WORKSHOP

Friday, October 15th

What you should know about

Transformerless Photovoltaic Inverter Technology

AGENDA

9:30 - 10:00 am
Registration

10:00 - 10:30 am
Introduction of the standard requirements for transformerless PV inverters
Tim Zgonena, Principal - Inverter Technologies

10:30 - 11:00 am
The product development addressing regulatory requirements regarding grid and personal safety
Joanna Marienhagen - Product Management Operations, Solar Inverters

11:00 - 11:30 am
Bill Brooks

11:30 - 12:00 pm
How does the National Electrical Code (NEC) address transformerless inverters?
Tim Zgonena, Principal Engineer - Inverter Technologies

12:00 - 12:30 pm
The regulatory perspective about emerging PV technologies
Al Ramirez - UL Regulatory Services

12:30 - 01:00 pm
Panel discussion opening the dialogue and providing the audience with the opportunity to discuss different perspectives

01:00 - 02:00 pm
Networking Lunch and opportunity to reach out to the subject matter experts individually

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Non-Isolated Transformerless PV Inverters

Tim Zgonena

Los Angeles,October 15th, 2010

Traditional Transformer Isolated PV Inverters Used in USA

Contain a transformer to isolate between the PV DC input circuit and the AC Grid output circuit.

Prevents / limits fault current between AC and DC circuits under most fault conditions.

Are traditionally used with a ground referenced PV array, where either the positive or negative current-carrying conductors is grounded if the PV system voltage is ≥50V.

This PV input circuit bonding conductor is often built into the inverter and is incorporated into the Ground Fault Detector Interrupter (GFDI).

UL 1741, Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources

UL1741 Does include:

- requirements for PV inverters with ground referenced PV arrays.
- requirements for GFDIs for ground referenced PV arrays.
- elements to address the safety concerns of isolated PV inverters.

Published UL1741 GFDI Limits

Device dc rating (kW)	Maximum ground-fault current detecting setting (Amperes)
0-15	1
25-50	2
50-100	3
100-250	4
>250	5

UL 1741 Did Not Include Requirements to Address the Safety Concerns :

… of non-isolated transformerless PV inverters,

... PV modules in ungrounded PV arrays,

balance of systems equipment and

wiring in ungrounded PV arrays

What is a transformerless PV inverter?

No galvanic isolation (transformer) between the PV DC input circuit and the AC Grid output circuit.

Ground referenced through the AC mains ground bond but no PV ground connection.

Benefits of transformerless inverters

- Higher Efficiency
- Protection based upon new requirement
- Reduced operating temperature
- Less Weight
- Lower costs

Development History of the Nonisolated PV Inverter Requirements.

- **VDE0126 was in use in Europe**
- **Draft IEC 62109 (IEC version of UL1741)**
- **Draft approach for UL1741 2005 based upon IEC 62109**
- **UL 1741 draft work back to IEC working group and expanded it over several years**
- **IEC 62109-2 draft Dec 2009**
- **In response to an increased interest and submittals in US for transformerless inverters**
- **UL published the Certification Requirement Decision, CRD in April 2010 and simultaneously proposed the requirements to the UL1741 STP.**

This U1741 CRD…

- **What is a CRD - Certification Requirement Decision (CRD) ?**
- **Establishes published set of requirements to address the technical safety concerns in the absence of existing published requirements.**
- **Upon publication the CRD is required to be submitted to the STP for review and comment with intention to be included into the published standard.**

Nonisolated Transformerless PV Inverter CRD for UL 1741

General - These requirements address Non-Isolated EPS Interactive PV Inverters with PV array inputs installed per NEC 690.35.

27 page CRD document that provides:

- Definitions
- Specific construction requirements
- Operational requirements and
- Tests to

evaluate the operation and functional safety of the protection systems.

New Definitions

Critical Isolation Component - A component(s) such as a contactor or relay that isolates the PV array input connection and associated circuitry from the EPS connections and associated circuitry.

Isolation Monitor Interrupter (IMI) - A device that monitors the insulation resistance of a PV array circuit to ground and prevents energization of the inverter AC output circuit or disconnects an energized output circuit when the PV array input circuit insulation resistance drops below a predetermined value. Some IMIs may have monitoring circuitry that verify functionality and take appropriate actions in the event of circuit failures. The IMI circuit may include or provide signals to control the critical isolation components.

Ground Fault - An unintentional current path from ground to a component or circuit.

Inverter Backfeed Current - Inverter current flow to the PV array and its wiring under inverter normal or single fault abnormal conditions.

