The development of rapid shutdown

With the popularity of photovoltaic plants, more and more emergency crew and firefighters of photovoltaic plants are aware of the potential safety hazards of photovoltaic systems. Generally, after a fault occurs in an AC circuit, there is sufficient protection equipment to cut off the fault point from the power supply to ensure that the fault does not always exist. Most of the circuits of photovoltaic plants used 600 ~ 1000V (some even up to 1500V) DC circuit. In an actual power station, DC arcs can be caused by fault such as poor connection, poor contact quality, insulation aging, and damp insulation, etc. Photovoltaic modules continuous generate electricity when a DC fault occurs. The DC current does not have a zero-crossing, so the fault current at the trigger location will persist for a long time and further cause a fire.

On the other hand, as long as there is a light, PV module generates power. When a photovoltaic system fire occurs, a 600V to 1000V high-voltage DC poses a threat to the personal safety of firefighters and hinders fire rescue.

Figure 1 solar panel fire accidient

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The publish of 2014 NEC 690.12

In order to shut down the photovoltaic system to prevent emergency crew from electric shock, it seems that switching off the DC isolation switch is a simple and logical solution. In fact, disconnecting the DC disconnect switch does not reduce the risk of electric shock from the photovoltaic system. Because there are voltages on both sides of the DC isolation switch, the photovoltaic array side has a DC voltage of 600-1000V during the day, and the other side of the switch is usually connected to an inverter with a large input capacitor. High voltages can be generated long after the disconnector is turned off (current has been switched off). Regardless of whether fire agencies understand this false sense of security, many fire agencies still require the use of a DC isolator to ensure the safety of firefighters. To this end, the relevant requirements of 2014 NEC 690.12 have been published to ensure the safety of photovoltaic systems in or on buildings. The main requirements are:

1. Outside the building, the border of the photovoltaic array is 10 feet from the edge of the photovoltaic array.
2. Within 10 seconds after the shutdown, the voltage of the conductor outside the boundary of the photovoltaic array or within 5 feet of the building drops below

30V.

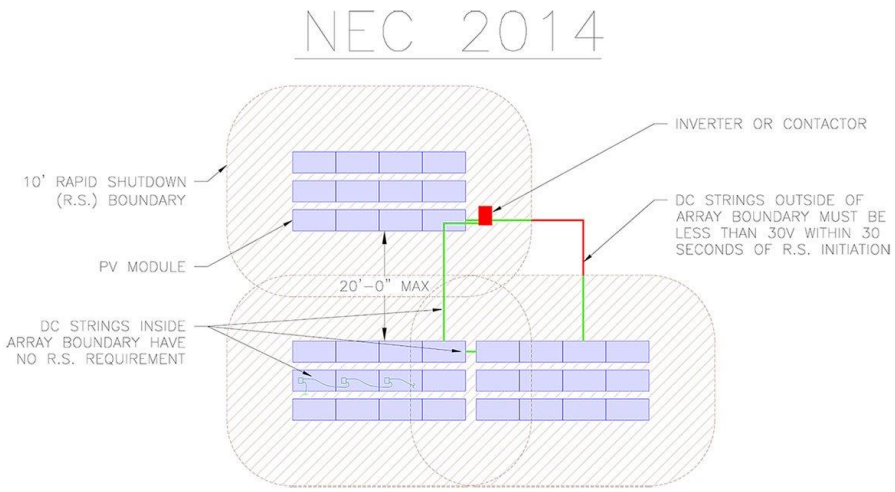

Figure 2 NEC 2014 requirements

This means that photovoltaic systems or auxiliary systems that are not installed in or on a building do not need to comply with the relevant requirements of 2014 NEC. And if the photovoltaic system needs to enter the building, it needs to have some remotely activated switch within 5 feet of the entry point (or closer to the photovoltaic array outside the building). On the inverter side, if the inverter cannot internally reduce the circuit voltage to 30V or isolate the capacitor within 10 seconds, you need to install another string-level rapid shutdown within 5 inches of the inverter.

To activate the string-level rapid shutdown, although a remote-control function is required, a specific controller is not required, as long as the firefighter switch off the AC power, the string-level rapid shutdown can be activated.

In hybrid grid-connected systems, the introduction of energy storage equipment makes the system more complex. Because energy storage equipment is generally used as a backup power source when the main power is disconnected. Therefore, if the mains power is disconnected, string-level rapid shutdown switching off the energy storage power will destroy the function of energy storage equipment. Therefore, these energy storage device-based systems require a starter that is independent of the mains AC power. If the cable from the energy storage device to the inverter is less than 5 feet, there is no need to install a rapid shutdown between

the inverter and the energy storage device. If because of this situation (because the cable is less than 5 feet, there is no rapid shutdown between the energy storage device and the energy storage device), the AC switch that can be remotely controlled needs to be installed on the AC output side of the inverter. And if the cable between the energy storage device and the inverter is more than 5 feet, you need to install a rapid shutdown at a place less than 5 feet away from the energy storage device, and the inverter's output circuit no longer needs to AC rapid shutdown, because once the DC input is cut off, the inverter will automatically shut down all AC outputs. By the same reason, if the inverter is outside the building and is less than 10 feet away from the photovoltaic array, there is no need to add a rapid shutdown between the inverter and the photovoltaic array.

