The Influence Of Photovoltaic Systems On Low-Voltage Grids

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Abstract:- The public support in photovoltaic (PV) technologies and increasing markets have resulted in extensive applications of grid-connected PV, in particular in the consumer side and electricity distribution grid. In this paper, the effects of a high level of grid connected PV in the low voltage distribution network have been analyzed with a case study. In the European Research Program ICOP DEMO 4080-98 there was installed a photovoltaic system of 10kWp made of 66 photovoltaic modules model OPTISOL SFM 72 Bx made by Pilkington Solar International and 24 ST 40 modules made by SIEMENS at the University of Valahia in Targoviste. The DC energy producted by the modules is inverted through the 8 SWR Sunny Boy inverter and directed to the network; in case the solar energy isn't enough the deficit is compensated by the network to ensure functionability of all the connected devices. The analysis of the connection to the system of an electric solar based source it's made in the purpose of analyzing the quality of the energy used to power up the consumers, to decrease the negative influences of perturbations over the parameters of the energy distributed and to see in what manner the consumers connected to the source measure in the allocated perturbance.

*Key-Words:*renewable energy, photovoltaic system, low-voltage grids, harmonic analysis, distributed power generation, quality parameters, LabVIEW.

1. Introduction

Liberalised energy markets, and growing use of renewable energy sources and combined heat and power (CHP) technology, are already causing noticeable changes in the power mix and grid structures today. New types of environmentally friendly technology are being introduced on a large scale within market stimulation programmes, and, if international agreements on climatic changes are to be honoured, this technology should make an even larger contribution in the future toward reducing emission of greenhouse gases and conserving resources[1].

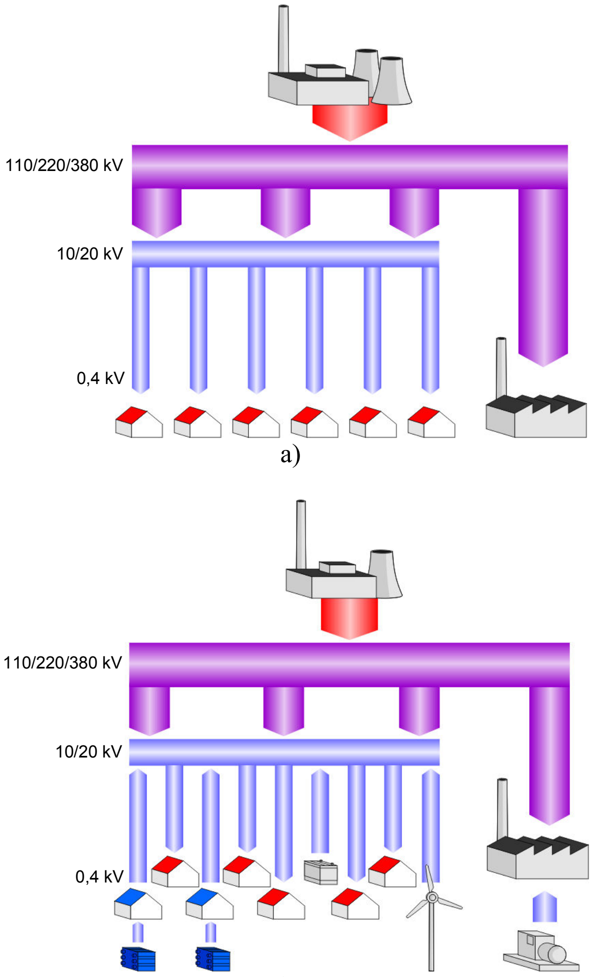
Operating private electricity-generating systems is thus becoming increasingly financially viable. Simultaneously, overcapacity is being reduced and cost-reducing potential is being exploited better. The trend toward a greater share of decentralised, so-called "distributed generation" is already clearly noticeable today in the medium-voltage distribution grids and the high voltage grids, particularly due to the rapid expansion of wind energy. Similar interactions between photovoltaic systems and low-voltage grids are not yet evident today to the same extent. However, in some regions with weak grids, the effects of photovoltaic systems on the grid and also the effects of the voltage quality on the operation of photovoltaic systems can be observed. In addition, as photovoltaic systems and other distributed generators such as CHP units increasingly penetrate low-voltage grids, aspects concerning "distributed generation" will become increasingly important and finally determine long-term success:

Technical: Effect of PV systems on power supply quality, voltage quality and safety and protection technology in grids; effect on grid control and so-called "system services"

Legal: Rights and obligations of system operators and grid operators if technical problems arise; new business models

Economic: Effect of PV systems on the economics of grid operation and electricity purchase by energy utilities; combination of PV systems with other electricity generation systems to form "distributed power stations"

Figure 1 illustrates the trend toward decentralisation. In today's grid structures, electricity is fed into the grid at high voltage by relatively few, large power stations, and is brought to the consumer via several intermediate grid voltages. As generation becomes more widely distributed, the number of electricity sources increases and the direction of flow can be reversed. The distribution grids assume the function of transporting electricity in different directions and become service providers between generators and consumers. In this scenario, central power stations will still continue to exist , but in addition there will be a large number of smaller, distributed systems[2]. This change in structure is demanding on communications and information technology to co-ordinate the operation of a large number of systems, as well as grid control and the distribution of system services (see below).



