White Paper

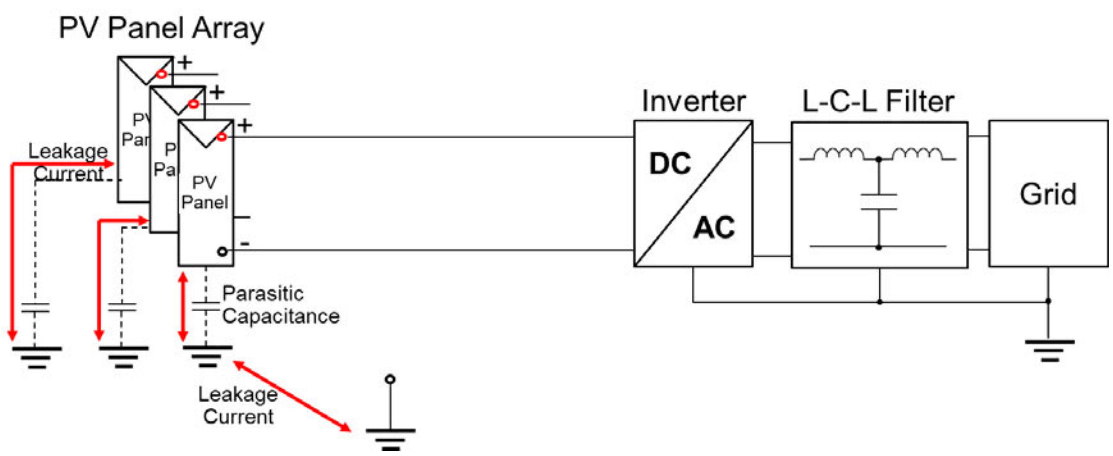
ASSR-601J

Insulation Resistance Measurement for Photovoltaic Panel Array in Transformerless PV Inverter System

Introduction

Transformerless photovoltaic (PV) inverter systems are getting popular these days due to lower system cost, higher efficiency, easier installation and maintenance. However, since the PV panel array is usually not grounded, DC leakage current may occur between the individual PV panel and ground through parasitic capacitance. Electric shock is possible if a person touches the PV panels. Figure 1 illustrates this DC leakage current.

Figure 1: Ungrounded PV Panel Arrays in a Transformerless PV Inverter System and Leakage Current That Can Occur Between Individual PV Panel and Ground through Parasitic Capacitance



Another trend in solar system is the increased in system voltages. Over the last 10 years, adoption of 1000 Vdc inverters have become more and more common over the traditional 600 Vdc system. Reason is simple. The higher the system voltage, the less is the copper content, and that lower the system cost.

Insulation Resistance Measurement for Transformerless PV System More Than 1000 Vdc

With these two trends driving the economics of solar PV inverters, the International regulatory standards require an automatic ground fault detections system to be equipped for installation of transformerless PV systems that are more than 1000 Vdc.

One method is to measure the insulation resistance of each panel with respect to ground. This indirectly also measures the leakage current. The measurement is usually done before the turning on of the PV inverter or at least once or twice per day. For a 1000 Vdc system, normal practice requires insulation resistance to be more than 1 MΩ. If the insulation resistance measured is less than this predefined level, than a fault feedback signal to the controller needs to be administered quickly enough to safely shut down the PV system.

ASSR-601J High Voltage Solid State Relay

Since the insulation resistance measurement is only performed once or twice per day, the measurement circuit will require a relay switch that can continuously withstand the rated voltage of the PV panel when the relay is opened, with very small off-state leakage current. During the measurement, the relay is switched on and closed.

The ON resistance has to be significantly smaller while allowing current of mA magnitude to flow through. In addition to the above, the relay should also provide sufficient high voltage isolation between the output high voltage on the side of the PV panel and the input side interfacing the low voltage controller circuit.

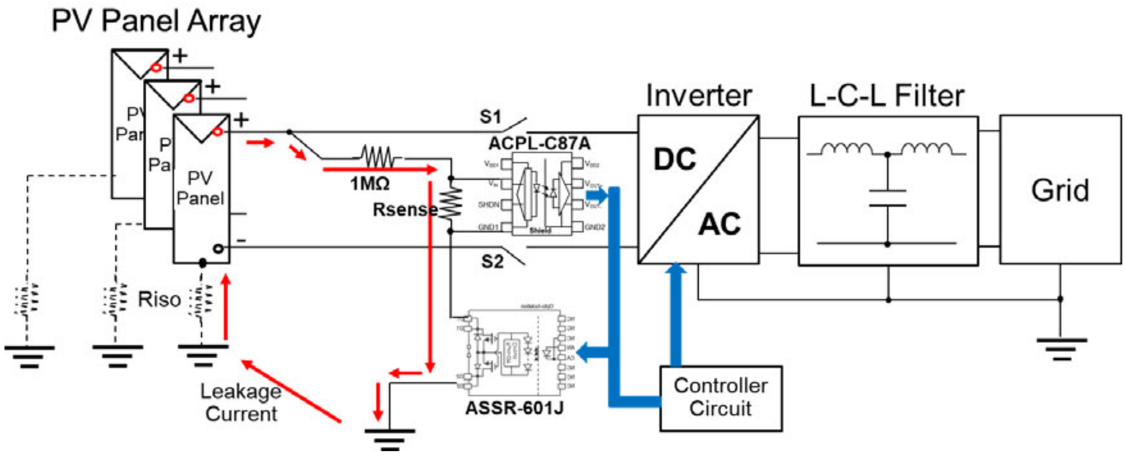
The Broadcom® ASSR-601J optically isolated high voltage solid state relay exhibits the following features that suit these requirements.

