# Operational sustainability in the field versus the laboratory: PV modules and insulation resistance

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ABSTRACT

Poor insulation resistance in modules is one of the primary contributors to module failure. Regimes currently in place to test the insulation resistance of crystalline silicon modules have proved problematic, as the conditions found in a laboratory are not on a par with environmental conditions at installation sites. This paper explores the shortcomings of current testing standards and recommends further tests that should be introduced to prevent module failures in the field.

## Introduction

PV module malfunctions can significantly impair the operational performance of solar projects, leading to decreased operating capacity and jeopardizing personnel safety. Since a PV module has no moving parts, its operating life is largely determined by the stability and resistance to corrosion of the materials from which it is constructed. Manufacturers' guarantees of up to 20 years indicate the quality of bulk silicon PV modules currently being produced. Nevertheless, there are several failure modes and degradation mechanisms which may reduce the power output or cause the module to fail. Nearly all of these mechanisms are related to water ingress or temperature stress.

As most people in the PV industry are aware, poor insulation resistance in modules is one of the primary contributors to module failure. This issue causes great concern to customers and manufacturers of PV modules. Even though the international standards for dry-insulation resistance are determined by rigorous laboratory testing procedures, extensive field failures persist. Both PV producers and customers have persistently questioned why PV modules that operate suitably in controlled laboratory settings intermittently malfunction in the field, and have contested the original testing results.

Source: Suntech.

Figure 1. Improved testing regimes are required in order to better understand module insulation resistance.

> "Even though the international standards for dry-insulation resistance are determined by rigorous laboratory testing procedures, extensive field failures persist."



Because of fluctuating weather conditions, PV module field installations do not operate in static, controlled conditions. Inverters very often enter into safe mode and shut down as a result of precipitation, as variations in weather conditions can stimulate energy leakages. In other instances, an inverter failure may be initiated by early morning dew. These situations suggest that PV modules have a low insulation resistance when operating in wet conditions. Nevertheless, when modules are returned to a controlled laboratory environment and retested, the modules function adequately under current testing standards.

## Insulation resistance testing

Currently, the measures for internationally permitted insulation resistance tests on crystalline silicon PV modules include the following tests: IEC61215ED2 10.3 Insulation Test, IEC61730-2 mst16 Dielectric Withstand Test, and UL1703 26 Dielectric Voltage Withstand Test. This sequence of tests is performed without illumination and at room temperature and a relative humidity of ≤75%. A study conducted by Suntech scientists, however, reveals that these testing conditions prove to be problematic, as laboratory conditions are not on a par with environmental conditions at installation sites [1].

Suntech's Quality Control team was tasked with examining the discrepancies. In an attempt to reform laboratory testing standards, and in turn reduce field malfunctions, Suntech's scientists were charged with isolating the integral inconsistencies between international testing standards for PV modules and the actual module operational conditions in the field.

## Suntech's experiments and results

Currently, Suntech has approximately 36 million PV modules installed globally; these modules have an operational failure rate as low as 0.04%. However, within the company's extensive corporate database, there are some reports of field module failure due to insulation performance deficiencies. Most malfunctions have occurred either in the early morning or on rainy days. The problematic PV panels exhibited a decline in insulation performance, which in turn triggered a leakage current, causing the inverter to shut down.

The team of Suntech scientists collected data for numerous elements that may affect PV module insulation performance; these included module temperature, relative humidity, illumination, and detection timing of system leakage current. The Suntech scientists conducted experiments, and results were established on the basis of each factor.

### Module temperature

With regard to increased module temperature, Suntech's tests revealed that the insulation resistance of a PV module measured at 25°C decreases by 75% when measured under field temperatures of 45°C (Fig. 2). As the field temperature rises, the decline in insulation resistance approaches 90% when the module temperature reaches 60°C.

### Relative humidity

The relative humidity results of Suntech's study confirm that an increase in relative humidity is exceedingly detrimental to the insulation resistance of PV modules. This behaviour poses a challenge, as relative humidity generally surpasses the laboratory standard of 75% in much of the world throughout the year. According to the study, the insulation resistance decreases approximately 50% when the relative humidity increases from 50% to 75%; the resistance drops again by half when the relative humidity rises to 90% (Fig.