a)

b)

Figure 1: Centralised grid structure today (traditional grid structure in figure1a) and a possible, more distributed grid structure (with distributed generation in figure 1b)

2. Possible technical benefits resulting from distributed electricity generation

In contrast to the problems which have been addressed so far, distributed generation can also be seen as an opportunity in countries and regions with weaker grids. In demonstration projects, photovoltaics has already been actively used to improve the power supply quality, create better operating conditions for equipment and reduce costs for grid operation and electricity purchase. In Romania and Europe also, the introduction of distributed generators is being discussed increasingly as a measure to specifically improve the power supply quality and to reduce the total system costs in the long term. The potential benefits can already be exploited in some grid segments today:

- Reduced losses in power lines and transformers
- More favourable operating conditions for equipment (ageing of transformers, cables, etc.)
- Postponement of investments for grid extension or new construction
- Active contribution to system services (voltage and frequency control)
- Improved voltage quality (e.g. harmonics)
- Increased back-up for emergency power supply, e.g. by planned formation of isolated grids ("islanding") after a major grid breakdown

These considerations apply generally for regions with weak grids. In this context, "weak" grids can be those in which equipment is operating at the limits of its capacity or where blackouts occur frequently. In developing and threshold countries, the average transmission and cable losses in such grids often amount to 20 %. However, even in industrialised countries there are regions with weak grids or overloaded equipment, in which targeted introduction of distributed generators can contribute to stabilisation[3].

3. Implications of distributed generators and PV for the distribution grids of tomorrow

In a long-term perspective, the discussed trends will have significant effects on all aspects of electricity generation and distribution: the electricity generation technology applied, load management, business models, etc. They also imply a substantial change in structure for distribution grids, moving away from passive distribution structures toward active networks. Grid operators, energy utilities and companies involved in the electricity economy and automation technology are discussing and analysing a whole series of different conceivable structures, which could enable distribution grids to provide new services in future:

- regulating power
- reactive power budget
- voltage stabilisation
- phase symmetry
- grid impedance
- restriction of unwanted current flows
- provision of short-circuit and start-up currents
- attenuation and compensation of harmonics
- provision of data for operation management, resource disposition, trade, accounting

At all times during the transition, essential but partly contradictory criteria must be met:

- safety, reliability, grid stability
- total costs
- up-scaling potential, flexibility, vulnerability
- market conformity
- simultaneous and separate optimisation of grid, generators and loads
- simple market access
- new, cross-linked business models and roles

A wide spectrum of concepts is being investigated in national and international research projects, which range from extremely flat hierarchies, similar to the Internet configuration ("distributed intelligence"), to extremely steep hierarchical concepts with the grid operators having appreciable control concerning generators and loads. These investigations are urgently needed to gain profound understanding both of the technological challenges and the implications for possible business models and regulatory boundary conditions. As was the case for information and communications technology, here also many years of development work must be invested before this structural change will become visible on a large scale and the market is penetrated by more than just the demonstration projects mentioned[4].

The benefits of grid-connected photovoltaics in these new structures can be classified into three distinct aspects:

- Macroeconomic benefits (environmental, employment etc.)
- Technical and microeconomic benefits for the market stakeholders
- External benefits (e.g. protection of the environment)

The technical and microeconomic benefits of grid-connected photovoltaics can be classified into four categories, with the operator model and regulatory framework determining who profits from the benefits:

Generation and consumption

- Payments for electricity sold resulting from feed-in tariff laws (e.g. renewable energy law - EEG - in Germany), credit subsidies (e.g. within the now concluded 100,000 Roofs Programme in Germany)
- Synergetic effects arising from e.g. building integration (avoided costs for the conventional building envelope)
- Correlation of generation and loads: Higher payments for peak-load electricity and reduction of private load peaks
- Greater security during emergency power supply operation (weak grids, examples from North America etc.)

Power transmission and distribution (benefits due to integration of PV systems in distribution networks)

- Reduced losses in power lines and transformers
- More favourable operating conditions for equipment (reduced ageing of transformers, cables, etc.)
- Postponement or avoidance of investments for grid expansion or new construction
- Active contribution to the reactive power budget
- Improved voltage quality (harmonics)

Planning

- Short planning periods (in comparison to large power stations)
- Modularity (small construction units)
- Strongly standardised power stations

Marketing

- Positive image for companies from all sectors
- New product offers (green electricity)

The costs for system construction, grid integration, operation, maintenance and dismantling represent the other side of the balance[5].

