ANALYSIS OF THE OPERATION OF SOLAR MICRO-INVERTERS

ANALIZA FUNCȚIONĂRII MICRO-INVERTOARELOR SOLARE

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Abstract: *This paper investigates the performance of microinverters in test conditions in both outdoor and indoor environments. A number of energy quality characteristics are analyzed considering variable solar irradiation. The aim of the study is given by the challenges and the impact of the integration of photovoltaic systems in low voltage networks. The experimental study also considers the correlation between the current and voltage harmonics identified for the analyzed case and the present two stages in which an analysis of IQ7 microinverters was performed considering a solar simulator for each microinverter and an experimental study involving testing microinverters in real climatic conditions.*

Keywords: micro-inverter, photovoltaic panel, irradiance, CTHD, VTHD.

Rezumat: *În cadrul acestei lucrări este investigată performanța microinvertoarelor în condiții de testare în mediul exterior cât și interior. Sunt analizate o serie de caracteristici cu privire la calitatea energiei considerând iradianța solară variabilă. Scopul studiului este dat de provocările și impactul integrării sistemelor fotovoltaice în rețelele de joasă tensiune. Studiul experimental are în vedere și determinarea corelației între armonicile de curent și cele de tensiune identificate pentru cazul analizat și prezintă două etape în care s-a efectuat o analiză a microinvertoarelor IQ7 considerând câte un simulator solar pentru fiecare*

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microinvertor și un studiu experimental ce presupune testarea microinvertoarelor în condiții climatice reale

Cuvinte cheie: micro-invertor, panou fotovoltaic, iradianță, CTHD, VTHD.

1. Introduction

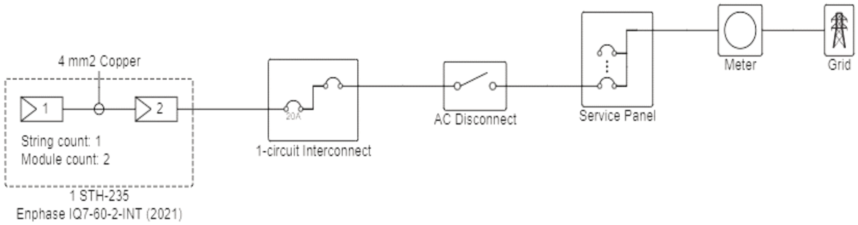
Over the last decade, there has been a rapid growth in the development of electricity-dependent devices to simplify human activities [1-5]. With the growth of the human population comes an even greater number of electronic devices. Traditionally, most of the energy supplied to consumers is generated using non-renewable energy sources, such as coal and oil, whose reserves will eventually become depleted with the continued expansion of the human population [6-8].

The technology of converters with integrated modules has gained universal popularity in grid-connected photovoltaic systems, demonstrating their benefit both in reducing the cost balance and in achieving a better overall cost of the system. Solar micro-inverters provide a higher energy capture compared to string inverters. They exist in the range of a few hundred watts, and the largest single-phase micro-inverter commercially available is rated at 300 W. Solar micro-inverters can generally be classified based on their topology, single-phase or three-phase. Topologies of three-phase micro-inverters can be found widely in the literature, but are rarely used in practice. In addition, each of these topologies can be networked or offline. But in reality, almost all commercially available solar micro-inverters are grid-connected inverters [9-10].

2. The structure of the experimental stand

The experimental stand for the study of photovoltaic microinverters consists of two Enphase IQ7 type solar microinverters, two solar panels (235 W), a bidirectional electricity meter, two consumers with a power of 20 W and elements for separating the power supply circuit and respectively of the microinverters. The stand allows the supply of additional consumers by introducing a single-phase socket into the circuit. Figure 1 shows an overview of the experimental stand made.

The single-wire electrical scheme for the model in question is presented in the following figure, being made up of the two photovoltaic panels, the associated microinverters and the interconnection elements with the public electrical network.



