Evaluation of PV connectors

Summary

Safety is a very important factor in the evaluation of PV plug connectors, which must take into consideration both the safety of persons and functional safety. The evaluation must cover normal operation as well as possible faults and extreme conditions. Other points that must be included in the assessment are the use of different leads, safety aspects of on-site installation and the possible environmental conditions. In order to make a meaningful assessment, a large number of different cases must be evaluated and tested.
These criteria are the basis for the development of PV products by Multi-Contact, and have been tested accordingly. An assessment of this kind cannot be reduced to a few laboratory tests. Tens of millions of MC plug connections have been installed and operated over the past twelve or more years, and this is a further practical demonstration of their safety.

1 Safety

With regard to the safety of PV plug connectors, here we should like to consider two aspects that are currently under discussion in the industry.
On the one hand we shall examine the safety of persons, in which respect the connectors are considered both with regard to their normal use and possible damage events. On the other hand functional safety is considered. This concerns, for instance, a poor electrical connection which can cause overheating and in the worst case result in arcing and fire.
Multi-Contact's PV plug connectors have already given proof of their safety in both these fields over a period of more than a dozen years. This is demonstrated in the tens of thousands of installations with many millions of Multi-Contact plug connections..

1.1 Safety of persons

Tests such as the touch protection test IP2X, which concerns the prevention of contact with live parts, or the voltage resistance test, apply to the safety of persons. In this document we should like primarily to discuss the latching and locking system.

1.1.1 Latching and locking systems

Safety considerations are a crucial factor in the design of latching and locking systems for PV plug connectors. In this respect the two plug connection systems of Multi-Contact are based on two different philosophies.
The latching system of the ∅3mm MC plug connection system (MC3) is based on the principle that in the event of unintentional disconnection the latching system rapidly breaks the contact so as to immediately extinguish any arcing. The insulating housing is fixed to the cable and the metal part by a positive connection whose design places its separating force in a constant range which is substantially higher than that of the plug and socket.
Most of the customary latching systems are based on the principle that the metal contact part engages mechanically in the insulating housing while a cable strain relief provides the necessary holding force between the plastic housing and the cable insulation. Due to the wide range of solar cables in use in the field and the effects of temperature and ageing, these forces can vary very widely. There is therefore a high risk that a predetermined breaking point will no longer be the weakest point and that the cable coupling will first yield in another place. In contrast, the MC4 plug connector is constructed in such a way that both the retention force of the metal parts in the housing and the holding force of the locking system are as high as possible, so that no inadvertent or accidental disconnection can occur.
An important feature of the whole plug connector, and particularly of the locking system, is stability. By appropriate design and choice of materials, in the MC connector system care has been taken that no delicate parts can be broken or snapped off in the rough environment of a construction site. Here, the good impact resistance of the chosen material is an important factor.

1.1.2 Operation of the locking and latching systems

In the following, a number of aspects with a relevance to safety are listed which are taken into consideration in the design of the two connecting systems:

Mating

- Simplicity of handling: The mating process is designed so as to be as simple as possible (in both systems by simply plugging together).
- Checking: It should be simple to check whether the two halves of the connector are properly plugged together; MC3: simple visual check / MC4: visual/acoustic check. In both the MC3 and the MC4 system it thus can be clearly ascertained if they are not properly locked or engaged.

Disconnection

With regard to the disconnection of a plug connection, a distinction is made between proper and improper disconnection, improper disconnection being of greater significance with regard to safety. Here are a number of examples of how improper disconnection can occur:

1. Tripping over a lead
2. Improper disconnection by pulling on a cable, e.g. during installation
3. Children playing with the PV installation / pulling on the plug connection
4. Accidental disconnection by persons grasping the plug connection.

Needless to say, improper disconnection can result from many other causes which cannot be discussed here.
In all the above-mentioned cases, with the principle of the MC3 plug connector, the connectors are completely separated if sufficient force is applied. The latching system ensures that the circuit is broken at a sufficient speed to immediately extinguish any arcing.
The MC4 plugging system is designed in such a way that in the first two cases the whole plug connection, including cables, does not become disconnected. This is ensured by the locking system, the fixing of the metal part in the housing and the cable strain relief. Since a sudden jerk has a completely different effect upon the plug connection from pulling at a steady rate, in order to test for safety in the event of tripping over the lead a practical test was carried out which showed that the MC4 connection does not come apart if a person trips over the lead.