The categories, "Generation and consumption", "Power transmission and distribution" and "Planning", are presently the most important for "distributed generation", i.e. the technical and economic optimisation of electricity grids with a high penetration rate of small generation and storage units. In addition to the development of communications structures, developments in inverter technology will become particularly significant. The perspectives for photovoltaics are specially interesting with respect to the following points:

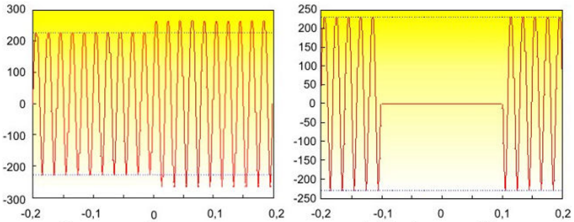
- Contribution to the reactive power budget in low-voltage grids (reduction of losses in low-voltage grids or even at the medium-voltage level)
- Active compensation of harmonics
- Deliberate exploitation of "islanding"

Whereas it is technically simple to make an active contribution to the reactive power budget with PV inverters, more complex control algorithms are needed for active compensation of harmonics and islanding mode operation. PV systems with good inverters are already contributing positively to the first two aspects today. Even at medium power levels, they feed in electricity with $\cos\varphi = 1$ and a low proportion of harmonics. Low-voltage grids in Romanian residential areas are generally inductively loaded with $\cos\varphi = 0.9$, and the grid voltage is distorted due to diode rectifiers, particularly with the 5th and 7th harmonics.

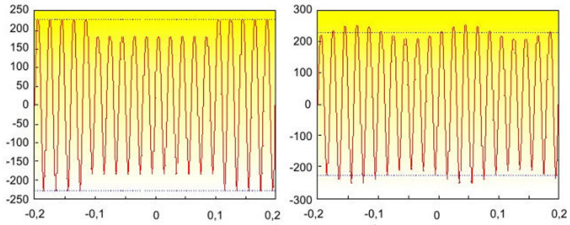
In combination with other types of electricity-generating technology such as wind turbines, hydroelectric power stations and biomass, and long-term and short-term storage technology including batteries and flywheels, a significantly larger potential can be expected in future. Today, the regulatory measures are not yet in place to reward the PV operator for additional system benefits such as the correlation between PV generation and electricity consumption. Another aspect is that in future, additional costs will arise for the integration in grids with a high penetration rate of PV systems. Ongoing interaction with concepts for distributed generation is important for both points.

4. Technical interactions between distributed generating systems and low-voltage grids: voltage quality

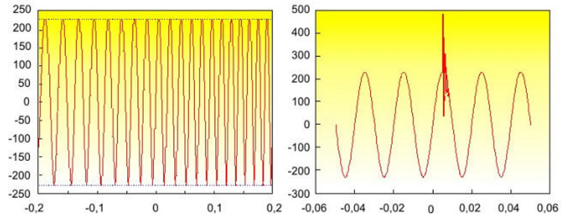
The technical quality and the interaction between electricity-generating systems, transport and distribution grids, electricity consumers and safety and switching technology eventually become evident in two ways: as the quality of power supply and the voltage quality. High-quality of power supply means constant availability (without interruptions) of electricity at the power level required for the electricity consumers that are connected. In many parts of the world, for example, the power which a household may draw is severely limited (in some cases to a few hundred watts), or the power supply is often interrupted. The voltage quality is defined by the waveform and quality of the grid voltage[6].



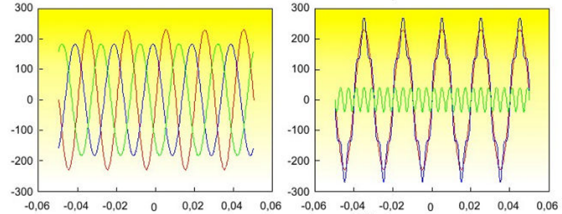
a) overvoltage b) interruption



c) dip d) flicker



e) frequency variation f) transient



g) phase asymmetry h) harmonics

Figure 2. (a)-(h): Possible events in a low-voltage grid

Figure 2 identifies grid events which affect the voltage quality and shows the associated deviations from the norm.

High voltage quality is the pre-condition for reliable operation and a long lifetime of electric appliances and machines. A distinction can be made between deviations in the voltage waveform from a pure sinusoidal form at 50 Hz (Fig. 2 (e) - (h)) and a short-term or long-term deviation from the specified voltage (in Europe 230 V, +6%/-10%, regulated in EN 50160) (Fig. 2 (a) - (d)).

In Romania, the power supply and voltage quality is generally very good, with a few exceptions, usually in remote areas. In some regions of Europe and in transformation countries, grid breakdowns, too high or too low grid voltages, or major disturbances in the voltage quality occur more often. In threshold and developing countries, the grids and distribution structures are often significantly weaker[7].

As well as the influence of photovoltaic systems on the grid voltage, inadequate quality of the grid voltage can affect the operation of photovoltaic systems. For example, if the grid voltage varies outside the permissible range, the inverters switch off. The waveform of the grid voltage can also affect the operation of photovoltaic inverters.

A phenomenon which has often been observed in larger low-voltage grids with many photovoltaic systems is the occurrence of phase asymmetry. Private photovoltaic systems in Europe usually feed single-phase current into one phase of the triple-phase low-voltage grids (system power ratings are usually below 5 kW). As the installation of inverters is not usually co-ordinated, the electricians often automatically connect the systems to the first phase, as the connection point is the first one on the left hand side of the connection box[8]. This results in a concentration of systems connected to phase 1 and thus, if a large amount of PV power is fed into a grid segment, to an asymmetric load which then also affects the grid voltage.