Not only the US market, but also the Italian, German, Australian, and Japanese, etc. markets have introduced regulations to protect emergency and firefighters in different ways.

The improvement of 2017 NEC 690.12

Through the 2014 NEC regulations, the safety of the US photovoltaic system has been greatly enhanced, and many other countries have quickly followed up with this regulation to ensure the safety of more firefighters. However, the above requirements cannot provide full-scale protection. On the one hand, there is no requirement to limit the voltage within the boundary of the photovoltaic array. When a fire occurs, firefighters cannot extinguish the fire on the photovoltaic array. On the other hand, the boundary range is quite large. For example, some wires connect two photovoltaic arrays as long as 20 feet, but the voltage of which is not limited by this regulation. This led to the publish of 2017 NEC.

Compared with the 2014 version, the 2017 NEC has made the following changes:

1. Reduce the boundary range from 10 feet to 1 foot;
2. The voltage within the boundary also specifies the limit that the system can drop

to 80V within 30 seconds, and the limit outside the limit is required to drop to 30V within 30 seconds;

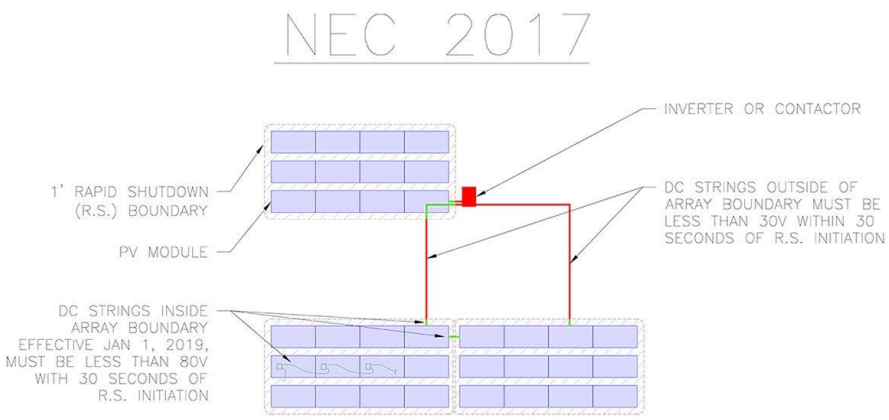

Figure 3 NEC 2017 requirements

The change of the boundary range has reduced the length of the two array connected cable from 20 feet to 2 feet. And this does not meet the requirements of fire lane width in many countries. On the other hand, the voltage between any two points within the boundary is limited to less than 80V, which is much lower than the system voltage of the photovoltaic system of 600V-1000V.

Therefore, new methods are needed to provide more secure guarantees. There are two main methods currently available:

1. Micro inverter

2, Module-level rapid shutdown or optimizer with rapid shutdown function

The micro-inverter can provide protection equivalent to the open circuit voltage of a single module, whether it is installed on the module or externally attached to the module (generally about 40V). Micro-inverters are a good choice for simple small systems, but there are many disadvantages to face:

1. Reliability: For a PV system, each panel needs an inverter. Due to the large amount of micro-inverters, the probability of failure compared to string inverters is also same number increased;

2. Low efficiency: The efficiency of micro-inverter is about 95%, and the efficiency of the string inverter is more than 98%.

3. Unable to connect energy storage equipment: In systems with energy storage requirements, micro-inverter solutions cannot be used.

A module-level rapid shutdown is a type of shutdown switch installed on or near a photovoltaic module. Each shutdown switch serves one or more modules, and when necessary, cuts off the connection between the panels to eliminate the DC high voltage present in the array. Normally, there is a controller powered by the AC terminal, which is controlled by a separate line or DC line.

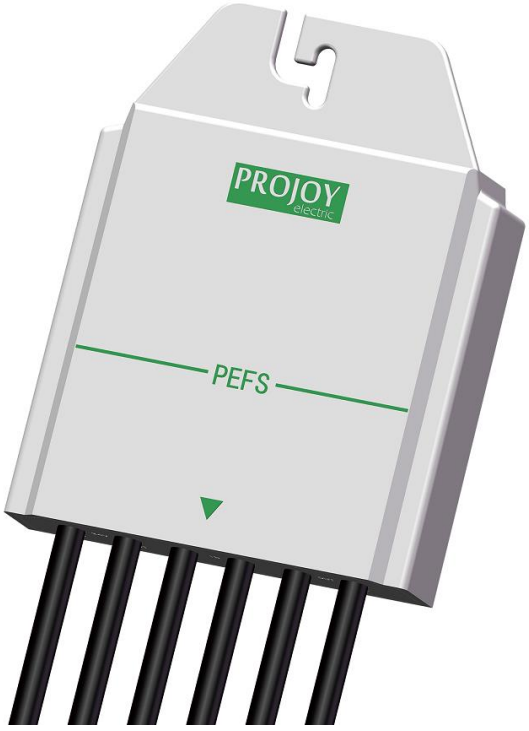

图 4 苏州普兆组件级快速关断

The rapid shutdown is flexible in use and can be used with string inverters to provide protection, that is to say, it could worked with energy storage equipment. For existing photovoltaic power plants, protection can be provided by simple series connection. Projoy Electric's module-level rapid shutdown keeps the safety of photovoltaic systems and firefighters.