On-Site Power Quality Measurements in a Photovoltaic System Connected with the Distribution Network

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Abstract. *This paper analyse the power quality in a Photovoltaic System connected with the Distribution Network Grid. The work was performed in the framework of the European Metrology Research Programme Project "Metrology for Smart Electrical Grids", Work Package 3 – Tools for portable and remote measurement of Power Quality [1].*

Keyword: Power Quality, Photovoltaic System, Distribution Network Grid, Harmonics, Voltage Unbalance

1. Introduction

The power quality (PQ) measurement and the data acquisition is based on the existing standards EN 50160 [2] which provides recommended levels for different power quality parameters, including a time-based percentage during which the levels should be kept and IEC 61000-4-30 [3] which provides measurement methods, describes measurement formulas, sets accuracy levels and defines aggregation periods.

2. Description of the network and measurement apparatus

The PQ measurements were performed in an electrical cabinet with the nominal voltage 230V, current transformers ratio 150A/5A, 3phase with neutral, fed by low voltage (LV) from a MV/LV substation. The Photovoltaic (PV) System is connected with the electrical cabinet via a 3phase underground cable.

We used for the measurement a Fluke Power Quality Analyzer and transducers (voltage sensors 600V and current clamps 50A/5A). The voltage measurement connections were made direct on 3phase bus bars using crocodile clips. Current clamps were connected on the secondary windings (5A) of the current transformers. The Power Quality Analyzer was calibrated prior starting on-site measurements. Current transformers were calibrated before installation within the electrical cabinet.

The exact phasing of the PV connections is unknown however from the results it can be inferred that the distribution between the three phases in uneven and is approximately distributed 35% - 40% - 25% across phases L1-L2-L3.

3. Measurement results and analysis

The power quality measurements were performed within the period June (before the PV panels were installed) and July 2012 (after the PV panels were installed), 2 months measurement campaigns.

A huge amount of data was collected during these surveys. The graphs presented in this section are for a period of 2 weeks, one week before the PV panels were installed and one week after the PV panels were installed.

It is interesting to consider the power flow at the monitoring point over a period of time when the PV systems are receiving variable exposure from the sun.

Voltage Level

We are expecting that the voltage will rise during periods of PV system generation due to the real (active) power flow from the PV to the distribution network grid. By measuring voltages before and after the PV panels were installed changes in the voltage level with generation were investigated.

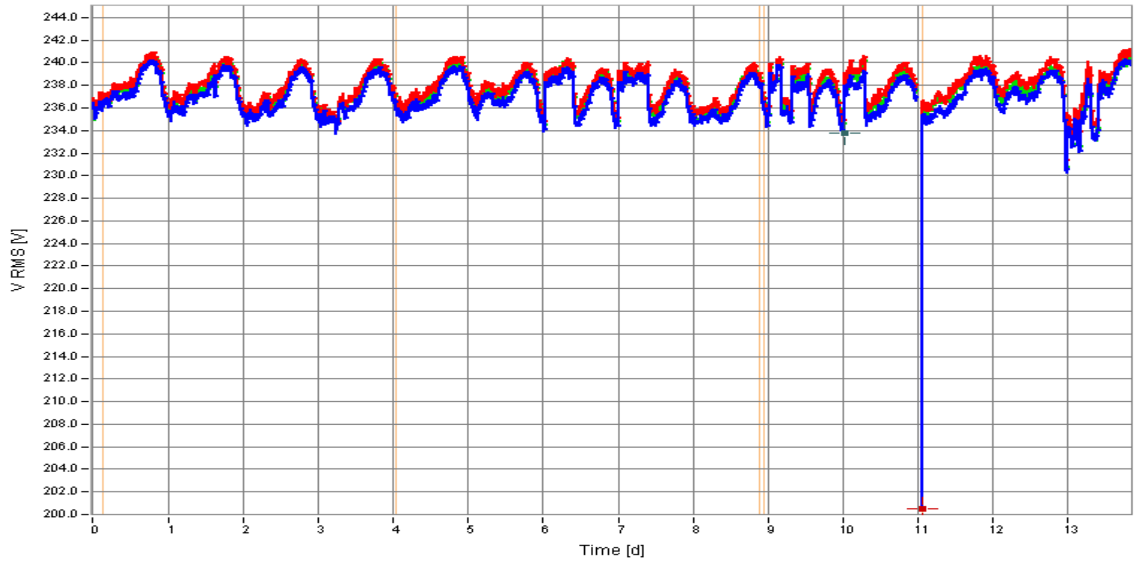

Fig. 1 Vrms (L1 blue, L2 red, L3 green) – June & July 2012

Fig. 1 shows the 3phase voltage levels within the 2 weeks period. We can visualize the variation in voltage due to PV generation compared to no generation.