Module Specifications	
2x 1 Soltech 1 STH-235	
STC Rating	235 W
Vmp	29.3 V
Imp	8.02 A
Voc	37 V
Isc	8.54 A

Inverter Specifications	
2x Enphase IQ7-60-2-INT (2021)	
Max AC Power Rating	240 W
Max Input Voltage	48 V
Min AC Power Rating	0 W
Min Input Voltage	16 V

Wire Schedule		
Tier	Wire	Length

Figure 1. Single-wire wiring diagram

Figure 2 identifies the two solar simulators as well as the experimental stand connected to the photovoltaic panels. To identify the behavior of the microinverters, connected in parallel with the low voltage electrical network, an AC 8334 energy analyzer was used connected at the point between the microinverters and the grid. The activation voltage of the microinverter is 16V and the operating range is between 16V-48V. The power of the microswitch is 240 W and the short-circuit current is 15A.

Figure 2. Experimental stand with two solar simulators

3. Experimental results

Two lighting levels were considered, the same for each photovoltaic panel. The range of variation of the panel temperature for the 5 min test was between 25 ° -30 ° C. For the first irradiance stage (75% of the maximum possible illumination value) the current supplied by each panel was 1.5 A and 36V voltage. For the second stage of illumination (25% of the maximum possible illumination value) the recorded current was 0.5 A and the voltage was 32 V. The specified values were measured with digital multimeters located in the photovoltaic circuit in front of the microinverters. Figure 4.2 shows the power variation recorded with the energy analyzer for the two stages of the experimental study. It is found that the power level transmitted in the network depends on the degree of illumination of the photovoltaic panels.

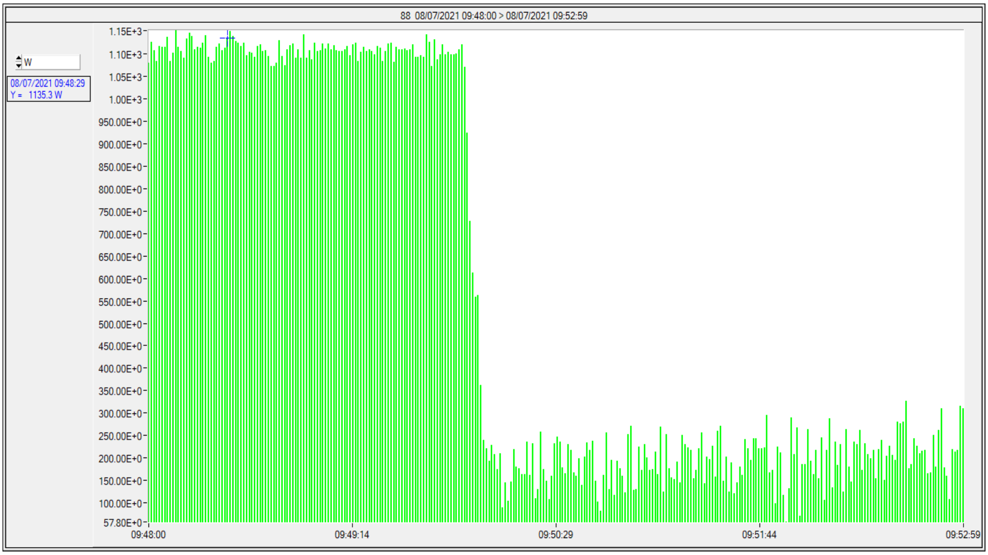


Figure 3. Power variation for the two stages

Regarding the variation of the power factor, it is observed that it is dependent on the power level produced, reaching an average value of 0.73 for the first stage of the experimental study and an average value of 0.2 for the second stage.