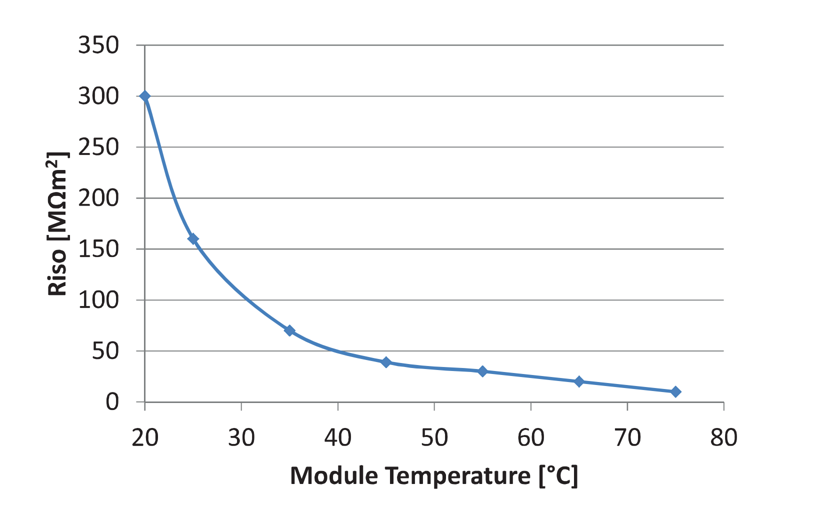


Figure 2. The effect of module temperature on insulation resistance.

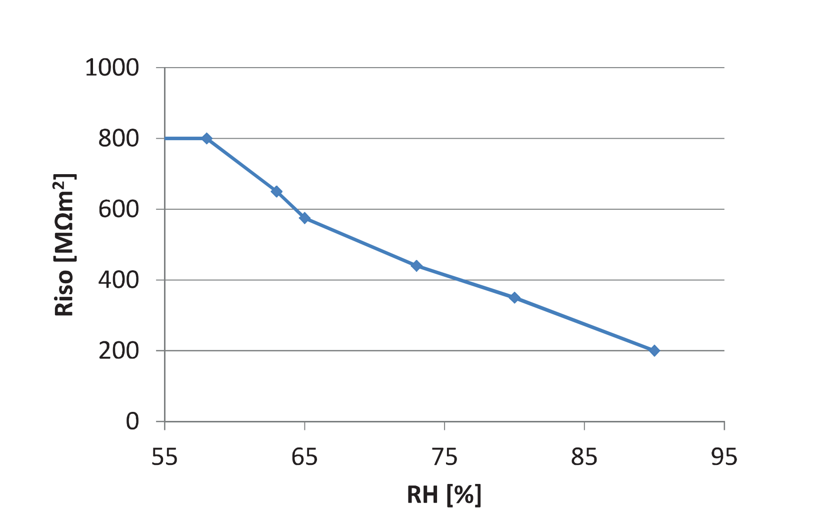


Figure 3. The effect of relative humidity on insulation resistance.

3). Relative humidity is a distinct and vital factor impacting the installation capabilities of a PV module once removed from the laboratory and operational in the field.

### Illumination

Suntech's Quality Control team also explored the influence of illumination on insulation resistance: the results revealed that illumination induces an increase in module temperature while simultaneously producing a significant decline in resistance. As a stand-alone factor, however, illumination does not have a major influence on resistance.

### Leakage current detection

A final factor that interferes with insulation resistance is the inverter settings. Suntech has established that inappropriate and rudimentary inverter settings can be the source of inverter malfunctions and system shut-downs, instigated by a temporary leakage current. The study indicated that the majority of devices have a protective measure that identifies leakage currents within five seconds of system activation.

Tests have shown, however, that there is a higher level of precision and stability 20 seconds after the PV installation is activated. Consequently, by implementing a 20-second delay in shutting down low-level leakage currents, the probability of false or unnecessary errors can be reduced. This factor, coupled with early morning dew, offers the true explanation as to why a considerable number of failures occur and are detected in the morning hours, when PV module installations power up.

> "Suntech recommends that current testing standards be enhanced by additional comprehensive testing measures."

## Conclusions

Suntech's findings show that the current international standards which are in place for testing insulation resistance are insufficient with regard to the prevention of operational malfunctions of PV modules once installed and functional in the field; furthermore, these standards are insufficient for ensuring personnel safety. Suntech's efforts have revealed that there is a distinct difference between laboratory test conditions and actual field conditions: laboratory testing conditions fail to simulate the increased temperature and high relative humidity that are common in PV installation surroundings. In order to decrease the number of malfunctions in PV module insulation on operational sites, Suntech recommends that current testing standards be enhanced by additional comprehensive testing measures.

Additionally, Suntech strongly recommends that the following tests be added to further reduce field failures: 1) extended dry-insulation test conditions, with a module temperature of 60±2°C and a relative humidity of 85±5%; and 2) extended wet leakage current test conditions, with a test solution temperature of 60±3°C. These testing conditions reflect the environmental and operational reality of PV module installations. If international standard procedures are enhanced through the addition of these tests, manufacturers and customers can experience minimal insulation malfunctions, better quality assurance and higher performance of PV modules with respect to insulation resistance.

### References


[1] Wang, G. et al. 2013, "Study on insulation resistance test of PV module", Presentation at the 28th EU PVSEC, Paris, France.


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### About the Authors


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