Active Power and Reactive Power

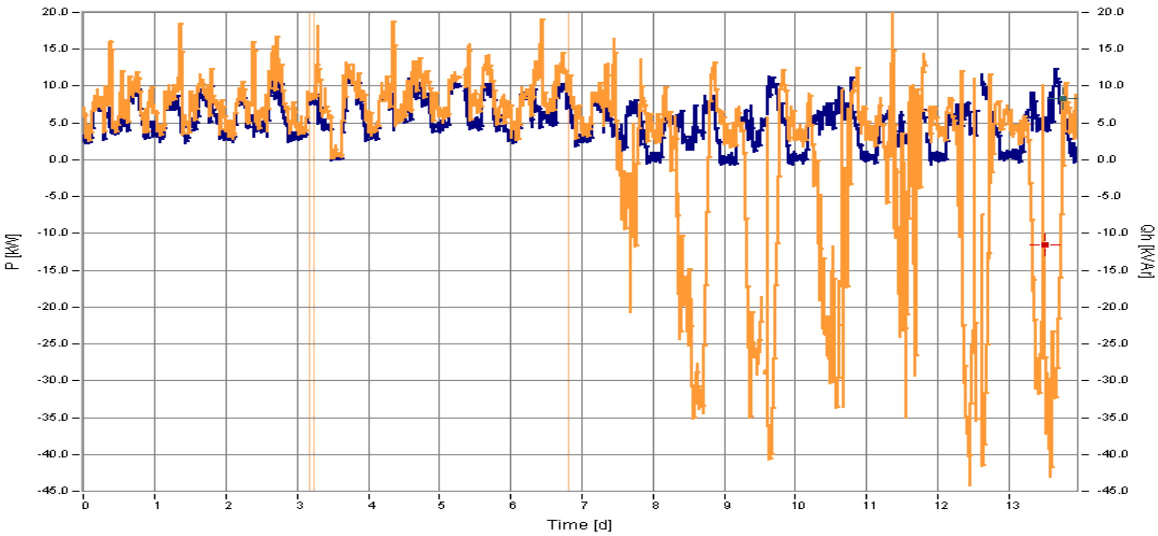

Fig. 2 Real Power P (orange) vs Reactive Power Qh (dark blue) – June & July 2012

Fig. 2 shows the sum of the Real Power vs the sum of the Reactive Power within the studied period. The Reactive Power is not strongly correlated to solar generation as PV panels/ inverter systems are only providing the active power during periods of generation.

As the reactive power for loads still needs to be supplied, it is left to the network to generate this wattless power for no revenue return. Aggregation of PV and other inverter generation on the network will leave an ever-increasing burden on network operators to generate the reactive power to satisfy the load.

Distortion and Harmonics

It is instructive as well to examine the recorded data for any effect of PV generation.

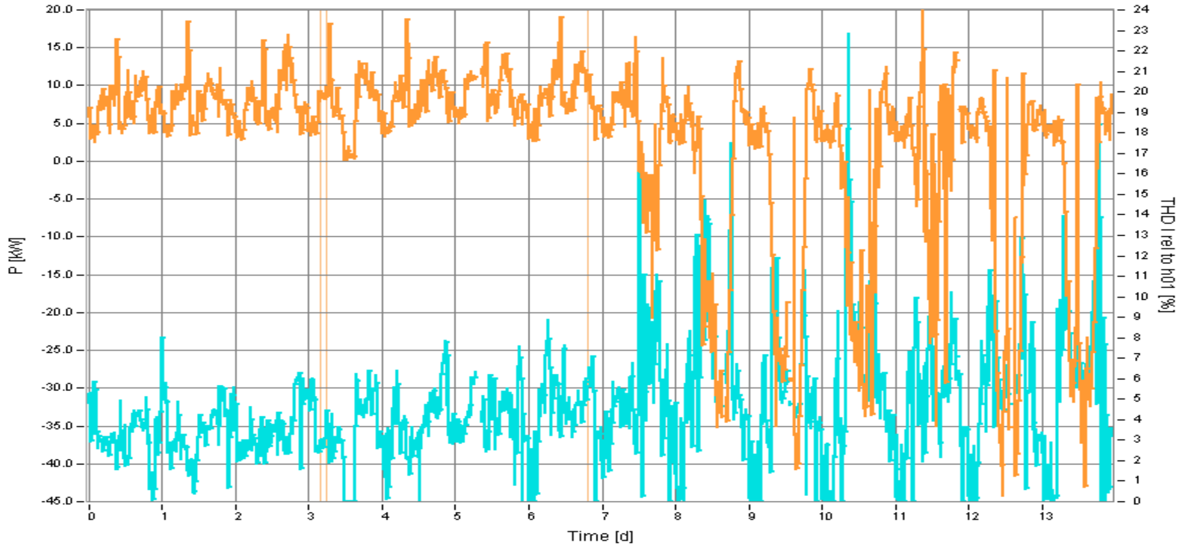

Fig. 3 Real Power P (orange) vs THD Irel to h01 (L2 light blue) - June & July 2012

