Technical Interactions Between Distributed Photovoltaic Systems And Low-Voltage Grids

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Abstract:- 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 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 generation, quality parameters.

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[6].

2. 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[2].

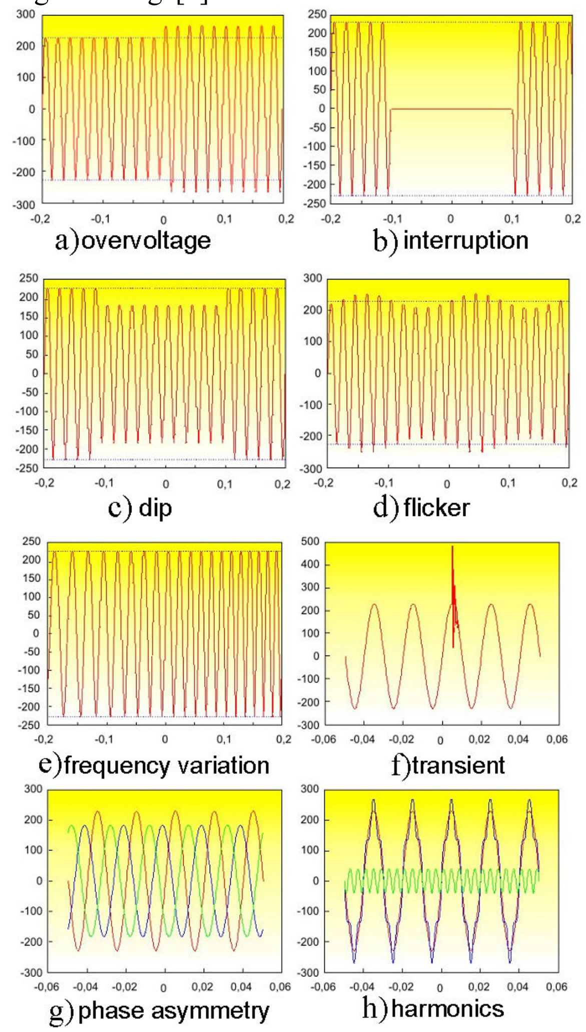

Figure 1. (a)-(h): Possible events in a low-voltage grid

Figure 1 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[3].

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. 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.

3. 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.

ISBN: 978-960-474-257-8

Typography through 8 invertors Sunny Boy made by SMA Regelsystem GmbH.

4. 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.

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.

5. 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 scheme 1 below:

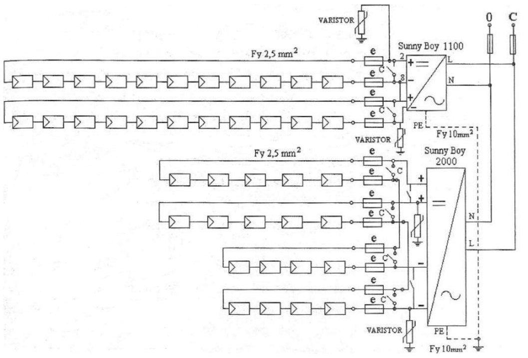

Figure 2. The electric energy production system with photovoltaic modules (phase c)

6. 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[7].

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 Lab View[4],[5]. (figure 3)

Figure 3. Three phase energy analyser CHAUVIN ARNOUX CA8352

In figure 4 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;

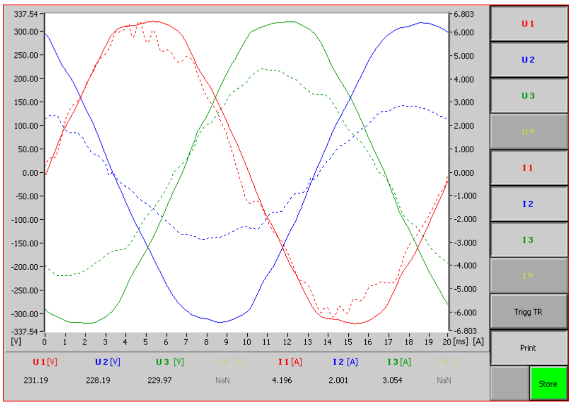

Figure 4. The manifestation of the current and tension on all the 3 phases

In figure 5 the phazorial diagram is displayed and in figure 6 timeline variations of tension, current, active and reactive power –on all the 3 phases of the PV.

