Creating a universal PV plug and socket standard

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Abstract:

Photovoltaic connectors are designed to be quick and easy to install. Current connector qualification standards, such as UL 6703 and IEC 62852, are only intended to evaluate connectors from the same manufacturer and were recently changed to explicitly specify that one cannot use connectors from different manufacturers together. Unfortunately, the industry has chosen to design connectors that will connect together with those from other manufacturers. This is done to simplify installation avoiding the situations such as when the connectors on a microinverter, or other module level power electronics, do not match the connectors on the modules in the system. This rampant violation of electrical codes worldwide indicates that there is a strong desire and need to develop a universal connector standard. Here we present the initial approach and philosophy behind the formation of an IEC subgroup under TC82 WG2 looking at this problem. We intend to develop a standard where the materials and geometry of construction are specified as a plug and socket to ensure compatibility high levels of quality. We expect that the connector will be more costly, but especially in rooftop installations where power electronics requires matching components from several manufacturers, the reduction in system compatibility design needs may still result in a net cost savings. These plugs and sockets must be of the highest quality because we wouldn't want to develop a connector that precluded the manufacturing of a higher quality product, and because these will most commonly be used on rooftop installations where safety is more of a concern. Also, because we do not know which brands of plugs and sockets will be used together, we cannot simply rely on test results to ensure safety but must create a design that is as inherently safe.

IEC Scope Statement:

This document, IEC 6XXXX, specifies the design criteria for a universal plug and socket for photovoltaic applications. These plugs and sockets are designed to be used in applications where the voltage is rated for up to 1500 VDC and current is rated for up to 32 A. Plugs and sockets will also be certified to a minimum temperature rating of Level 1 according to IEC TS 63126, but certification to Level 2 is also permitted. These plugs and sockets will also be designed to Class II certification.

Scope Rational:

- Creating plug and socket designs for every combination of voltage, current, temperature Level, and safety class would be very complicated and require the different specifications to not be inter-connectable. This would be very complicated. Manufacturers are likely to use one design that encompasses the majority of applications anyway.
- The greatest problem is with the plugs and sockets on the module for which a 32A, 1500 VDC, Class II connector will cover most applications.
- Level 1 (T_{98}<80°C, IEC TS63126) will cover very close roof mounted systems in most climates while not making the materials choice onerous.
- We are designing a universal plug and socket as opposed to a connector. This will allow for a manufacturer to qualify the plug or socket end independently.

The Problem

Micro inverters, and other power electronics, are constructed with plugs and sockets for easy connection but may not be compatible with the plugs and sockets of the module.

If a separate customized pigtail connector is used, it can more easily ensure compatibility with the modules. However, this introduces more connections and more points of failure and still requires knowledge of the connectors used on the module.

The connecting of mis-matched PV plugs and sockets is much more common on rooftop systems where inverters, switches, and other power electronics are used. But they may also be used in utility scale systems for the home run wires. The ability of a system designer to specify compatible connectors from the module manufacturer can be limited.

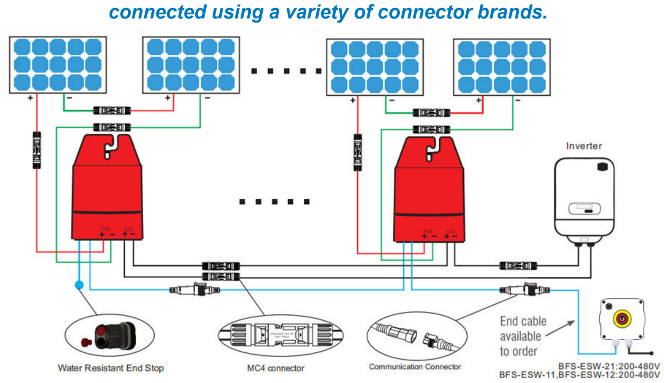
Because of the greater number of components, rooftop systems are more likely to have larger issues with the cross-mating of connectors.