- OFF-state (open)
  - Continuous output withstand voltage: up to 1200 Vdc[1]
  - Min. breakdown voltage: 1500 Vdc
  - Max. leakage current at 1 µA at 1000 Vdc; T_A = –40°C to +105°C
- ON-state (close)
  - Load current: recommended max. 10 mA
  - ON resistance: max. 250Ω at I_O = 10 mA

The ASSR-601J is also certified to input-output isolation component safety regulation of maximum working insulation voltage (Viorm) of 1414 Vpeak in accordance to IEC 60747-5-5 and isolation withstand voltage (Viso) of 5000 V_{rms} per minute per UL1577.

1. Even though the recommended continuous output withstand voltage is 1000 Vdc as stated in the *ASSR-601J Data Sheet*, the part has been subjected to 1200 Vdc in the qualification tests without any failures.

Figure 2: Insulation Resistance Measurement Circuit Using the ASSR-601J High-Voltage Solid State Relay and ACPL-C87A to Sense Leakage Current



One example of PV panel insulation resistance measurement circuit is shown in Figure 2. Assuming that the rated voltage of the individual PV panel is 1000 Vdc during bright sunny day, good PV panel insulation resistance recorded is 2 MΩ and a bad insulation resistance is 100 kΩ. Leakage current across Rsense will be converted as input voltage to the ACPL-C87A isolated voltage sensor. The ACPL-C87A has an input linear range of 0V to 2V and for sensing current of mA magnitude, assumed that Rsense is selected as 2 kΩ in this application example. Since Rsense << Riso, Rsense can be ignored from the following calculation.

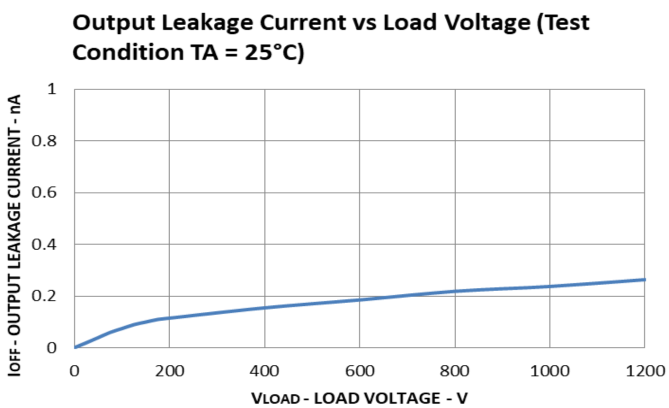
- Example of good insulation resistance Riso = 2 MΩ

  Leakage current = 1000 Vdc / (1 MΩ + 2 MΩ) = 0.3 mA. ACPL-C87A input voltage will record, Vin = 0.3 mA x 2 kΩ = 0.6V
- Example of bad insulation resistance Riso = 100 kΩ

  Leakage current = 1000 Vdc / (1 MΩ + 100 kΩ) = 0.9 mA. ACPL-C87A input voltage will record, Vin = 0.9 mA x 2 kΩ = 1.8V

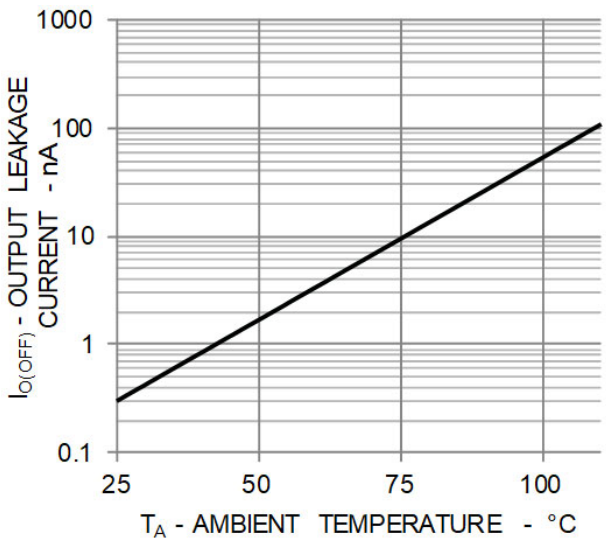
In some cases, the output voltage of a rated 1000V PV panels might experience surge as high as 1100 Vdc when the PV panels are exposed to maximum sunlight. In this situation when ASSR-601J is in the OFF state, the leakage current will be less than 1 µA. Figure 3 here shows the plot of the leakage current at room temperature up to load voltage of 1200 Vdc for a typical unit, extended from Figure 5 on page 7 of *ASSR-601J Data Sheet*.

