Solis Arc-Fault Protection Solution

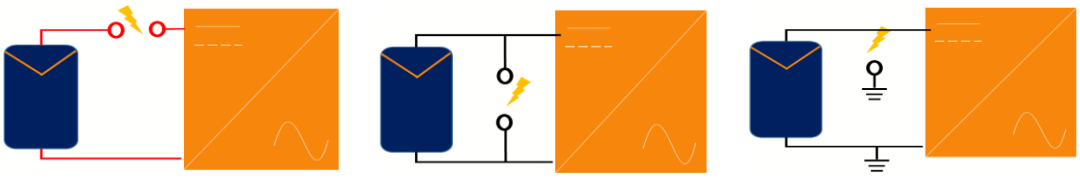
1. Background

Distributed PV system is difficult to achieve unified management and regular maintenance like ground power station system due to its complex and uncertain installation environment. The characteristics of distributed PV systems create higher difficulty of operation and maintenance, thus more security risks are likely to occur. Most distributed PV systems take advantage of the rooftop of factories and residences. Once a safety accident occurs, it will not only affect the normal operation of PV systems, but also may cause incalculable losses to the attached buildings and personnel.

The fire hazard of PV system is mostly caused by DC arc-faults, so the prevention of DC arc-faults of PV system is increasingly a concerned for all involved. Due to the high voltage and high current characteristics of the DC side of the PV system, common conditions such as aging of cable insulation, damp or poor contact of connection terminals, wear and corrosion of contact points, and loosening caused by external pressure may cause DC arc-faults. For industrial and commercial rooftop power stations, due to the large number of solar panel strings, the probability of arc-faults are greater and the ancillary facilities such as factories are endangered, resulting in greater accident consequences and potential losses.

2. Common types of DC arc-faults

According to the location where the DC arc occurs in the PV system, there are two types of arc-faults: series arc-faults and parallel arc-faults (To ground arc-faults belongs to parallel arc). Most of the parallel arc-faults are caused by short current between positive and negative and ground due to the insulation damage of the cables and this kind of arc-faults is easy to recognize. However, the series arc-faults are more likely to occur due to virtual connection, and the fault current is small, so it is not easy to be recognized. The arc temperature is high enough to burn down the insulation layer of the cable and further cause fire accidents.



a. Series b. Parallel c. To Ground

Fig1- Types of DC Arc-Faults in PV Systems

3. Solis Arc-Fault Protection Solution

In terms of industry standards, UL1699B defines the AFCI functional test requirements for PV systems, and the draft IEC63027 has not been formally implemented. As one of the inverter manufacturers that entered the American market many years ago, Solis has a detailed interpretation of the standard requirements of UL1699B, and the AFCI scheme of Solis inverter fully meets the requirements of UL1699B. Based on the 2018 version of UL1699B requirements, Solis AFCI solution has the following features:

- **Arc detection feature algorithm**：Solis uses the software arc feature recognition algorithm to realize the real-time detection of arc-faults in combination with the inverter's existing high-precision current-voltage sampling circuit. Compared with the traditional hardware detection method, the reliability is higher and there is no failure caused by damage of AFCI hardware detection components.
- **Arc feature database:** Solis studied and analysed a significant number of different arc-faults, arc laws, arc characteristics, electrical parameters and frequencies of arc-faults, and established the characteristic value database of arc-faults. This database has been developed over many years of continued analysis to increase the effectiveness of arc fault detection.
- **Misjudgement prevention** : The arc fault has the characteristics of fast current rise and high frequency noise component. By using double detection of fault arc spectrum and energy, arc-fault false alarms can be prevented effectively. Based on the statistics in US market, the percentage of false alarms in DC arc- fault detection was far less than 0.1% in the operation of more than 40,000 PV power stations equipped with Solis AFCI solution.

- **String-level arc-fault location**： The arc current can be the same as the maximum MPPT current 26A and the inverter will shut down and give an alarm within 0.5 seconds. It can accurately locate the arc-fault point to a specific string.

Item	Parameter
Arc-fault type	Series arc-faults
Detect arc-fault range	All strings
Arc-fault location	String-level
The maximum length of the cable can be detected	Single phase：80m Three phase：200m
Maximum arc-fault current	Maximum MPPT current
Accuracy of arc-fault detection	100%
Arc-fault energy	<300J
Turn off time	<0.5s

4. Experiment

Solis simulated DC arc-faults under various scenarios in the laboratory to test the AFCI function of the inverter. The test waveform shows that the inverter can turn off and give an alarm within 0.5 seconds when there is a DC arc-fault in the circuit, which can effectively avoid the potential fire caused by the DC arc-fault.

Fig2- Fault arc waveform at arc-fault generator (312V, 3A)

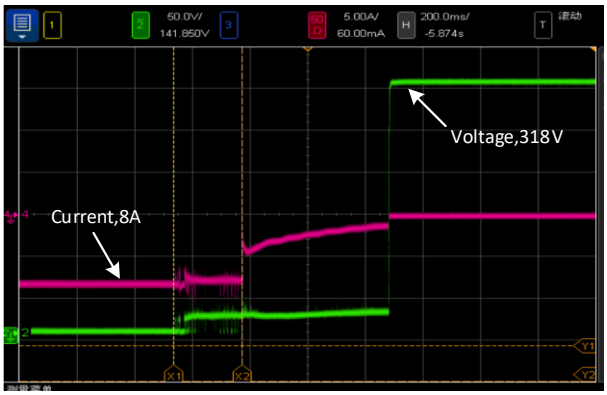


Fig3- Fault arc waveform at arc-fault generator (318V, 8A)

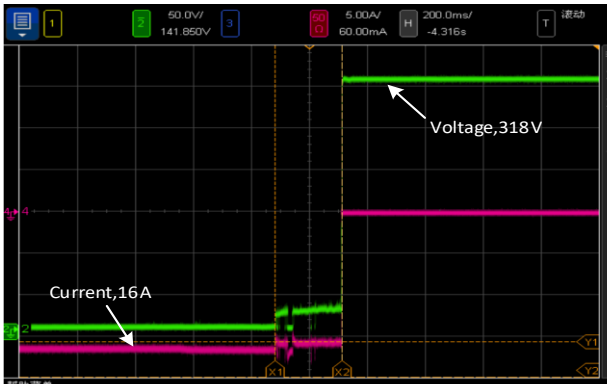


Fig4- **Fault arc waveform at arc-fault generator (318V, 16A)**

5. Conclusion

DC arc-fault is the biggest security threat to rooftop distributed PV systems. Solis AFCI intelligent arc-fault detection solution can realize accurate arc-fault location. By extracting and analysing the characteristic values of arc-fault voltage, current, frequency and harmonic components, the arc-fault and noise interference can be distinguished effectively, so as to avoid the occurrence of arc-fault misjudgement.