ARC FAULT DETECTION IN PV INVERTERS AND HOW PLANT OPERATORS CAN REDUCE ELECTRICAL FIRE THREATS

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Delta has launched inverters with DC arc fault detection function for distributed PV systems. Arc fault detection circuits are now mandatory in the USA and requires a full certification based on UL 1699B-2018. With such requirements, European installers can be ensured that arc fault detection function has been implemented in a safe way.

Delta released this technical white paper on arc fault detection to allow an easy understanding of this function and how it works.

This white paper gives an overview on development background, based on physical phenomena and associated state of the art measurement technologies, to allow a full and efficient arc detection possibility.

Technology Development Background

In distributed PV, the mainstream deployment method involves installing PV modules on various buildings, including building integrated photovoltaics (BIPV). As such, electrical safety is the focus of accident prevention for this type of power generation form. Based on feedback from experience in the last years throughout Europe, the focus has turned particularly to the protection of the DC-side infrastructure against electrical fire, electric shock, and lightning strike accidents.

Figure 1 - picture of electrical fire damage in a PV system

Some Key ideas

- Arc faults result from a failure in the intended continuity of a conductor
- When a conductor is interrupted and forms sparks, it will produce light and a high amount of heat, which will lead to fires and property damage.

For the photo to the right, arc fault may have been caused by:

- damaged, pinched or abraded conductors,
- loose or separated connections or terminations,
- cracked or corroded solder joints in modules or other components.

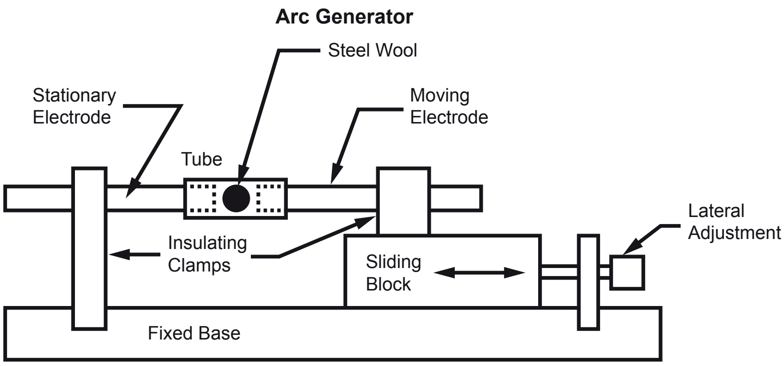

Figure 2 - Arc Fault Generator

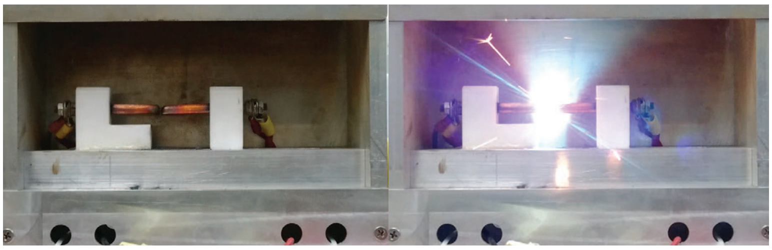

Figure 3 - Illustration of arcs in a lab environment (pictures from Delta Electronics R&D)

Safety Standards

The safety standards and safety protection technology concerned with AC are currently mature. As such, the IEC and countries across the world are focusing on the formulation of standards concerning DC. Currently, PV power plants installed in Europe, have to comply with several standards, whereby all of them bring complementary requirements (IEC 62109-1/-2, IEC 62548, IEC 60364). None of these standards bring specific requirements for arc fault detection yet.

In case of damaged DC strings and wherever the location of damage occurs (module frame/cells, cable/array, etc…), maximal potential peak current is strongly related to the modules short circuit current (or sum of the current of several strings). One way to efficiently reduce the risk of fire, is to interrupt DC current, by stopping current conversion from the inverter DC stage to AC stage, and finally by stopping the current injection.

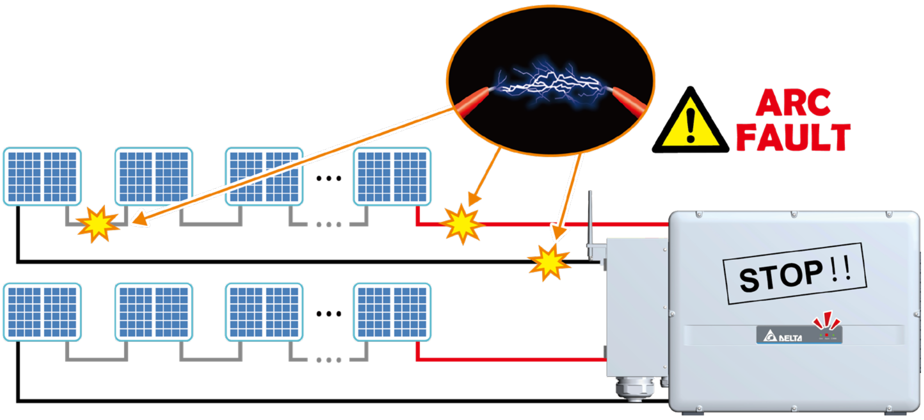

Figure 4 - Arc Fault Detection in a Delta M250HV inverter

Electrical fires — mainly caused by DC arcing — are the primary risk that needs to be prevented for distributed PV systems. This is why it is mandatory that new functions are employed, especially arc detection and rapid disconnection solutions, in order to improve the safety and surveillance of PV plants.