A question which has not yet been answered in detail concerns the way in which power quality effects add up in grids due to many individual systems, e.g. concerning harmonics. According to the relevant standards, each individual system can feed electricity into the grid with harmonics within the specified limits. A multitude of systems can then result in a perturbation level which is no longer acceptable. However, the opposite effect can often be observed today in residential areas: PV inverters can also reduce the proportion of harmonics. Many household loads such as electronic devices and power supplies cause harmonics in significant proportions, particularly the 5th and 7th harmonic. By contrast, modern PV inverters supply AC electricity to the grid with a considerably "cleaner" sinusoidal waveform, so that the overall content of upper harmonics actually decreases[9].

5. Conditions needed to connect a photovoltaic module based electrical source to the system

Regarding the research/experiments made there were made rows made of 4,5,6,9 and 11 photovoltaic modules connected in a row and in parallel. The PV system of the solar amphitheatre is connected to the Red of 6 kV in the neighborhood between P.T.Z high school C.O.S.T and P.T.Z. 44. Typography through 8 invertors Sunny Boy made by SMA Regelsystem GmbH.

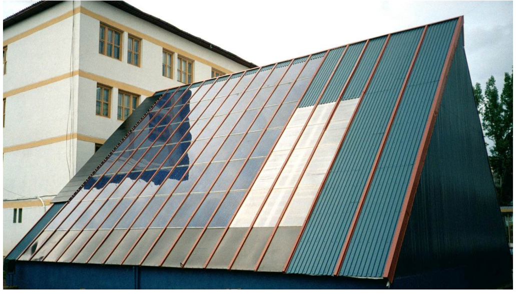


Figure 3. Photovoltaic System at the University of Valahia in Targoviste

6. The conversion installation (from A.C. to D.C.)

Converters are built to obtain desired and alterable values and frequency for alternative tensions needed by the consumers.

The inverters used in the Solar amphitheatre installation have different power output as following: five inverters Sunny Boy 700; one inverter Sunny Boy 1100E, one inverter Sunny Boy 2000 and one inverter Sunny Boy 2500.

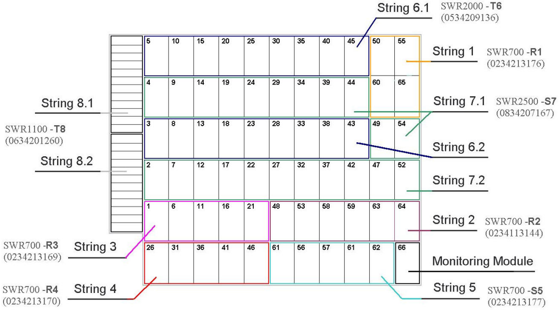


Figure 4. PV modules layout at the University of Valahia in Targoviste

The inverters are connected to the RE in order to debitate equilibrate to all the 3 phases as the following:

- Phase a - four inverters Sunny Boy with a total amount of 2800W;
- Phase b - one inverter Sunny Boy 700 and one inverter Sunny Boy 2500 with a total amount of power of 3200W;
- Phase c - one inverter Sunny Boy 1100E and one inverter Sunny Boy 2000 with a total amount of 3100W.

These inverters are made to work at high randaments on a wade scale of powers, and don't need an operator because they can monitor input and output parameters by them selfs. The inverters are connected to a pc through a modem in order to monitor parameters in real-time.

Figure 5. The inverters and Sunny Boy Controller

7. The connection of the photovoltaic module to the electroenergetic system

The pulg-in installation of the inverters and modules to one of the three phases is presented in figure below:

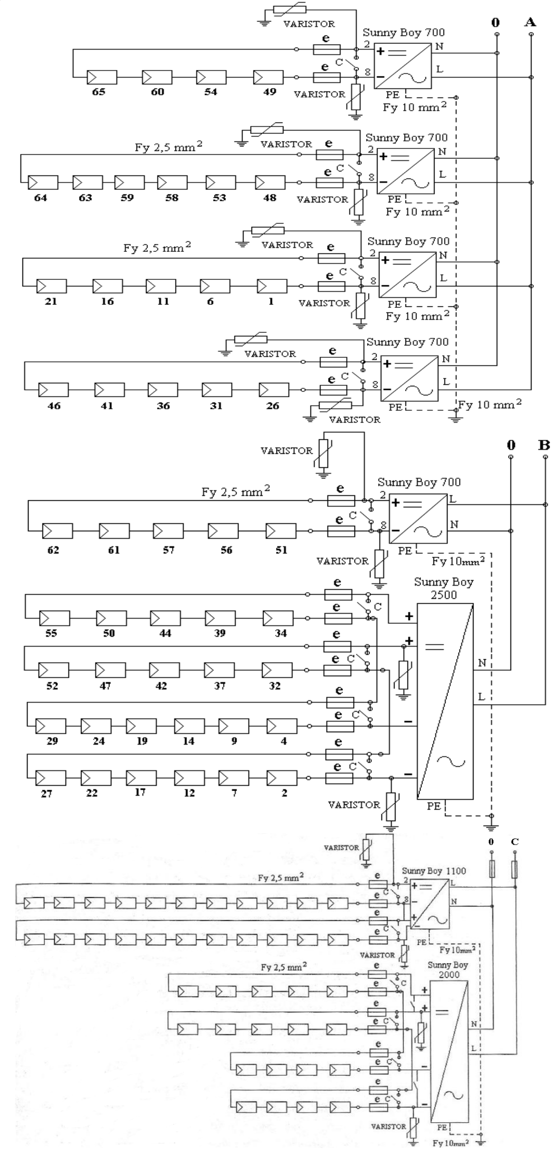


Figure 6. The electric energy production system with photovoltaic modules (phase a,b,c)

8. Power quality indicators

A number of indicators are used to quantify and evaluate the harmonic distortion in current and voltage waveforms, namely:

- Power factor
- Crest factor
- Distortion power
- Harmonic spectrum
- Harmonic-distortion values[10].

