Improved Safety of PV against Fire using a novel Arc Detector

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ABSTRACT

Despites of its youth, PV has already a sinister history of fires. The amount of damages caused by fire amounts to around 5 Mio US $. This is a very high number with regard to the still limited number of installed PV systems.

Just to mention a few of these accidents: the fire which destroyed the control room at the 1 MW PV plant in Sacramento, the fire in the control room of the PV system at the airport in Nice, the fire which destroyed one residential house in Switzerland, a fire in a switch gear in the 500 kW installation at Mont Soleil in Switzerland and many insignificant small arcing fires which destroyed connectors and combiner box, but have fortunately not led to dramatic fire.As PV-systems are supposed to spread out as a source of renewable, non polluting energy, the risk of fire will increase may even become a barrier for large volume applications for residential and commercial roof top systems if no means will be developed to control the risk of arcs which are producing these fires.

Alpha Real has invented such an arc detector and collaborated with the School of Enginners in Burgdorf to develop and test an arc detector. Test results have shown that the arc detector represents a very powerful mean to detect any arc in the DC wiring of a PV system. Problems with relevant "noise to signal levels" may only arise if the inverter produces more noise on the DC level than is allowed by relevant IEC standards.

The arc detector is hooked by two capacitors onto the plus and minus of the DC array wiring. The arc detector detects arcs which are developed within the cables or connectors but also arcs which develop over plus and minus lines. A schematic overview is given in the figure below. The alarm signal can either be used to disable the array or inform any personnel.

1. Working principle

Every arc develops electromagnetic emissions. The spectra of arcs from AC systems are well known and are mostly very intense. The reason why arcs from AC currents are very intense is that the field in the plasma changes its direction every time the voltage goes through O. Therefore, e.g. in a 50 Hz system, the plasma changes its field direction 50 times per second. The main consequences are twofold:

- the electromagnetic emission is very intense and very strong
- the intensity of the plasma is quite low since jons are travelling forth and back and therefore, their kintetic energy cannot build up over the distance of the two electrodes.

The characteristics of the DC arc, however, is quite different. The main differences, again, are twofold:

- The energy content of the plasma is extremely high, since jons are always travelling in the same direction and are accumulating kinetic energy travelling through the space between the electrodes.
- Since DC current has no 0-passage of the voltage and the field between the electrodes remains quite stable, electromagnetic emission from the arc is quite low.

One would assume that such a DC is much more dangerous in terms of fire and much more difficult to detect by electromagnetic detection. Extensive tests have shown that the energy of the arc is much higher than an arc generated by an AC system,

working at the same voltage and same current. Therefore, fires are much more likely to come from a DC arc than from an AC arc. Furthermore, spectra from DC arcs are almost in order of magnitude smaller than those from an AC arc.

2. Working principle of the detector

A serious resonance detector, combined with an LC-impedance, is hooked with two capacitors on the current carrying Plus and Minus cables of the PV DC wiring system. Extensive field testing in several PV configurations have shown that an arc will stimulate eigenfrequencies in the LC-oscillator. In fact, sevral volts of signal-to-noise-levels have been measured over the impedance of the LC-impedance (in fact, the voltage drops have been measured over the capacotor). The reason for this very high sensitivity even for very small arcs within the DC cabeling system is the following:

The arc has a negative impedance and therefore stimulates the oscillating resonance characteristic of the detector.

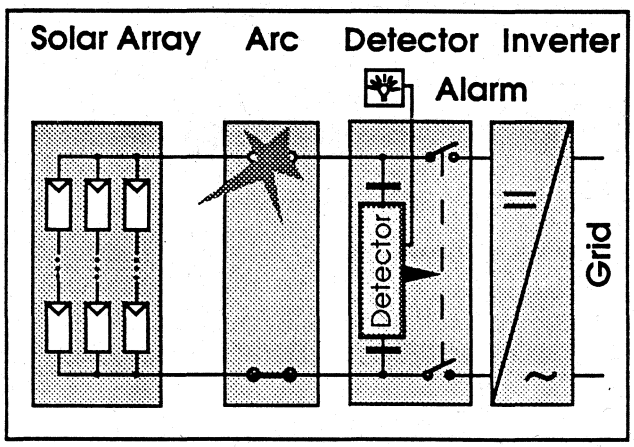
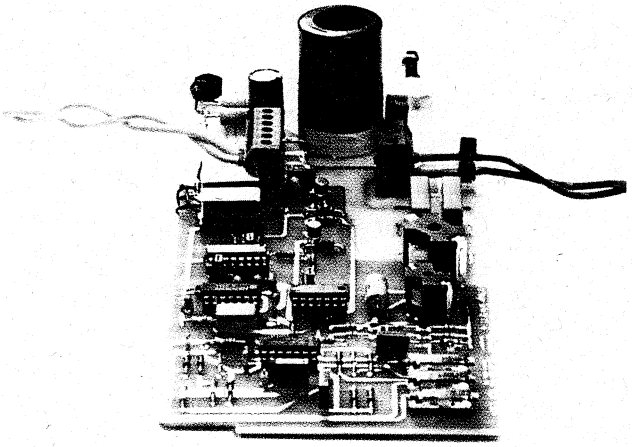


Fig. 1 shows the general configuration of the PV array, a typical situation where an arc can develop within a combiner box, the arc detector and the inverter as the interface to the grid. The arc detector will develop an alarm and disable the alarm and/or give an alarm for maintenance

3. Test results

Several prototypes have been built and successfully tested. E.g. within the 60 kW-array at the Ingenieurschule in Burgdorf, Prof. Häberlin and his crew have detected even small arcs at the end of the large array.

The signal-to-noise ratio is large enough to differentiate between signals from arcs within the DC array and signals from arcs from other devices and houshould appliancies such as motors and other switches.



Figur. 2 shows the print board of the arc detector. The arc detector by itself carries about a third of the print board. The rest is for power supply and some special logic circuitry, which helps to distinguish arcs developed the cabeling or between plus and minus of the array.

The arc is in some way sensitive to the harmonics which are generated by the inverter. It has been shown, however, that if the harmonics of the inverter are within the specification of the European Standard, signal-to-noise ratios are still good enough for safe and reliable operation of the arc detector. However, e.g. with one inverter, the arc detector couldn't trim to a safe signal-to-noise operation because the inverter generated by itself so much noise on the DC side that it interfered with the arc detector. Applying a filter on the DC entrance of the inverter, and therefore bringing emissions from the inverter within allowable tolerances, cured the situation. Tests of such an improved distortion of an inverter with the arc detector have been conducted successfully.

4. To show reliable operation, further and more extensive field testing is necessary

The arc detector proved to be the missing link in a novel safety concept. In order to carry out these tests and to elaborate an overall safety strategy and a safety device, an international consortium has

been put together to carry out the continuation of the very promissing approach. The partners of the project will be ANIT and ENEL from Italy, Fraunhofer Institute in Freiburg from Germany, Alpha Real AG and the Engineering School from Switzerland.

5. Acknowledgement

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