Technical Description

Wikipedia gives the following definition of an arc flash: An arc flash is the light and heat produced from an electric arc supplied with sufficient electrical energy to cause substantial damage, harm, fire, or injury. Electrical arcs experience negative incremental resistance, which causes the electrical resistance to decrease as the arc temperature increases.

Figure 5 - An arc flash produces light and heat and can cause substantial damage

As mentioned above, arcs can be generated by several kind of mechanisms in-between electrical and energized wires, and metallic parts. Neither the average current producing the arc, nor the rms value of the alternative component can be used to describe such phenomena.

As shown below, the current flowing via the arc has high dynamic current variations (due to ionization of the air / easy to recognize by typical associated acoustic noise). In a spectral representation, the high density of current variation refers to an increase in wide band noise level (can be considered so-called “white noise”).

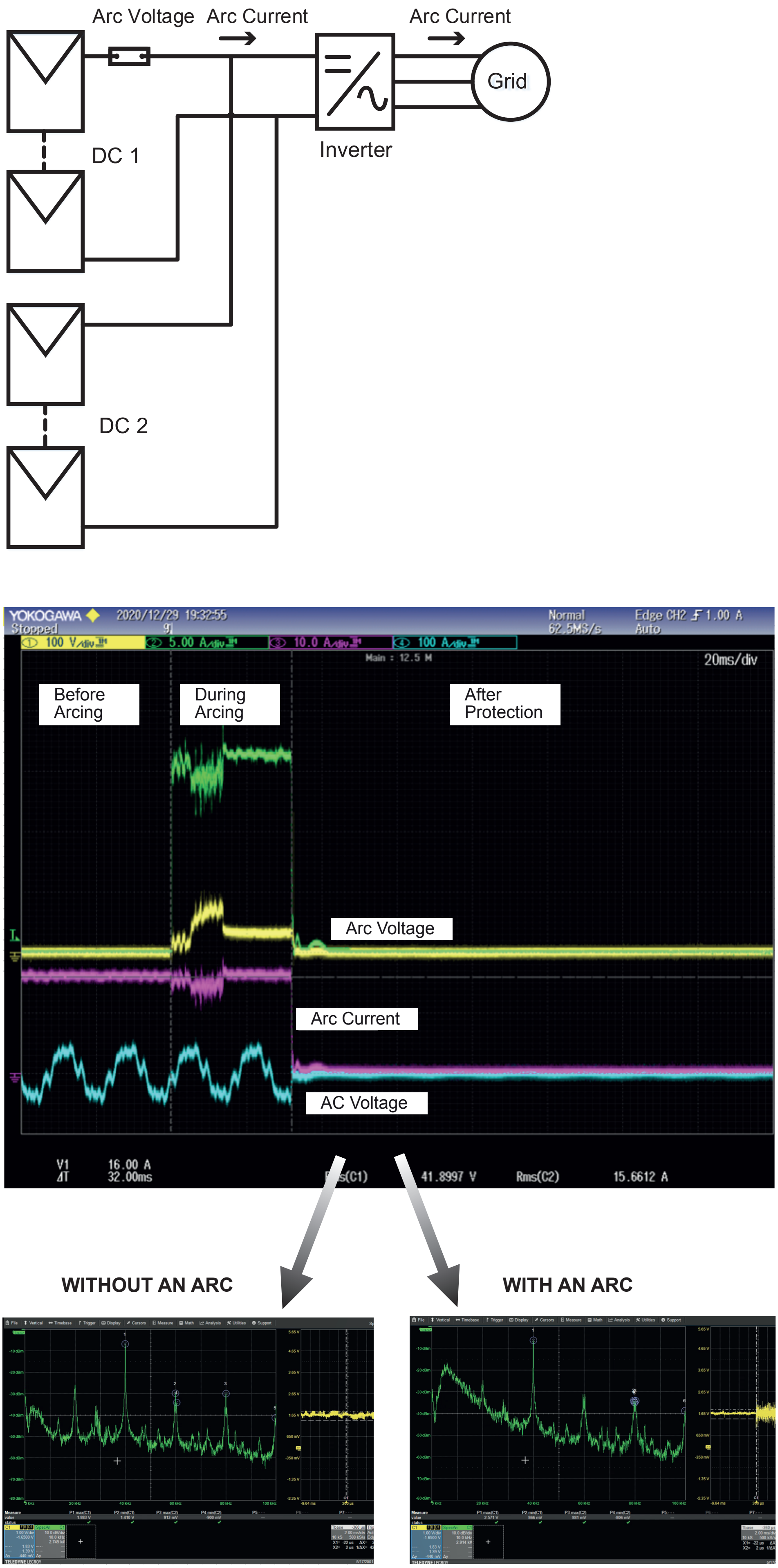

Figure 6 - Arc faults can be detected by anomalies in electric currents. Increase of noise at varying levels of high frequencies are characteristic of an arc fault event

Due to an equivalent model of the modules, attenuation of the signal, depending on the string length can be considered as marginal. Despite an impact on the impedance of the number of used modules, the attenuation is changing depending on PV current (NNSA report / free for publication).

Based on the above research results and observed feedback from experience, UL defined a needed test setup to make sure the minimal requirements given in UL 1699B-2018 are fulfilled.

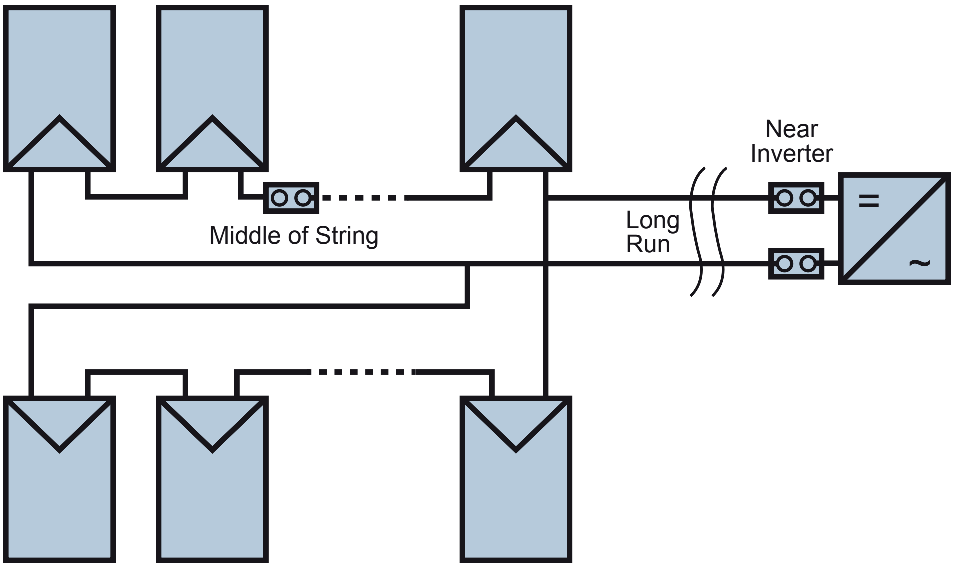

Figure 7 - The position of modules must be optimized in order for high power inverters to utilize the arc fault detection function

Concept Limitations

Despite optimized sensitivity of arc detection devices and the algorithm used, the environment where the PV plant has been installed can be polluted due to industrial activities (uses of electrical engines). This localized EMI pollution, either conducted or radiated, can through several routes of electromagnetic couplings impact the arc detection solution and create parasitic alarms.