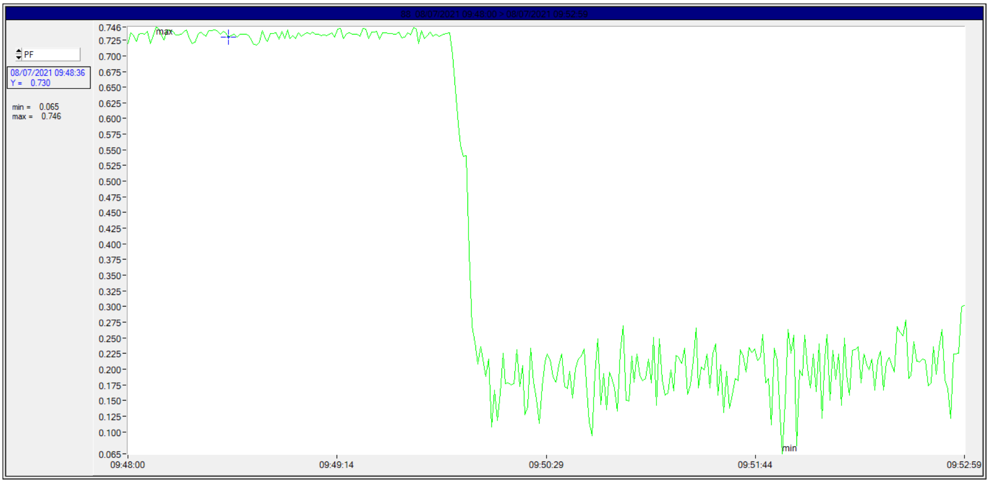


Figure 4. Power factor variation

In current harmonics, it is observed that the closer the microinverters operate to the nominal area, the lower the CTHD component, being visible in figure 5.

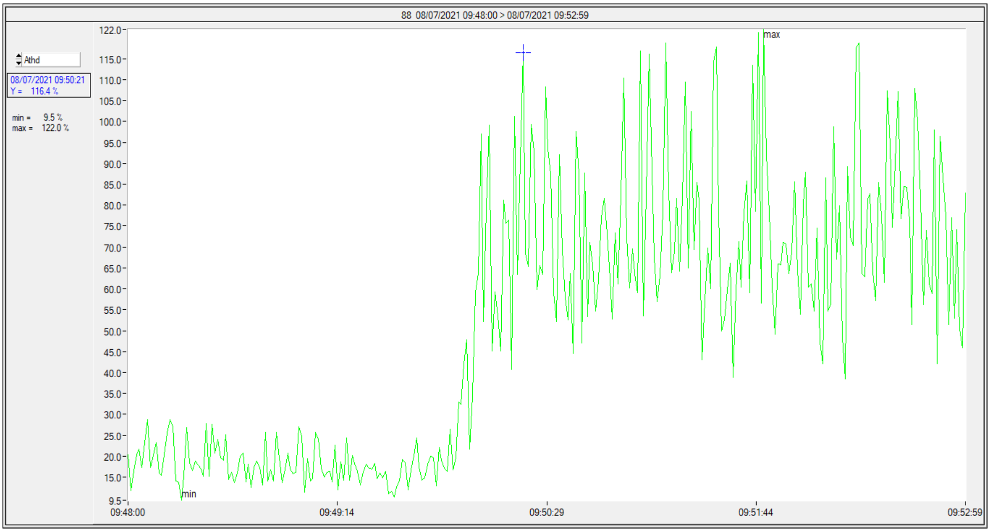


Figure 5. CTHD component

The variation of the current registered with the energy analyzer, for the two lighting stages can be observed in figure 6, reaching an average maximum value of 6.8 A and an average minimum of 4.5 A.