These indicators are indispensable in determining any necessary corrective action.

- *Power factor*

The power factor PF is the ratio between the active power P and the apparent power S.

$$PF = \frac{P}{S}$$

- *Crest factor*

The crest factor is the ratio between the value of the peak current or voltage (I_m or U_m) and its rms value.

- For a sinusoidal signal, the crest factor is therefore equal to 2.
- For a non-sinusoidal signal, the crest factor can be either greater than or less than 2.

In the latter case, the crest factor signals divergent peak values with respect to the rms value.

- *Distortion power*

When harmonics are present, the distortion power D is defined as

$$D^2 = S^2 - \left(P^2 - Q^2\right)$$

where S is the apparent power[11].

- *Harmonic spectrum and harmonic distortion[15]*

Each type of device causing harmonics draws a particular form of harmonic current (amplitude and phase displacement).

These values, notably the amplitude for each harmonic order, are essential for analysis.

- *individual harmonic distortion*

The individual harmonic distortion is defined as the percentage of harmonics for order h with respect to the fundamental.

$$U_h(\%) = 100\frac{U_h}{U_1} \qquad i_h(\%) = 100\frac{I_h}{I_1}$$

By representing the amplitude of each harmonic order with respect to its frequency, it is possible to obtain a graph called the harmonic spectrum.

- *rms value*

The rms value of the voltage and current can be calculated as a function of the rms value of the various harmonic orders.

$$I_{rms} = \sqrt{\sum_{h=1}^{\infty} I_h^2} \qquad U_{rms} = \sqrt{\sum_{h=1}^{\infty} U_h^2}$$

- *Total harmonic distortion (THD)*

The term THD means Total Harmonic Distortion and is a widely used notion in defining the level of harmonic content in alternating signals.

-Definition of THD

For a signal y, the THD is defined a as:

$$THD = \frac{\sqrt{\sum_{h=2}^{\infty} y_h^2}}{y_1}$$

This complies with the definition given in standard IEC 61000-2-2.

Note that the value can exceed 1.

According to the standard, the variable h can be limited to 50. The THD is the means to express as a single number the distortion affecting a current or voltage flowing at a given point in the installation.

The THD is generally expressed as a percentage.

- *Current or voltage THD*

For current harmonics, the equation is:

$$THD_i = \frac{\sqrt{\sum_{h=2}^{\infty} I_h^2}}{I_1}$$

The equation below is equivalent to the above, but easier and more direct when the total rms value is available:

$$THD_i = \sqrt{\left(\frac{I_{rms}}{I_1}\right)^2 - 1}$$

For voltage harmonics, the equation is:

$$THD_u = \frac{\sqrt{\sum_{h=2}^{\infty} U_h^2}}{U_1}$$

9. Monitorization over the quality parameters of the electrical energy

Monitorization of the energy quality it's needed in order to define electromagnetically any point of the electric network[12],[13].

The purpose of monitorization is:

- To diagnose the incompatibilities between the source and the consumers;
- To evaluate the performance of working equipments;
- To eliminate infunctionability problems of some receptors;

A mass control over the quality parameters is needed more and more and so it is highly necessary to monitor the energies quality parameters.

In order to do this monitorization some problems need to be resolved and these are:

- To set some general theoretical conditions needed by the measuring devices;
- To set a theme for every parameter monitorized;
- To decide which mode and what requirements need to be med in order to start the measuring campaign;

An actual problem, practically specking is the measuring of perturbations given to the RE regarding:

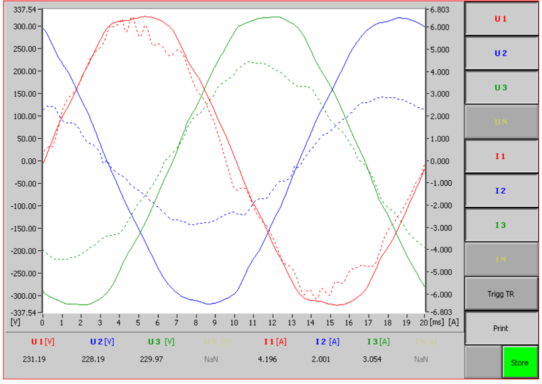
- The necessity to analyze the quality of the energy given to the consumers;
- The limitation of the negative influences of perturbations over the parameters of the energy given;
- To see if the perturbance of the consumers connected to the network of the source fit in the stats;

With the help of a device – CA 8352 used to measure the quality of the electrical energy, a monitorization over the parameters of the energy debited to the system by the photovoltaic source was possible, and also an analysis over them was made using LabView. (figure 7)