Non-Isolated Inverter - An inverter that does not provide galvanic isolation between its input and output circuits.

Functional Ground - An intentional impedance path from ground to a component or circuit in a PV array and/or inverter circuit. Functional grounding may be used during PV array isolation measurements. The intentional impedance path to ground may be a permanent or temporary connection. A permanent PV array connection to ground without limiting impedance is not considered a functional ground.

Maximum Ground Fault Current and Response Time (Table 89.1)

Inverter Power Rating	Maximum Continuous Fault Current Limit	Maximum Allowable Time to open the critical isolation component. (Seconds)
≤ 30 kVA	300 mA [a]	0.3

a - A manufacturer may specify up to a +5% measurement tolerance on this limit.

Sudden Ground Fault Current Change and Response Time (Table 89.2)

Maximum Sudden Increase in Isolation Fault Current Magnitude	Maximum Allowable Time to open the critical isolation component. (Seconds)
30 mA	0.3
60 mA	0.15
150 mA	0.04

Most Critical UL1741 STP Comments

Expand to >30KW

Revise to match most recent version of IEC 62109-2

UL1741 Path Forward is Intended to Harmonize with the IEC 62109-2 Requirements

Following the publication of the UL1741 CRD this spring, the IEC 62109-2 writing team drafted new expanded requirements for inverters >30KW.

These expanded requirements are going out for IEC ballot and comment in the next month and will provide us with a means to harmonize internationally.

New Ground Fault Protection Methods

Step 1 – measure PV array insulation resistance

Step 2 – If the array resistance is above a min level the inverter can export power

Step 3 – The inverter must cease to export power and open redundant isolation devices upon:

- Ground fault current exceeds a hard limit of 300mA
- Low level step changes in ground fault current

Step 4 - An isolation monitor interrupter may automatically reconnect, provided it is limited to no more than 4 reconnections within a 24 hour period.

Step 5 – Inverter is required to perform a self test to verity continued protection functionality.

New Ground Fault Protection

Transformerless Inverter Ground Fault Protection has a significant increase in protection over existing GFDI protection required by UL1741.

This new protection scheme will be proposed for all PV inverters in early 2011 after we receive international comments on the new IEC 62109-2 requirements.

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NEC 690.35 Ungrounded Photovoltaic Power Systems.

Photovoltaic power systems shall be permitted to operate with ungrounded photovoltaic source and output circuits where the system complies with 690.35(A) through (G).

690.35 (A) Disconnects

All photovoltaic source and output circuit conductors shall have disconnects complying with 690, Part III.

690.35 (B) Overcurrent Protection.

All photovoltaic source and output circuit conductors shall have overcurrent protection complying with 690.9.

690.35 (C) Ground-Fault Protection.

All photovoltaic source and output circuits shall be provided with a ground-fault protection device or system that complies with (1) through (3):

(1) Detects a ground fault.

(2) Indicates that a ground fault has occurred

(3) Automatically disconnects all conductors or causes the inverter or charge controller connected to the faulted circuit to automatically cease supplying power to output circuits.

690.35(D) Photovoltaic Source Conductors

The photovoltaic source conductors shall consist of the following:

(1) Nonmetallic jacketed multiconductor cables

(2) Conductors installed in raceways, or

(3) Conductors listed and identified as Photovoltaic (PV) Wire installed as exposed, single conductors.

690.35(E)

(E) The photovoltaic power system direct-current circuits shall be permitted to be used with ungrounded battery systems complying with 690.71(G).

690.35(F)

The photovoltaic power source shall be labeled with the following warning at each junction box, combiner box, disconnect, and device where energized, ungrounded circuits may be exposed during service:

WARNING - ELECTRIC SHOCK HAZARD. THE DC CONDUCTORS OF THIS PHOTOVOLTAIC SYSTEM ARE UNGROUNDED AND MAY BE ENERGIZED

690.35(G)

The inverters or charge controllers used in systems with ungrounded photovoltaic source and output circuits shall be listed for the purpose.

Need to Update NEC for 2014

Need to better define grounded and ungrounded arrays and address nonisolated inverters that provide a ground reference to the circuit during inverter operation.

Is an ungrounded array as simple as not having a direct PV array connection to ground?

Need to clarify if and how 690.35 applies to nonisolated inverters.

How do we address the AC ground bond reference through the nonisolated inverter?

How is this different from isolated inverters intended for use ungrounded PV arrays?

Thank you

Tim Zgonena

Underwriters Laboratories Inc.

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