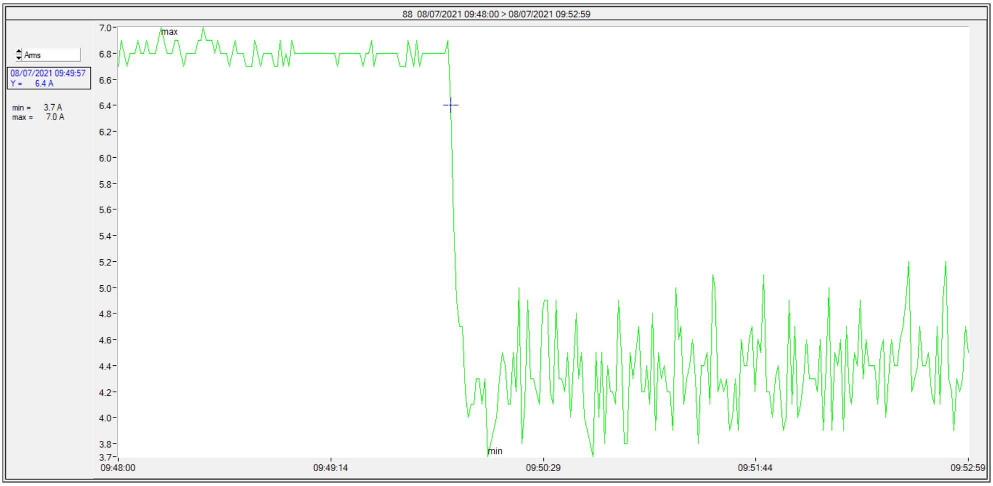


Figure 6. Current variation

The evaluation of the microinverters in real climatic conditions was performed in order to test the microinverters, from the point of view of the parameters related to the quality of electricity. In this sense, the photovoltaic panels were positioned to the south at an angle of approximately 33 ° and connected to the solar microinverters. Measurements were taken between 11: 32-13: 27 one day in June.

Figure 7. Photovoltaic panels and experimental stand in real climatic conditions.

The power factor of the microinverters measured with the electric energy analyzer in real climatic conditions depends significantly on the available solar irradiance. This is an indicator of the quality of the voltage and current curves and the phase shift between them. The power factor is for this type of microinverter, between 0.32 and 0.99 with significant variations when there are significant decreases in terms of power produced by photovoltaic panels.

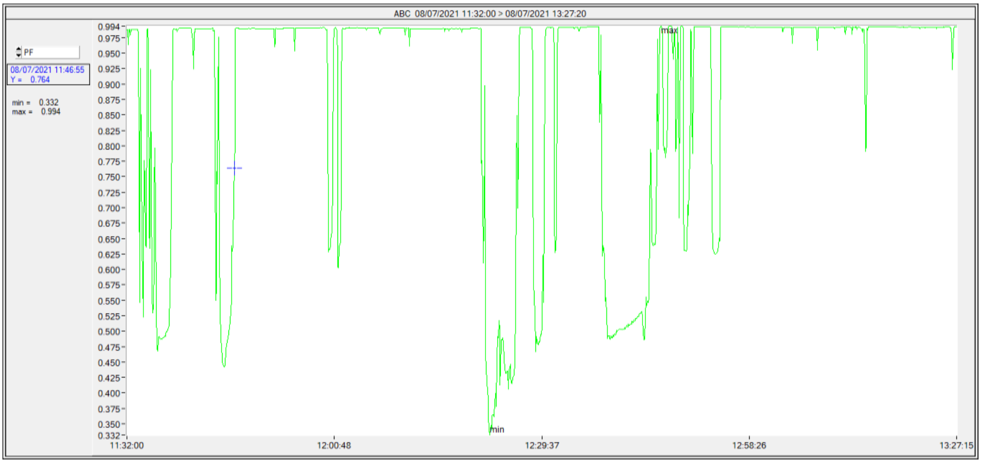


Figure 8. Power factor graph

The power produced by the photovoltaic system can be analyzed by the following graph.