Figure 7. Three phase energy analyser CHAUVIN ARNOUX CA8352

In figure 8 is present the results of the tensions on all the 3 phases:

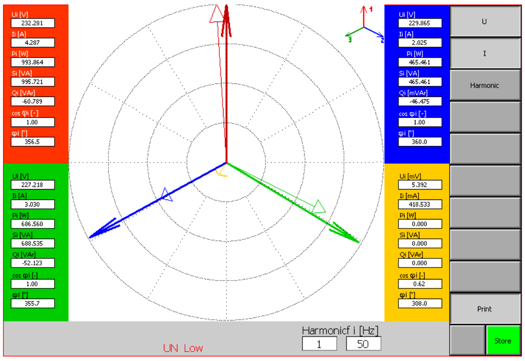
- On phase A : $U_{10} = 231,19$ V;
- On phase B : $U_{20} = 228,19$ V;
- On phase C : $U_{30} = 229,97$ V;



U 1 [V]	U 2 [V]	U 3 [V]	U N [V]	I 1 [A]	I 2 [A]	I 3 [A]	I N [A]
231.19	228.19	229.97	NaN	4.196	2.001	3.054	NaN

Figure 8. The manifestation of the current and tension on all the 3 phases

In figure 9 the phazorial diagram is displayed and in figure 10 timeline variations of tension, current, active and reactive power –on all the 3 phases of the PV.



Ui [V] 232.281
Ii [A] 4.287
Pi [W] 993.864
Si [VA] 995.721
Qi [VAr] -60.789
cos φi [-] 1.00
φi [°] 356.5

Ui [V] 227.218
Ii [A] 3.030
Pi [W] 686.560
Si [VA] 688.535
Qi [VAr] -52.123
cos φi [-] 1.00
φi [°] 355.7

Ui [V] 229.865
Ii [A] 2.025
Pi [W] 465.461
Si [VA] 465.461
Qi [mVAr] -46.475
cos φi [-] 1.00
φi [°] 360.0

Ui [mV] 5.392
Ii [mA] 418.533
Pi [W] 0.000
Si [VA] 0.000
Qi [VAr] 0.000
cos φi [-] 0.62
φi [°] 308.0

Harmonicf i [Hz] 1 50

Figure 9. Phazorial diagram

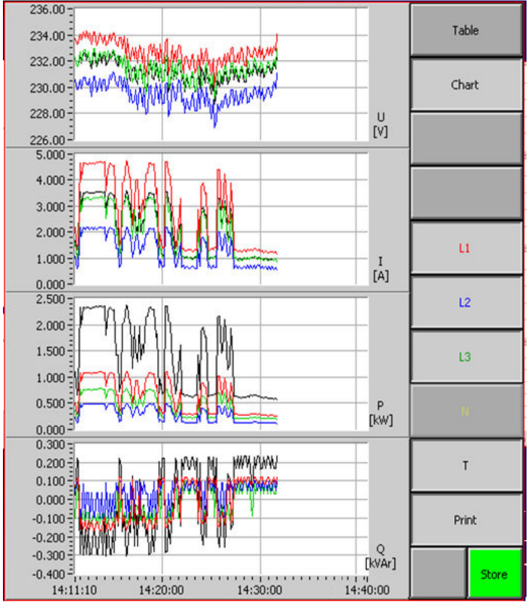


Figure 10. Timeline variations of tension, current, active and reactive power – on all the 3 phases of the PV.

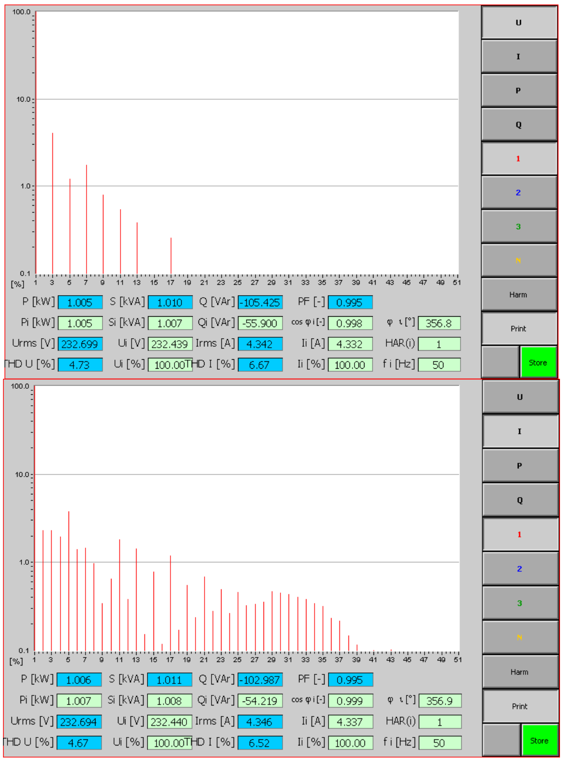
In figure 11 is present the table – parameters of the electrical energy on all the 3 phases and in figures 12,13,14 harmonic specter on all the 3 phases.

