204 with Internal Scanning Matrix connected to Solar Panel

Wet Leakage Test

Solar panels are subject to a wide spectrum of environmental conditions including dew, rain and snow. Atmospheric conditions involving moisture must be taken into account when running electrical safety tests on a solar panel. Despite its name, the wet leakage test isn't technically designed to measure leakage current directly. The limits of a wet leakage test, like the insulation resistance test, are given in MΩ.

This test is performed in a similar fashion to the dielectric withstand and insulation resistance tests. The positive and negative leads of the panel are shorted together and connected to high voltage. However, for this test, the solar panel is placed in a tank of saline solution and this solution acts as the return point for measuring the insulation resistance value. This simulates a solar panel with exposure to a wet environment to simulate the worst case scenario that someone may touch the panel while it is covered in water.

DID YOU KNOW?

- The saline solution must have the following criteria per the standard: 35ohm-meter max resistance, 0.03N/m max surface tension, temperature 22±3ºC
- An easy way to achieve this is to use a surfactant in water. A simple formula of 300 parts water to 1 part laundry detergent can do the job.

The wet leakage test is not required as a routine safety test. However, with the proper setup on a production line, it can be included as a means of achieving the proper conductive medium for the insulation resistance and dielectric withstand tests on panels that do not have a conductive frame. Recall from UL 1703 that "For tests on exposed surfaces of insulating parts, the part is to be covered with conductive foil or the equivalent."[2] Thus, the saline solution is considered a type of conductive contact. Arranging the setup at a saline solution station along with the Associated Research 7650 with internal scanning matrix for dielectric withstand and insulation resistance testing can help in achieving an all in one test station.

The Fully Automated Solar Panel Setup

The Associated Research 7650 and 8204 with a scanning matrix are systems designed to fully automate electrical safety testing for solar panels on a production line. The sections above describe setting up a 7650 or 8204 unit to test a solar panels for dielectric strength, continuity (or ground bond), insulation resistance and wet leakage testing. These setups contain minimal connections and operator intervention. Using the Associated Research Inc. Autoware software further simplifies the setup by including a software package to completely control the station remotely through a PC. The Autoware software allows the user to setup all test sequences, run the tests and automatically dump data into a specified directory:

