

# Analysis of a single phase inverter for photovoltaic systems operating in a weak electric grid

Gorazd Štumberger, Sebastijan Seme, Klemen Deželak, Andrej Hanžič, Jože Voršič

University of Maribor  
Faculty of Electrical Engineering and Computer Science  
Smetanova 17, 2000 Maribor, Slovenia  
phone: +386 2 220 7075, fax: +386 2 220 7272  
e-mail: [gorazd.stumberger@uni-mb.si](mailto:gorazd.stumberger@uni-mb.si)

## 1. Introduction

Single-phase inverters for photovoltaic systems are normally analyzed when they are connected to the strong electric grid with low impedance. This work focuses on analysis of a single-phase inverter operating in a weak electric grid with relatively high impedance. Presented are experimentally determined results for the inverter's efficiency, voltage and current total harmonic distortion and power factor. The results presented show substantial contents of sub harmonic components in the inverter's output current.

**Key words:** photovoltaic system, single-phase inverter, experimental methods, efficiency, power factor, THD

## 2. Problem definition

Operational characteristics of single-phase inverters for photovoltaic systems are normally determined by tested performed in a strong electric grid with low impedance. However, photovoltaic system can be also connected to the electric grid at the end of radial distribution line which is often the case in rural areas. In this case the grid impedance is relatively high.

In the case study, this work focuses on analysis of a single phase inverter for photovoltaic systems operating in a weak electric grid where impedance is just below one Ohm. In order to eliminate the impact of solar cells and changing solar irradiation on obtained results, the tested inverter is supplied from a DC voltage source. During the tests currents and voltages on the inverter input and output were measured. They were used to determine input and output power of the inverter, its efficiency and power factor. By applying Fourier analysis current and voltage total harmonic distortion is determined. The results presented show high presence of sub harmonic components in inverter output current caused by the maximum power point tracking algorithm.

## 3. Experimental set-up and results

Experimental set-up consists of the tested single-phase inverter, a variable DC voltage source, a transformer, current and voltage measurement chains and a signal processor board dSpace DS 1103 which is used as data acquisition system with sampling frequency 10 kHz.

The inverter's input and output currents were measured by appropriate LEM currents sensors while differential probes were applied for voltage measurement.

The variable DC voltage source consists of an autotransformer, a full wave input rectifier and a capacitor with relatively high capacity. In order to simulate a weak electric grid the tested inverter was connected to the electric grid through a transformer which had the same rated power as inverter.

Different operating points of the inverter, which means different output powers, were set by changing DC voltage on the inverter's input.

The results of performed analysis are summarized in the Tables 1 and 2. Figure 1 shows the time behaviour of inverter's output current, voltage and instantaneous power as well as voltage and current amplitude spectra at output power 247.66 W.

## 4. Conclusion

Analysis of a single-phase inverter for photovoltaic systems operating at weak electric grid is preformed in the paper. It is shown that output current of the inverter contains substantial amount of harmonic components lower than 50 Hz. They influence energy transmission and like higher order current harmonic components increase transmission losses. One of the reasons for appearance of these harmonic components is algorithm for tracking of maximal power.

Table 1: Power, voltage and current measured on inverter input and output, power factor on efficiency given for 7 different operating conditions

	a)	b)	c)	d)	e)	f)	g)
$P_{AC-output}$ [W]	107.33	247.66	543.68	796.98	1043.20	1254.50	2748.00
$U_{AC-output}$ [V] RMS	223.9080	224.2371	223.5745	223.8780	224.0995	224.3813	226.4311
$I_{AC-output}$ [A] RMS	1.0650	1.4622	2.6060	3.6883	4.7553	5.6697	12.2477
$P_{DC-input}$ [W]	140.5772	332.5651	579.9884	833.8860	1087.8	1318.0	2978.9
$U_{DC-input}$ [V] RMS	163.5200	181.5812	150.4855	151.1309	151.7242	154.2427	164.6138
$I_{DC-input}$ [A] RMS	0.8601	1.8336	3.9935	5.6252	7.2561	8.6196	18.1242
PF	0.4501	0.7553	0.9331	0.9652	0.9789	0.9861	0.9909
$\eta$	0.7635	0.7447	0.9374	0.9557	0.9590	0.9518	0.9225