To ensure that the connector is not separated by playing children or by adults who grasp it when bending or seeking to steady themselves, in the MC4 connector the locking catches are recessed so as to ensure that the connector cannot become accidentally separated. For still greater safety in this respect, an additional locking element is available which is simple to fit and allows the connector to be opened only with a tool.

1.2 Functional safety

The electrical transmission resistance of a plug connection is the determining factor for temperature rise and power loss. This value should therefore be as low as possible. However, the way it develops over a prolonged period is much more crucial than its level in a new product. To withstand the very severe environmental conditions, it is important to use good, durable materials and to adopt an appropriate design throughout. For instance, it is important to ensure that crimp terminations are properly pressed together, since in time poor crimp terminations can increase transmission resistances and thus result in failures. The same applies to the spring contacts between the male and the female part. A high contact force, and, above all, a good long-term contact behaviour, is achieved by the use of contact material with a good relaxation behaviour (spring force in relation to time). A rise in resistance leads to overheating and ultimately to melting or burning of the connector.

1.2.1 Corrosion

Corrosion of the contact carrier material (copper) or of the spring element (copper-beryllium) is not relevant, since these parts are tin-plated.
However, Multi-Contact prevents the occurrence of electrochemical corrosion by ensuring that all parts are tin-plated and therefore in the same potential range as the connected leads. The high contact force between plug and socket rules out the occurrence of friction corrosion.

1.2.2 Effects of temperature and weather

PV connectors are installed outdoors, where they are exposed for decades to temperature variations, moisture, rain, sun and other environmental influences. Multi-Contact has for many years conducted field tests with PV components in order to determine their long-term behaviour. Simulation tests are also carried out in which, for instance, temperature cycles over more than 20 years are simulated.

1.2.3 Certifications

Both the MC3 and the MC4 connectors have been tested and certified according to the latest standards by the TÜV as well as by UL. These products thus conform worldwide to all safety requirements for PV plug connectors.

1.3 Discussion of safety aspects

1.3.1 General risk

When viewing and discussing the safety aspects, it must be borne in mind that a PV system is an installation that operates with voltages and power levels that can be dangerous if the relevant rules and instructions are not observed. It is therefore of crucial importance that assembly and installation should be properly carried out. Neither plug connectors nor other components of a PV system can be so safe, as individual parts, that nothing can go wrong.

1.3.2 Probability of damage or injury

Before a any assessment of probability can be made, it is first necessary to categorise the potential damage events that can occur. Far-reaching consequences can result from both a functional defect in a PV plug connector and from direct personal injury.
If one considers the potential probability of damage or injury it becomes evident that in the shorter or longer term, a malfunction due to poor design or an incorrect choice of material can lead to a wide range of adverse consequences It is therefore not appropriate to base a safety assessment solely on a single type of occurrence.

2 Ease of assembly

2.1 Tools

For the assembly of MC plug connectors, the prescribed tools must be used. This gives the above-mentioned good long-term characteristics that are needed in a PV plug connection.
To cover the whole range of cross-sections and outside diameters, MC has separate tools for the individual installation operations.
An assembly device which integrates all the functions for a single conductor cross-section would make little sense, since installers generally work with a number of different conductor cross-sections.

2.2 Variety of parts

The MC4 plug connector system uses only two types of plug and socket metal parts and two types of insulator to cover the whole range of cross-sections from 1.5mm^2 to 6mm^2 and a wide range of outside diameters. By minimising the variety of parts and the use of a simple coding system, it simplifies the work of the installing electrician and also reduces the potential for errors, which must also be regarded as a positive factor for safety.

2.3 Connectability

The two MC plug connection systems have been tested with the solar leads in customary use. They can therefore be used with European, American and Asian solar cables.