INTERPRETATION OF IEEE Std C57.159 - 2016

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This document is specifically written to discuss and demystify the interpretation of IEEE Std C57.159-2016 – Application in Distributed Photovoltaic (DPV) Power Generation Systems

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AT ISSUE

The use of Solar Medium Voltage Transformers (MVT) connected to inverters is a relatively new practice, with major installations taking place just over the past decade. Technology is still rapidly growing and evolving.

IEEE Std C57.159 -2016 is a guide that provides **general and specific recommendations** on application of step-up and step-down liquid-immersed and dry-type transformers in distributed photovoltaic (DPV) power generation systems for commercial, industrial, and utility systems.

The guide focuses mainly on the inverter transformers of the DPV power generation systems that are connected to the inverters supplying ac voltage and current to the primary (LV) winding of the transformer. It also points to certain responsibilities the inverter supplier has vis-a-vis the MVT manufacturer which will be discussed in this document.

The main objective of this guide is to support a harmonized approach to the supply of specification, design, and use of the MVT's described in the scope of the guide as a component of a DPV power generation system.

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Although the guide was published in 2016 and covers MVTs' up to rated power of 4,000 kVA, up to 36 kV, it supports currently evolving industry of DPV power generation by providing guidance on specification, design, and application of transformers for these systems with the help of inverter suppliers. This guide also intends to help avoid potential problems caused by improperly defined, missed, and/or misinterpreted points of consideration. Further, it is addressing constraints that are important for the correct specification, efficient design, and reliable application of transformers in DPV power generation systems.

As this guide was published in 2016 considering inverter technology available, one has to look at the latest invertor generation.

In virtually all modern inverters, IGBT (Insulated Gate Bipolar Transistors) are turned on and off rapidly with a commutating frequency most typically in the 4-5 kHZ range to develop the power frequency output 50 or 60 HZ that couple to inverter transformers. Line to line and /or line to neutral output voltages are well filtered in the inverter, predominantly with capacitors and are **normally devoid** of high frequency harmonics. However, just by the very nature of the power electronics, line to ground and / or neutral to ground voltages are not filtered and contain very high frequency harmonics.

Depending on exact inverter design this can have an effect on the inverter transformer and therefore needs to be specified.

The IEEE C57.159 document was written specifically with this type of operation in mind. WEG transformers adhere to the teachings of C57.159.

The discussed guide is NOT A TRANSFORMER standard it is a guideline ONLY.

GUIDELINE

***Definition of guideline**: a general rule, principle, or piece of advice.*

In short IEEE Std C57.159-2016 is not a standard.

Both transformer and inverter manufacturers have each a high stake in this guide. Indeed the guide recommends that the end user, system designer, **inverter specialist**, and **transformer specialist collaborate** on the specification of the transformer parameters, assuring all important aspects of the application are properly specified such that transformer manufacturer can design and build for the correct application. System and power quality studies can be considered to confirm system related requirements. It is very clear that each transformer design is very specific to each inverter supplier such that skid assembly with transformer and invertor are made project specific.

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WHY?

The guideline explains the interaction and working principle of transformer and inverter. It is very clear that current harmonic content in DPV power generation systems depends on the inverter-transformer interaction and possible resonances in the system. The harmonic content needs to be specified by the inverter suppliers and taken into consideration by the transformers manufacturers.

The harmonic content needs to be specified as a) line to line and 2) line to ground. Section 4.3.2 - DC bias of C57.159 specifies clearly what some of the consequences are when the harmonic content is not specified in its totality, meaning line to line and line to ground.

Section 5 of C57.159-2016 – Transformer parameter selection and transformers designs, states very clearly that the design, construction, and testing of rectifier and inverter transformers are covered in IEEE Std C57.18.10. The specifics of DPV power generation system transformers are discussed in this guide meaning C57.159 – 2016. Of specific interest is Section 5.1.2 – Nominal Voltage, where it states that the inverter transformer needs to be designed to work with the pulse voltage shape of the inverter. This means indeed that transformers manufacturers will design in accordance to the AC voltage output of the inverter, hence a) conductor voltage to ground and b) line to line voltage needs to be specified by the inverter supplier.

When specifications are calling out 3-5% THD, or referencing C57.159-2016, **5% THD will be considered by WEG;** indeed, the guideline is clear: *"Depending on the DPV inverter type, the typical harmonic current content is less than 5%. The relatively low harmonic profile in the DPV power generation system is due to the filtering provided in the inverters to meet interconnection requirements. The relatively high switching frequency of modern inverters requires relatively small filters to achieve acceptably low harmonic output distortion. Unless otherwise specified, harmonic content is expected to be maintained at or below levels described in IEEE Std 519".*

Section 6 of C57.159-2016 – Transformer general requirements, construction and protection. We need to point out that design consideration under section 6.2, is reflective of wound core design application and not stacked core design application. WEG's design is a stacked core design and not a wound core design.

CONCLUSION

WEG Transformers follows the C57.159-2016 guideline. It shall be understood by the reader that this guideline is not a manufacturing standard; hence our transformers do comply with this guideline in which it is defined that transformer design shall be robust to

withstand a) the line to line THD and b) the line to ground THD as specified by the inverter manufacturer. Again by the very nature of the power electronics and systems used by the inverter suppliers, line to ground and / or neutral to ground voltages may not filtered and contain very high frequency harmonics, therefore for exact inverter design these high frequency harmonics must be specified. In absence of this high frequency harmonics profile the inverter transformer may not operate as was designed for or may later in the field show symptoms of high hydrogen gas generation equal to a daily rise not acceptable to the transformer supplier.