There is no legal certification for a safe "MC4 compatible" connector

This is an MC4 connector. This a specific model made by Staubli.

These are not Staubli MC4 connections and are not certified to be compatible with MC4 connectors despite being designed to physically connect with them.

Components from many different manufacturers are sometimes connected using a variety of connector brands.



We will design as a pin and socket as opposed to a blade design. This is understood to have better current carrying capacity.

Definitions:

- ***Connector*** – The assembled plug and socket making an electrical connection.
- ***Plug*** – A device for making an electrical connection with pins designed to fit into a socket.
- ***Socket*** – An electrical device designed to receive a plug to make an electrical connection.
- ***Gauge*** – A standardized plug or socket that is used to evaluate compatibility.
- ***Terminal*** – The permanent connection of the plug or socket to the wire. May be welded or soldered but is usually crimped.
- ***Contact Resistance*** – Pin to socket-gauge or socket to pin-gauge.

Design Philosophy and Considerations:

- Longevity of 25 to 50 years.
- Environmental factors. UV light, rain, snow, animals, ice. Heat/cold.
- Installation environmental factors. Moisture, dirt, bugs, unmated period.
- Full power for many hours during the day. Intermittent current.
- Heat relaxation of metal stresses. Look for tests to check for and design to minimize.
- Consider foreseeable misuse of the connectors and the qualifications of the people doing the assembly.
- Design for easy field assembly.
- Do not design in a way that unreasonably limits durability, safety or performance.
- Put most of the focus on the aspects that are related to intermateability leaving the other aspects to follow the lead of IEC 62852.

Testing:

- *Plug and socket gauges will be designed.*
  - *A large and small pin and socket gage will be specified for evaluating electrical continuity.*
  - *The size of these gauges will be larger than the allowable tolerance for manufacturing.*
  - *A correctly sized gauge will be designed to be used for stress testing evaluation and to verify function under ideal circumstances.*
- *Resistance requirements.*
  - *Connector contact and terminal resistances will be strict and tested for durability.*
  - *Checked during testing to look for intermittent failure.*
- *Accelerated stress testing.*
  - *Will borrow from IEC 62852 and other standards as appropriate.*

Future Points of Discussion:

- ***Metal options for pins and sockets considering the Electromotive or Galvanic Series.***
- ***Specifics of the dimensions of parts. This includes ensuring an inability to connect to non-universal plugs and sockets.***
- ***Specifics of the stress testing.***
- ***Polymeric material choices.***
  - ***Oring, connector housing, nuts, and gasket material.***
  - ***Must consider additives that can leach out.***
  - ***Number, type and location of seals.***

Decisions For the Approach so far:

- Design for plugs and sockets, not connectors.
- Design for 1500 VDC, 32 A, Class II, Level 1.
- Contacts will be a round pin and socket.
- Design socket-gauges and pin-gauges.
  - Upper and lower limits for testing and checking resistance for pass/fail.
  - Check mechanical aspects, force for insertion or removal.
  - Use gauges to check resistance, pass/fail.
- Suggested that terminals start at less that 0.55 mΩ and can only increase by 0.33 mΩ after stress testing.
  - Use IEC 60352 and IEC 60909 to design terminal resistance and thickness of plating.
- Specify construction requirements
  - The thickness of material in the pin or socket and plating. (The question is how do we prevent the use of a flimsy or resistive pin or socket).
  - Specify bimetal potential or electronegativity.
- Accelerated stress testing.
  - Measure change in resistance after testing sequences.
  - Thermal cycle test IEC 60684, IEC 62852 includes a thermal shock test.
  - Measure resistance after and during the exposure.
  - Include many of the tests of IEC 62852, possibly at greater stress levels.

How to Get Involved and Help:

Contact the Project Leader Michael Kempe at: Michael.Kempe@NREL.gov

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