	1	2	3	3 ~	N
U [V]	232.93	229.90	231.77	231.53	0.00
I [A]	1.199	0.645	0.897	0.941	0.000
P [kW]	0.265	0.124	0.205	0.594	0.000
S [kVA]	0.279	0.148	0.208	0.636	0.000
Q [kVAr]	0.089	0.082	0.032	0.203	0.000
P1 [kW]	0.265	0.124	0.206	0.594	0.000
Q1 [kVAr]	0.061	0.030	0.018	0.109	0.000
cos φ	0.97	0.97	1.00	0.98	0.00
PF	0.95	0.83	0.99	0.93	0.00
AP [kWh]	0.214	0.097	0.154	0.465	0.000
AS [kVAh]	0.217	0.099	0.156	0.472	0.000
AQ [kVArh]	-0.006	0.012	-0.010	-0.004	0.000
AP1 [kWh]	0.214	0.097	0.154	0.465	0.000
AQ1 [kVArh]	-0.004	0.007	-0.008	-0.005	0.000
APin [kWh]	0.214	0.097	0.154	0.465	0.000
APout [kWh]	0.000	0.000	0.000	0.000	0.000
AQL [kVArh]	0.014	0.014	0.005	0.025	0.000
AQC [kVArh]	-0.020	-0.002	-0.015	-0.029	0.000

Avg
f [Hz] 50.00
α u [%] 14183.98

Energy

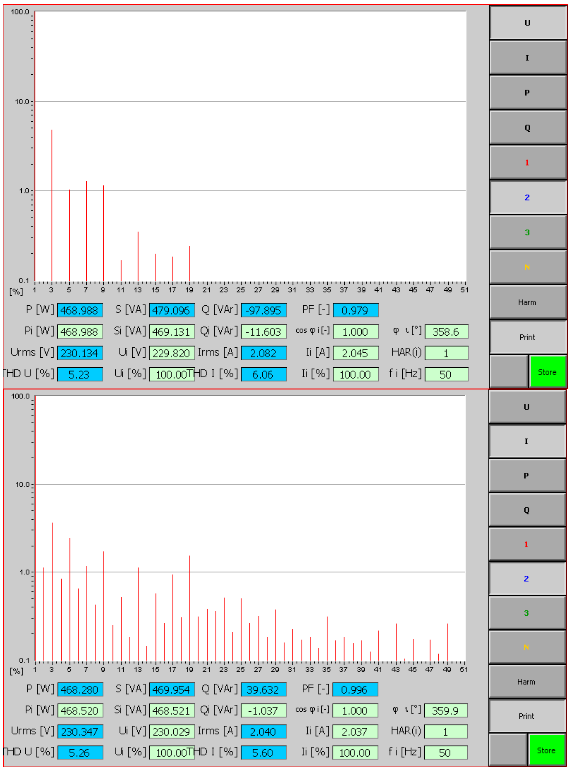
Figure 11. Table – parameters of the electrical energy on all the 3 phases



P [kW] 1.005
S [kVA] 1.010
Q [VAr] -105.425
PF [-] 0.995
Pi [kW] 1.005
Si [kVA] 1.007
Qi [VAr] -55.900
cos φ i [-] 0.998
φ ι [°] 356.8
Urms [V] 232.699
Ui [V] 232.439
Irms [A] 4.342
Ii [A] 4.332
HAR(i) 1
THD U [%] 4.73
Ui [%] 100.00
THD I [%] 6.67
Ii [%] 100.00
f i [Hz] 50

P [kW] 1.006
S [kVA] 1.011
Q [VAr] -102.987
PF [-] 0.995
Pi [kW] 1.007
Si [kVA] 1.008
Qi [VAr] -54.219
cos φ i [-] 0.999
φ ι [°] 356.9
Urms [V] 232.694
Ui [V] 232.440
Irms [A] 4.346
Ii [A] 4.337
HAR(i) 1
THD U [%] 4.67
Ui [%] 100.00
THD I [%] 6.52
Ii [%] 100.00
f i [Hz] 50

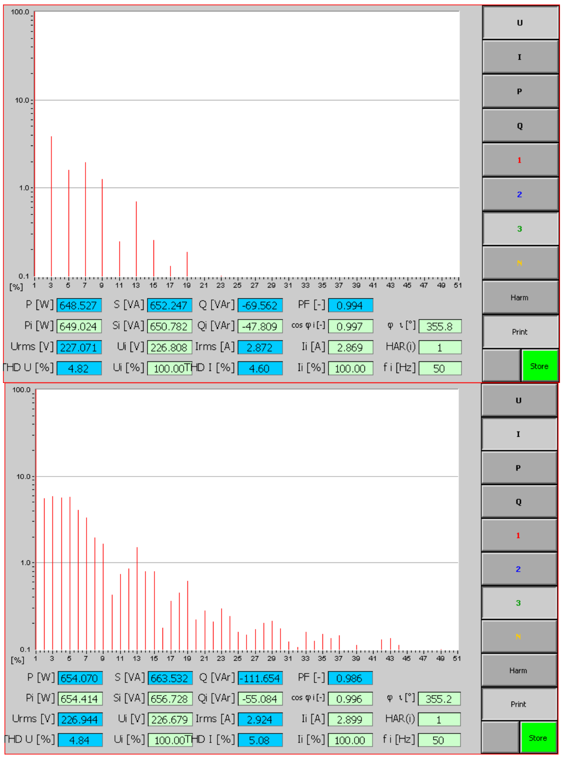
Figure 12. Harmonic specter (U,I) for phase A