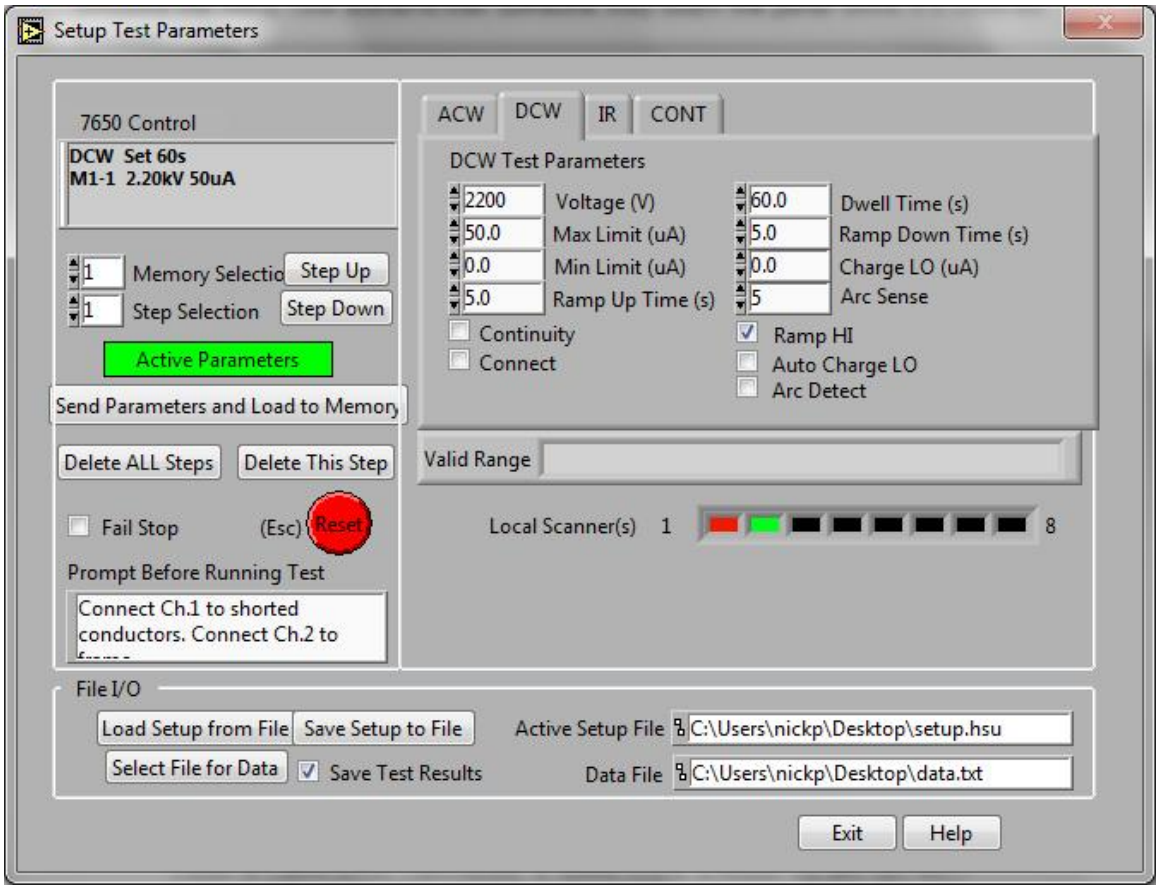

Fig. 3: Autoware Test Setup with 7650 and Internal Scanner

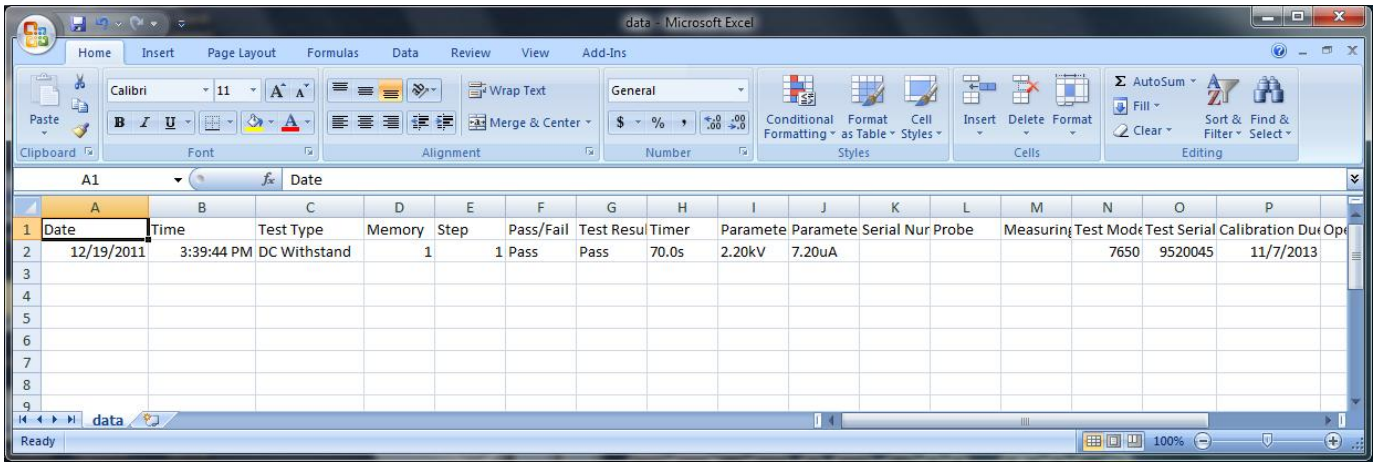

Fig. 4: Example Data File from Autoware

Figure 3 illustrates a test setup with a 7650 using Autoware. The right hand side of the screen details the DC hipot test parameters as well as the scanner channel settings (red = high voltage and green = return). The bottom right hand side of the image also shows the saved setup file on the PC as well as the associated data file for keeping track of all test data. Figure 4 is an example data file that shows the data dumped from the test file. Using this system, the operator only needs to make a single set of connections and then run the test sequence. Whether running minimal tests on the production line or running automated performance and production testing, Associated Research Inc has a variety of units available to meet all solar panel testing needs.

[1-2]IEC 61730-2 2004-10, *Photovoltaic (PV) module safety qualification Part 2: Requirements for testing,* Geneva, Switzerland, International Electrotechnical Commission.