Figure 3: Output Leakage Current vs Load Voltage Plot up to 1200 Vdc at Room Temperature



Since the leakage current measured at 1200 Vdc is only slightly higher than that at 1000 Vdc, it is safe to use Figure 4 on page 7 of the *ASSR-601J Data Sheet* as reference to predict the leakage current at T_A = 110°C and at load voltage of 1200 Vdc. It is quite clear from Figure 4 here that the leakage current will likely to be less than 1 μA.

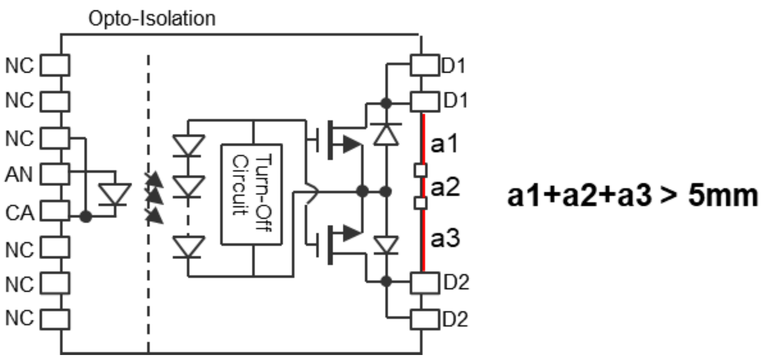
Figure 4: Figure 4 on page 7 of *ASSR-601J Data Sheet* Shows the Plot of Output Leakage Current vs Ambient Temperature at Load Voltage of 1000 Vdc



Functional Isolation

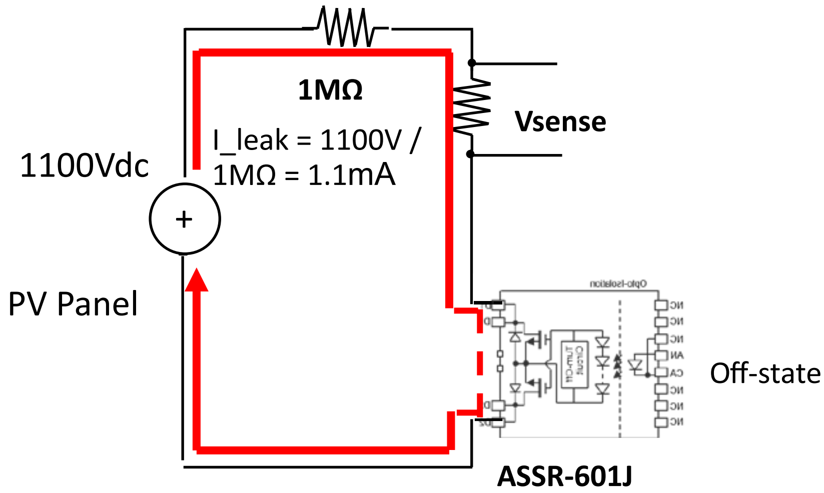
The ASSR-601J output pins are designed to have a minimum creepage distance of 5 mm. At this distance, the ASSR-601J provides an optional output functional isolation up to 1000 Vdc. This can be useful if the system standard requires functional isolation to limit the leakage current to a certain specified value, for example <2 mA during the off-state.

Figure 5: Total Output Pins Creepage Distance (a1+a2+a3) Is a Minimum of 5 mm



If the output pins voltage is more than 1000 Vdc, the 5 mm min. creepage distance might not be sufficient. The high voltage might creep along the side surface of package between the output pins. In that case, putting a 1 MΩ resistor in series with ASSR-601J can provide the system functional isolation instead of the 5 mm creepage distance between the ASSR-601J output pins. This is illustrated in Figure 6.

Figure 6: System Functional Isolation Provided by the 1 MΩ in Series with ASSR-601J



Conclusion

High voltage system in PV inverters operation requires a safe insulation resistance between the PV panel to ground. A poor insulation resistance less than 1 MΩ leads to a high leakage current (about 1 mA), which not only will damages the system but also injure the user.

Broadcom's new 1500 High Voltage, 1Form A, Solid State Relay (SSR) switch offers high reliability and fast response time at less than 0.5 ms. This industrial SSR has an ultra low leakage current at less than 1 micro-ampere.

References

ASSR-601J High Voltage, 1Form A, Solid State Relay (MOSFET), ASSR-601J-DS101 Data Sheet, Dec 5, 2017

ACPL-C87B, ACPL-C87A, ACPL-C870 Precision Optically Isolated Voltage Sensor, AV02-3563EN Data Sheet, Dec 18, 2017

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