Solar Systems – AC V DC

Within the PV industry, the risk presented by DC arc faults is gaining significant attention, and for good reason. The DC circuits within a PV installation can generate, and sustain, arcs of considerable intensity. Not only have these arcs started fires, but the intensive energy that generates these arcs also poses a significant risk to firefighters during their efforts to suppress the fire.

DC system with panel failure which caused arcing and subsequent fire in SA Nov 2011.

Reliable detection of arc faults is a serious challenge, and determination of the appropriate corrective action is difficult. PV system design philosophy has a significant impact on both prevention and suppression of fires, with an increasing preference being given to AC-based systems that mitigate the risk of fire by avoiding distribution of high DC voltage and high DC current altogether.

As an industry, we have done a good job of providing adequate system protection and safety mechanisms. Widespread deployment of PV systems teaches us new lessons. We must learn from those lessons and continue to improve the safety of PV systems. Arc fault detection is a necessary next step.

Aspects of DC Arc Fault and Safety

Recent proposed changes to the National Electric Code in the US underscore the gravity of DC arc fault risks. The changes (which have NOT yet been adopted as of this writing) will mandate detection of — and preventative measures for — series DC arc faults in systems where the DC voltage exceeds 80VDC. This is a step in the right direction as it addresses the prevention element of DC arc fault safety. There are two elements to the DC arc fault/safety issue:

1. **Prevention** – this aspect deals with the mechanism and factors necessary to create an arc, especially one that is capable of becoming the source of ignition of nearby combustible materials. It should be noted that DC arcs can reach temperatures of over 3,000 degrees C. Arcs of this temperature can melt metal, which can fall as slag and ignite nearby combustible materials. Preventative measures are therefore necessary to minimize the risk of starting the fire in the first place.
2. **Suppression** – this involves all aspects related to extinguishing the fire after it has started. Fires are typically started by some means other than the PV system, but the presence of relatively high DC voltage and high DC current presents a significant risk to the firefighters.

Types of Arcs

Three types of arcs are of particular concern:

1. **Series** – A series arc occurs when a connection is pulled apart while the PV is producing current. Any intermittent connection in the DC circuit has the potential for producing a DC arc fault. These connections may include soldered joints within the module, compression type wire connections, or the actual connectors that are commonly used on the wire leads attached to PV modules.

2. **Parallel** – Parallel arcs occur when an insulation system suffers a breakdown. Two conductors of opposite polarity in the same DC circuit are often run in close proximity to each other. The insulation between the two wires can become ineffective due to animals chewing on them, UV breakdown, embrittlement, cracking, moisture ingress and freeze/thaw cycles.

3. **To ground** – This fault only requires the failure of one insulation system. While GFDI (Ground Fault Detector & Interrupter) provides some measure of protection against this fault, there have been cases of faults to ground that failed to trip the GFDI protection yet created an arc.

Challenges with Arcs

Detection of the arc is the first real challenge. It is paramount that the arcs are reliably detected without raising “false alarms.” Many different techniques can be employed, with most relying on voltage, current, radiated energy, or a combination of these.

Taking appropriate action once the arc has been detected is the second challenge. Furthermore, the correct action for series arcs is the opposite of the action necessary for parallel arcs. In fact, the corrective action for a series arc can actually exacerbate a parallel arc.

To extinguish a series DC arc, power production must be ceased and current flow in the DC circuit must be reduced to a very low level. It is preferable to reduce the DC current flow to zero in order to guarantee that the arc is extinguished. The PV inverter can accomplish this by ceasing exportation of power.

A parallel arc requires the opposite action. The two DC conductors must be shorted together to bring the array voltage to zero. Once the voltage is near zero, the arc extinguishes and the protective device must be capable of carrying the array short circuit current indefinitely.

System Design

Three aspects of system design contribute to the arc fault risk: high DC voltage, high DC current and large geographic distribution of DC wiring. To sustain an arc of significant temperature, the voltage across the arc gap must be in the range of 20 volts or more. DC short circuit current capabilities below 2 or 3 amps have a difficult time sustaining an arc of any real danger. Wide distribution of wiring systems increases the likelihood of physical damage and increases the degree of exposure to firefighters during the suppression phase of a fire.

A traditional string/central inverter PV system design is not beneficial in terms of addressing arc fault risk and firefighter safety. Strings are designed for the highest DC voltage to reduce I^2R losses, and multiple strings are placed in parallel to increase the DC current. This design also results in a large geographic distribution of DC wiring systems. All three of these design factors increase the risk of arc faults and make it more difficult to suppress a fault once it occurs.

The impact of DC-DC converters, which operate at high DC bus voltages and connect to a traditional string/central inverter, resulting in the large geographic distribution of DC wiring, is uncertain. Certain types of arc faults could fool the control system into taking inappropriate control actions and theoritically worsen the problem. Some of these systems also rely on communication controls for safety functions. Without appropriate safety measures similar to those used in aerospace control systems, this is a questionable approach.

Microinverter and AC module designs work at much lower DC voltages, lower DC current, and limit the distribution of DC wiring to the vicinity of the module. These inverters are Utility-Interactive, which means that the removal of Utility AC power from the system, results in no AC voltage being distributed, and low voltage DC under each PV module. This approach reduces arc fault risk and provides the greatest degree of safety for the firefighters.

In summary, as the concern for fire prevention and suppression rises in the PV industry, more attention is being paid to the threat of arc faults. Challenges with arc faults include understanding the type of arc fault and ensuring that the appropriate corrective action is taken. System design also has a significant effect on both prevention and suppression of fires, with increasing preference being given to AC-based systems that mitigate the risk of fire by avoiding distribution of high DC voltage and high DC current altogether.