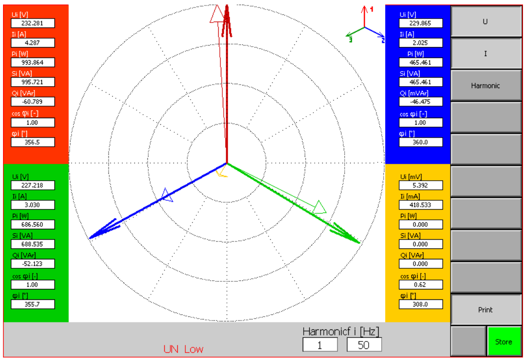

Figure 5. Phazorial diagram

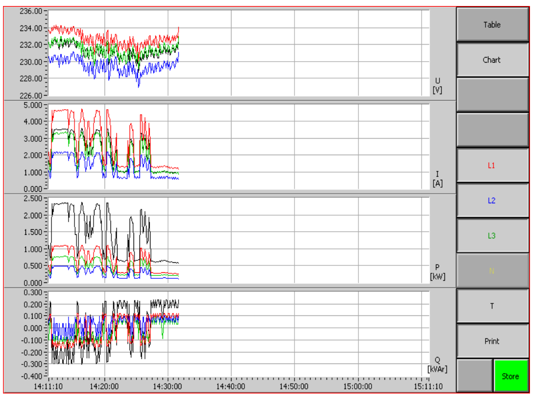

Figure 6. Timeline variations of tension, current, active and reactive power – on all the 3 phases of the PV.

In figure 7 is present the table – parameters of the electrical energy on all the 3 phases and in figure 8 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

Figure 7. Table – parameters of the electrical energy on all the 3 phases

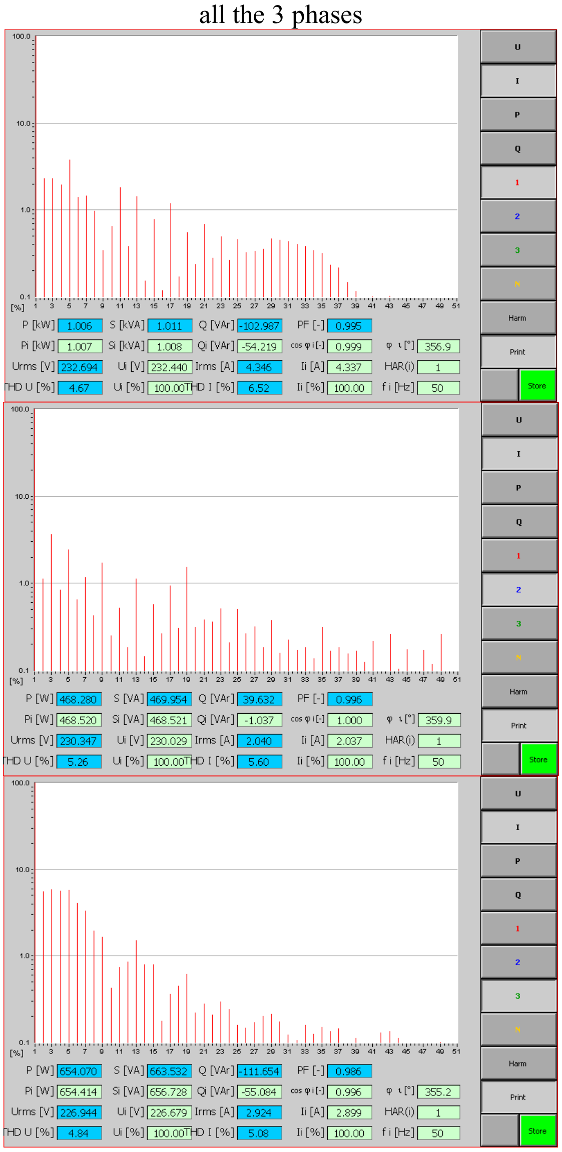

Figure 7. Harmonic specter on all the 3 phases

6. 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 functionability 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[8], [9].

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