Study Committee C6

Active distribution systems and distributed energy resources

11026_2022

EXPERIMENTAL COMPARATIVE ANALYSIS OF PHOTOVOLTAIC INVERTERS PROFILES IN RELATION TO THE EUROPEAN NETWORK CODE NC RFG, THE TECHNICAL STANDARDS, AND THE REQUIREMENTS OF DISTRIBUTION SYSTEM OPERATORS

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Introduction

The presently observed rapid increase in photovoltaic (PV) micro-installation connections to European low-voltage networks, resulting from numerous financial support initiatives, European Union (EU) energy policy and growing social awareness of environmental and economic issues, raise the questions if the PV inverters, widely available in EU market, fulfil the numerous technical requirements specified in European and national regulations as expected by local distribution system operators.

Objects of investigation

26 brand new PV inverters, widely available for sale in the EU, from over 20 various manufacturers, from and outside the EU. For the purposes of this research, all tested PV have been made available by their manufacturers or regional distributors which confirms the origin of the devices from official distribution channels and their designation for the EU market.

Scope of research

The conducted research covers the technical aspects of PV inverters operation and performance included in the NC RfG network code, technical standard EN-505049-1:2019 and internal regulations of distribution system operators. The test stand (Fig. 1) was based on the technical report IEC TR 61000-3-15 specifying the methods of testing low-frequency electromagnetic compatibility for distributed generation systems

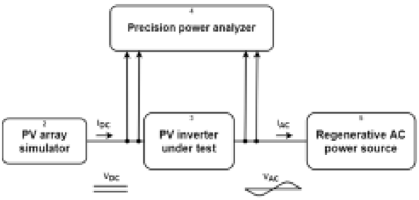

Fig. 1 Block diagram of the stand for laboratory tests of PV inverters

Reactive power regulation of PV inverters

Characteristics of only 12 of seventeen PV inverters are available on the Figure 2, since it was not possible for 5 PV inverters to set the Q(U) regulation mode. Based on the obtained results the following conclusions can be formulated:

- PV inverters, running in the Q(U) mode, basically perform the reactive power regulation, however readings obtained for individual PV inverters are dispersed and most of them do not meet the given criterion.
- Required accuracy for the Q(U) mode, which is ± 2% the maximum apparent power of the inverter, seems to be very demanding when comparing it with the criterion for P(f) which was defined as 10% of rated active power. The reasonableness of such a difference in requirements for technically similar power indicators raises doubts.

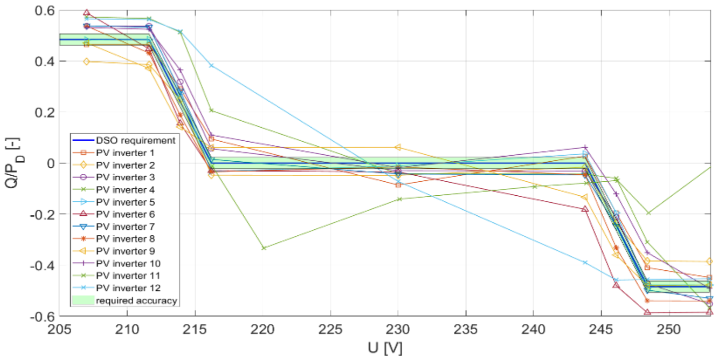

Fig. 2 Reactive power regulation performance for 3-phase photovoltaic inverters

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PV inverters performance (cosφ = 1)

In normal operation i.e., when reactive power regulation modes are deactivated, PV inverters should generate energy without reactive power, so their cosφ should be as close as possible to 1. This performance was verified for both 1-phase and 3-phase inverters.

For the testing procedure the operating points of PV inverters were successively set to 25, 50, 75 and 100% of their rated powers, and at the rated voltage 230 V. For each test step the values of cosφ and power factor and were measured.

Depending on the PV inverter and actual active power, the value of cos φ was within the range from 0.97 to 1.00. The value of PF of 3-phase inverters tends to decline for lower powers. Unlike cosφ, which includes only the first harmonic component, PF considers reactive power from higher harmonics. Its reduced values indicate a relatively high current distortion on the AC side and thus resulting reactive power of higher harmonics. This was confirmed by measurement of the total harmonic distortion indicator of current.