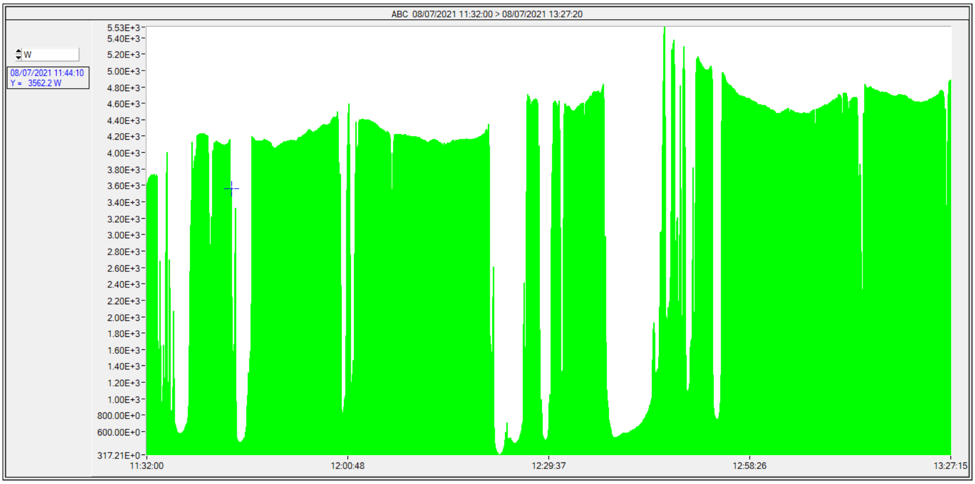


Figure 9. The electrical power produced by the photovoltaic system

The CTHD component can be tracked by the representation in Figure 10. During the analysis, the minimum value of these components is 2.6%. Significant variations are observed for this component, depending on the level of solar irradiance available in the study time frame. Therefore, a strong correlation between the CTHD component and the variation of solar irradiance is evident. In other words, the CTHD component increases significantly during periods of unstable or low value solar irradiance, registering values that reach and even exceed the threshold of 27%. At the same time, it is observed that this component is stable around 2.6% when the level of solar irradiance is constant and at normal values for this period.