Fig. 3 shows a chart of current total harmonic distortion (THD) on L2 without and with the generation of the real power into the distribution network grid. We can see that current THD increases as PV export increases. This effect occurs on all three phases, the L1&L3 effect being less visible due to a little bit lower generation on these phases.

The rise in current THD with generation is most likely to do with the increasing dominance of the sinewave (inverter output) generation current increasingly overwhelming generally low-level load current.

This raises the issue (as with the case of reactive power) that whilst the fundamental current is supplied by the PV systems during periods of generation, the harmonic currents required by the agitate load, must be supplied by the network. This could lead to planning issues as the proportion of inverter-based generators continues to grow.

Voltage & Current Unbalance

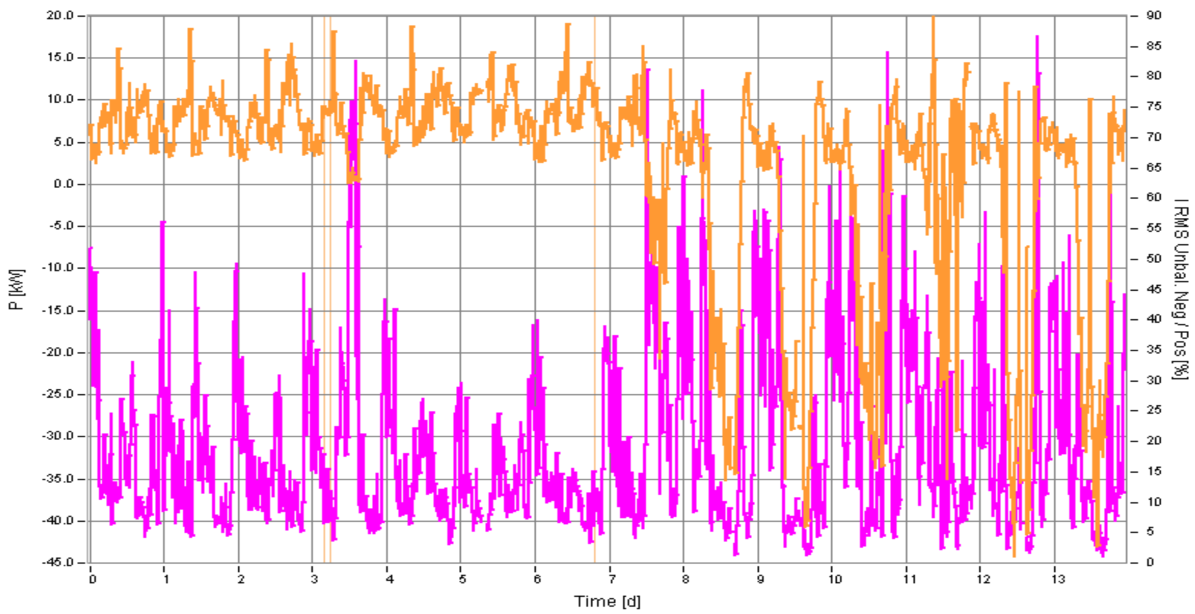

Fig. 4 Real Power P (orange) vs Irms Unbalance (pink) - June & July 2012

Voltage unbalance factor is defined in EN 50160 as the ratio of the negative sequence voltage to the positive sequence voltage. In all cases no unbalance factors above the 2 % limit in EN50160 were observed.

We can see in Fig. 4 that the current unbalance negative /positive was higher when the PV exports increases.

4. Conclusions

The monitoring of power quality on a low voltage feeder connecting a significant amount of PV generation reveals power quality degradation during periods of PV generation.

A significant effect seen during the study was a rise in voltage associated with PV generation. The analysis of the results presented shows that the voltage at the electrical cabinet increased by about 3 V during periods of generation. It was also observed a Voltage Dip and a Short Interruption (approx. 1.5 min.) during the PV generation.

It is noteworthy that on average the PV units are generating at approximately full capacity on the sunniest days during the survey.

The other point of interest is more general and concerns the supply of reactive power and harmonics during periods of PV generation. As the inverters in the system generate fundamental active power, the grid is required to supply the harmonics and the reactive power as it would without the presence of the PV, but with reduced billable watts.

Acknowledgements

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