P [W] 468.988
S [VA] 479.096
Q [VAr] -97.895
PF [-] 0.979
Pi [W] 468.988
Si [VA] 469.131
Qi [VAr] -11.603
cos φ i [-] 1.000
φ ι [°] 358.6
Urms [V] 230.134
Ui [V] 229.820
Irms [A] 2.082
Ii [A] 2.045
HAR(i) 1
THD U [%] 5.23
Ui [%] 100.00
THD I [%] 6.06
Ii [%] 100.00
f i [Hz] 50

P [W] 468.280
S [VA] 469.954
Q [VAr] 39.632
PF [-] 0.996
Pi [W] 468.520
Si [VA] 468.521
Qi [VAr] -1.037
cos φ i [-] 1.000
φ ι [°] 359.9
Urms [V] 230.347
Ui [V] 230.029
Irms [A] 2.040
Ii [A] 2.037
HAR(i) 1
THD U [%] 5.26
Ui [%] 100.00
THD I [%] 5.60
Ii [%] 100.00
f i [Hz] 50

Figure 13. Harmonic specter (U,I) for phase B



P [W] 648.527 S [VA] 652.247 Q [VAr] -69.562 PF [-] 0.994
Pi [W] 649.024 Si [VA] 650.782 Qi [VAr] -47.809 cos φ i [-] 0.997 φ ι [°] 355.8
Urms [V] 227.071 Ui [V] 226.808 Irms [A] 2.872 Ii [A] 2.869 HAR(i) 1
THD U [%] 4.82 Ui [%] 100.00 THD I [%] 4.60 Ii [%] 100.00 f i [Hz] 50

P [W] 654.070 S [VA] 663.532 Q [VAr] -111.654 PF [-] 0.986
Pi [W] 654.414 Si [VA] 656.728 Qi [VAr] -55.084 cos φ i [-] 0.996 φ ι [°] 355.2
Urms [V] 226.944 Ui [V] 226.679 Irms [A] 2.924 Ii [A] 2.899 HAR(i) 1
THD U [%] 4.84 Ui [%] 100.00 THD I [%] 5.08 Ii [%] 100.00 f i [Hz] 50

Figure 14. Harmonic specter (U,I) for phase C

10. Conclusions

After measurements with the Chauvin Arnoux 8354 the following conclusions can be regarded:

1. After analising the curves of tension and current on all the 3 phases the following occured:

- Tension curves are very alike and very close to the fundamental sinusoidal, and so measure in the standard curves guaranteed by the inverter's license constructor;
- Tension curves are symmetrically defazed one another, defazation between the tension and current curves point that during monitorization the PV source worked as an capacitive generator ;
- There weren't any tension variations that go beyond admittance limits or power drop under neutral limit (fact guaranteed by the producer) ;
- Measured distortion coefficient of the tension curve is THDU = 5% under 8% of it's value (limited admission value for the JT-MT in conformation with PE-143/94);
- An accentuated deformation of the current curves can be observed due to incorrect functionality of the inverters filters: THDY=3% value that can't be contested due to the lack of normative for this indicator for the quality of electrical energy .
- Infunctionability of two of the inverters connected to phases b and c reflects in small currents obtained on this two phases (2.01A on phase b and 3.05A on phase c) compared to 4.19A measured on phase a.

2. From the harmonic analysis results that overlimit levels of compatibility (set in PE-143/94) for current harmonics on phases b and c were found. This faults are caused by the infunctionability of the inverters filters connected on those two phases.

3. A final conclusion over harmonic influences and the way in which the photovoltaic panel source influences the quality parameters of the given electrical energy, can be met only when all the inverters will function correctly and of course all the elements within them. Over limit levels of compatibility for current harmonics mentioned before should not be neglected, a motivation is needed to find and put to use optimal solutions to solve this inconvenient, because the negative effects of this over limit are found in: affected functionability of devices and equipments plugged to the PV source; increase in number of errors given by the measurement devices; perturbance in the functionability of loads connected to the PV; the overcharge of LES and PT at witch the PV source is connected[14].

Based on the current dissemination level of photovoltaics, generally it will not be necessary to limit the number of systems that can be accommodated within existing electricity grids in the foreseeable future. Limitations apply only in regions with weak grid segments. However, the penetration rate could still be increased considerably even in such regions, and may even help to support the weak grids. Restrictions or possible benefits should be considered for individual cases, as they depend on the specific conditions concerning grids, loads and generation profiles. Nevertheless, the interactions between PV systems and grids should not be ignored in grid segments with a high penetration rate[15].

Current trends in distributed generation demand a substantial structural change in grid planning and operation. At the same time, they make new functions feasible for PV systems and inverters. Added value can be created by offering e.g. so-called system services. The necessary preparations e.g. in standardisation committees must be made in good time, as the investments in grids and infrastructure have amortisation periods of several decades. Integrated operation management of many distributed generators, and co-ordinated operation management of electricity, heat and gas, will open up new opportunities, also for photovoltaics[16].

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