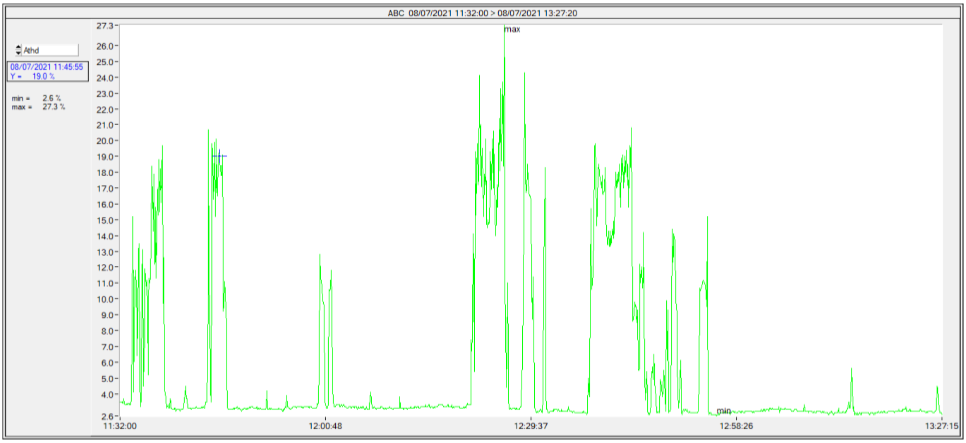


Figure 10. CTHD component

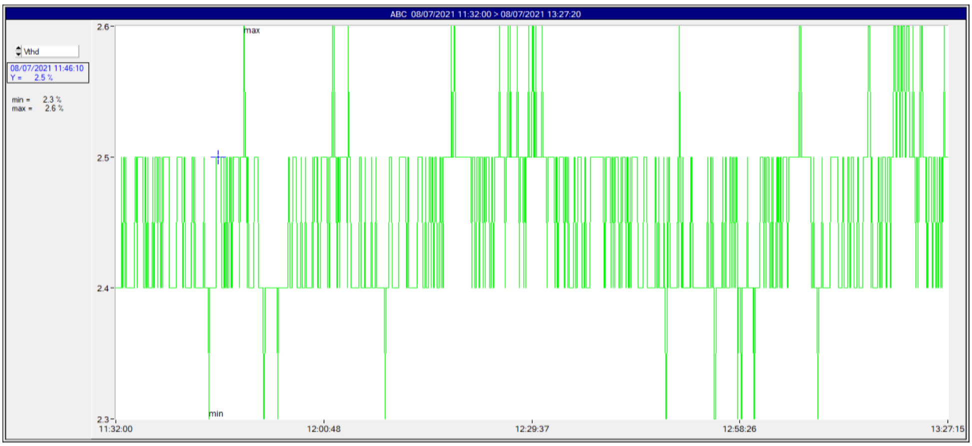


Figure 11. VTHD component

The VTHD component has a variation between 2.3% and 2.6%, and its variation can be followed by figure 11.

The frequency variation recorded using the analyzer is shown in Figure 12 and is in the range of 49.9 Hz-50 Hz.

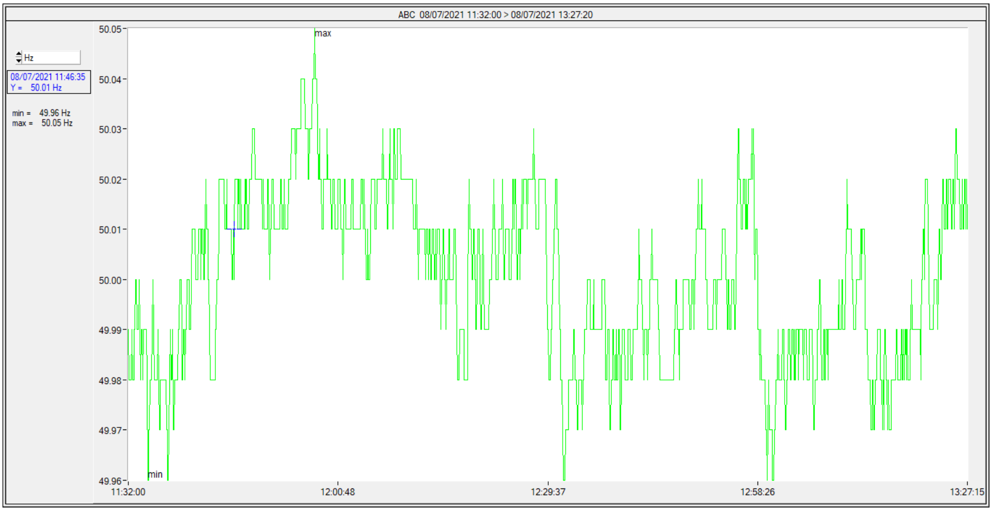


Figure 12. Frequency variation

4. Conclusions

This paper analyzes the behavior of photovoltaic microinverters integrated on an experimental stand. The experimental study has two distinct directions. In a first stage, the operation of photovoltaic microinverters was analyzed in the situation when they are connected to the two solar simulators, and in the other stage they are connected to the same solar panels but which were exposed in real climatic conditions.

Studies identified in the literature have shown that for different microinverters (Holland) the CTHD component recorded for different types of photovoltaic panels recorded values of up to 387.39% and a minimum of 4.55%. For the same study it shows that for the microinverters produced by Solarex the maximum value of the CTHD component is 291.82% and the minimum value 57.44%. Compared to the IQ7 microinverter analyzed in the paper, much lower values of the CTHD component were obtained, the maximum being 122% and the minimum being 2.6%. These values were obtained considering that the panels are fixed and facing south. A decrease in the CTHD component would have been obtained if the photovoltaic panels had been installed in a biaxial system.

The experimental study by the recording values shows that the higher the CTHD component, the lower the power factor.

R E F E R E N C E S

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