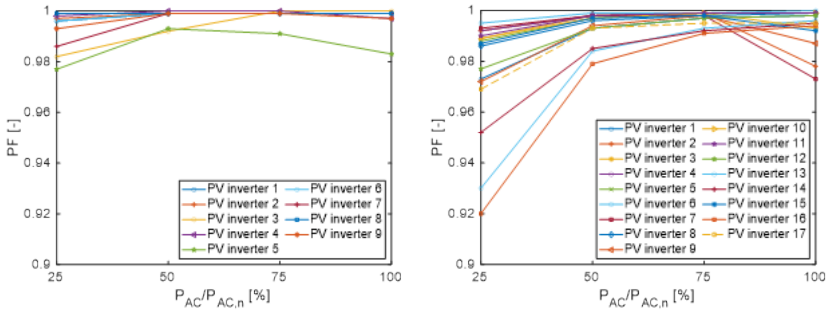

Fig. 2 Power factor of 1-phase (left) and 3-phase (right) PV inverters in relation to their active power generation

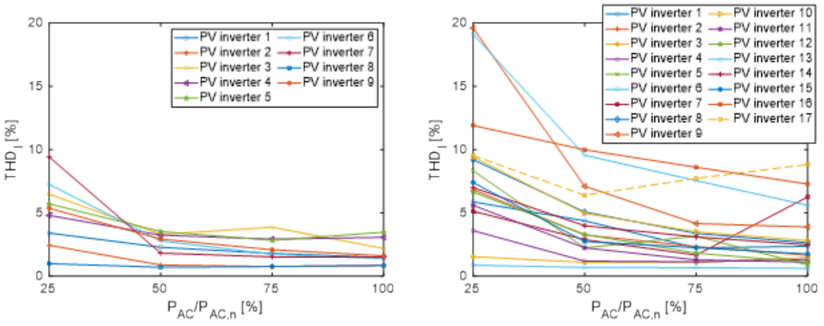

Fig. 3 THD_I of 1-phase (a) and 3-phase (b) PV inverters in relation to their active power generation cigre PARIS 2022

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UVRT immunity

The procedure for verification of the UVRT (Under-voltage ride through) was performed for 3-phase PV inverters. Every time after the PV inverter reached the steady state operation, corresponding to stable AC active power generation, voltage event was generated, simulating voltage sag or short interruption from the AC grid side. Generated voltage events lasted from 100 ms to 2000 ms and had the amplitudes from 2% to 98% of the rated voltage 230 V.

PV inverters' responses to voltage events were recorded and classified into three distinct groups (Fig. 4): (a) continuous operation without a significant reduction in phase currents – labelled as green dots; (b) continuous operation with a significant reduction in phase currents below 10% of a pre-event level. The PV inverter returns to operation immediately after event ends – labelled as orange dots; (c) PV inverter shuts down and starts the grid resynchronisation procedure – labelled as red dots.

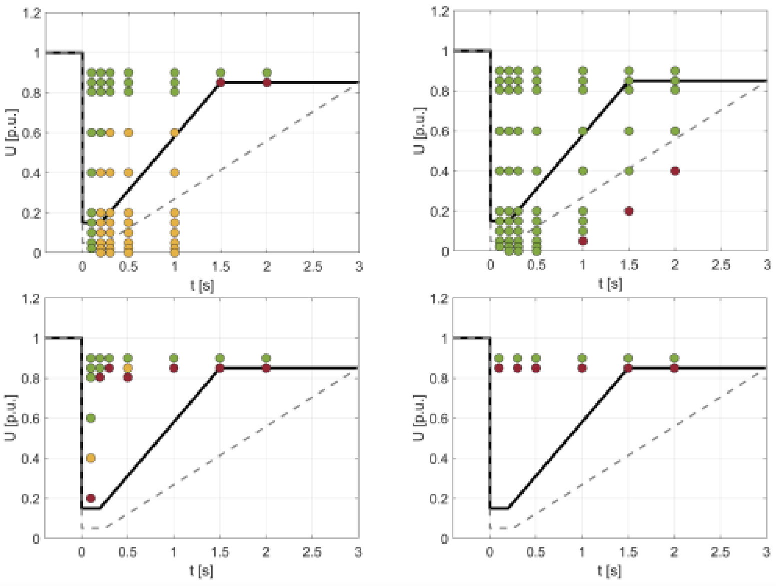

Fig. 4 Example responses of tested 3-phase PV inverters to voltage events

Conclusion

- Equipment certificates complied with the network code NC RfG will not contribute to solve DSOs problems with high concentration of photovoltaic micro-installations, because tests of PV inverters performed by accredited laboratories covers relatively limited scope of functionalities resulting only from the network code NC RfG for type A power-generating modules.
- The local requirements may differ significantly from each other and may be less achievable for PV inverters manufacturers. Moreover, the network code NC RfG does not contain any provisions that the generating modules should also be certified for compliance with the requirements specified by the DSO. All this together means that manufacturers of inverters, especially those from outside the EU, often do not have knowledge of local requirements determined by the DSO, which results in the lack of their implementation in the PV inverters sold in a given country.