For the use of the arc detection function in high power inverters, the length of DC cables and their positions must be optimized. If on a theoretical approach, it has been shown that the number of modules does not impact the efficiency of the arc detector, long cables and parallel laid (even overlaid) cables sharing the same cable trails will get coupled and can produce uncontrolled effects on arc detector efficiency. The design and the use of a separate and exclusive cable trail, per inverter, would be a favourable solution.

Furthermore, as shown in fundamental research results, the more the string current increases, the more difficult it becomes to define arc detection thresholds. In applications with high current modules, the above points need to be observed most seriously to have a well-designed and efficient system.

Technical Features

Thanks to collected experience throughout the world and especially in the US market, Delta Electronics is continuously considering the latest improvements needed in its embedded arc detection feature (for e.g algorithm adaptation, sensitivity improvements…)

Delta Electronics focuses first on serial arc fault detection, which is the most probable fault that can happen.

The arc detection feature has successfully performed according to the requirements in the above-mentioned standard, particularly in demonstrating a disconnection time clearly below 1s / 80m (default length =/= max length).

About the author

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The engineer studied electrical engineering at Polytech Paris-UPMC and works as Product Manager for the European market at Delta Electronics (Netherlands) BV. He also holds a master's degree in business administration (MBA) from the University of Strasbourg. A native of France, he worked in the telecommunications industry for eleven years before moving to the solar industry in 2008. He joined Delta in 2010.

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