Table 2: Current and voltage THD given for frequencies between 50 Hz and 2 kHz and for frequencies between 0 Hz and 5 kHz as a function of inverter output power

	a)	b)	c)	d)	e)	f)	g)
$P_{AC-output}$ [W]	107.33	247.66	543.68	796.98	1043.20	1254.50	2748.00
THD <sub>I</sub> : f=50Hz to 2 kHz	0.3718	0.1837	0.0935	0.0692	0.0598	0.0555	0.1005
THD <sub>U</sub> : f=50Hz to 2 kHz	0.0250	0.0240	0.0237	0.0229	0.0222	0.0240	0.0238
THD <sub>I</sub> : f=0Hz to 5kHz	0.9395	0.5949	0.3026	0.2196	0.1823	0.1426	0.1230
THD <sub>U</sub> : f=0Hz to 5kHz	0.0293	0.0464	0.0500	0.0586	0.0693	0.0470	0.0289

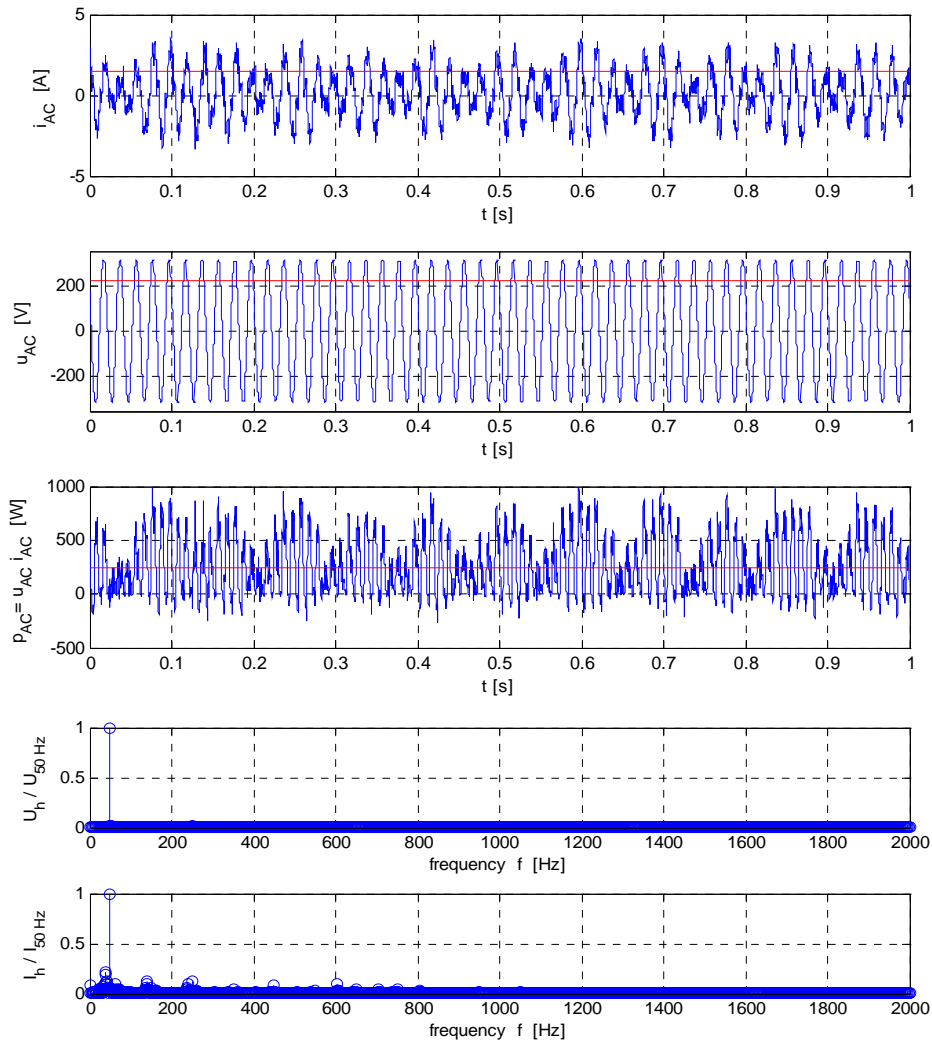


Figure 1: Time behavior of current  $i_{AC}$ , voltage  $u_{AC}$  and instantaneous power  $p_{AC}=i_{AC} u_{AC}$  as well as voltage and current amplitude spectra at the inverter's output power  $P_{AC}=247.66$  W