MEASUREMENTS OF ELECTROMAGNETIC COMPATIBILITY IN DISTRIBUTED POWER GENERATION

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Abstract: *The purpose of this paper is to elaborate on the tests related to the operation of distributed generation (photovoltaic systems in particular) connected to low and medium voltage power distribution grids, and also related to the electromagnetic compatibility and power quality in different network loads, and in a power consumption mode, namely in a night mode.*

Key words: *generators and renewable energy source plants, Total Harmonic Distortion, distributed power generation.*

INTRODUCTION

In recent years, photovoltaic systems for power production, connected to low and medium voltage distribution grids, have gained extremely high popularity. The promotion of renewable energies in a number of countries, including Bulgaria, led to strong growth in installed capacity for electricity generation. Most wind turbines, photovoltaic plants, and small hydroelectric power plants are usually built in areas with extended power distribution grids, thus connected to the power distribution system. The operational requirements for the connection of wind power plants (WPP) to the medium voltage power distribution grid in Bulgaria are regulated. These requirements could be applied to other power plants that use renewable energy sources (RES). Below are some requirements applicable to the tests done:

- The allowable voltage unbalance caused by WPPs at the point of connection to the power distribution grid is 2.0 %, and 3.0 % to the distribution grid;
- The allowable quantity of harmonics produced by WPPs at the point of connection to the electricity grid (Total Harmonic Distortion) is THD ≤ 8% (MV grids).

The parameters of the harmonic distortion ratio in voltage and current [2,3] are calculated as follows:

$$THD_i = \frac{\sqrt{\sum_{h=2}^{\infty} I_h^2}}{I_1} \quad (1)$$

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

MEASUREMENTS AND GRAPHICS

The tests were performed with a networl analyzer that was set up to measure and recorc the values of the parameters set in 10 minute intervals within 168 hours. [1, 2]
Measurements were obtained from the power quality parameters taken from Solar Engineering Project EOOD, a small photovoltaic power plant, with a capacity of 96 kWp, connected at 20kV, at 0,4kV and also to a medium voltage grid located in the village of Obnova,
Figure 1 illustrates the results from the measurements of the change in the harmonic distortion ratio in the electrical current as per the percentage change in the electrical current in Phase I. For the other two phases, the results from MV and LV grids are identical.

Figure 3 and Figure 4 show the relationsh between LV and MV voltage grids in differe phases as a percentage value of the nomin voltage divided by the square root of three ar the asinusoidal voltage ratio. The provide graphs show that the power quality indicato (voltage deviation and asinusoidal voltage rati in MV and LV grids are within range for th production of electricity, with parameters clos to the nominal values. By reducing th production of electricity, with the electricit consumption generated from the inverters in standby mode, the power factor decrease sharply and the low-voltage asinusoidal ratios i all three phases reach up to 100% in each phas namely they exceed the allowable values (Fig and Fig. 4, 6). Built-in inverter filters are n effective in these modes. Parametric tests of th power quality of the LV grids were conducte on a cabale gland coming from the inverter.

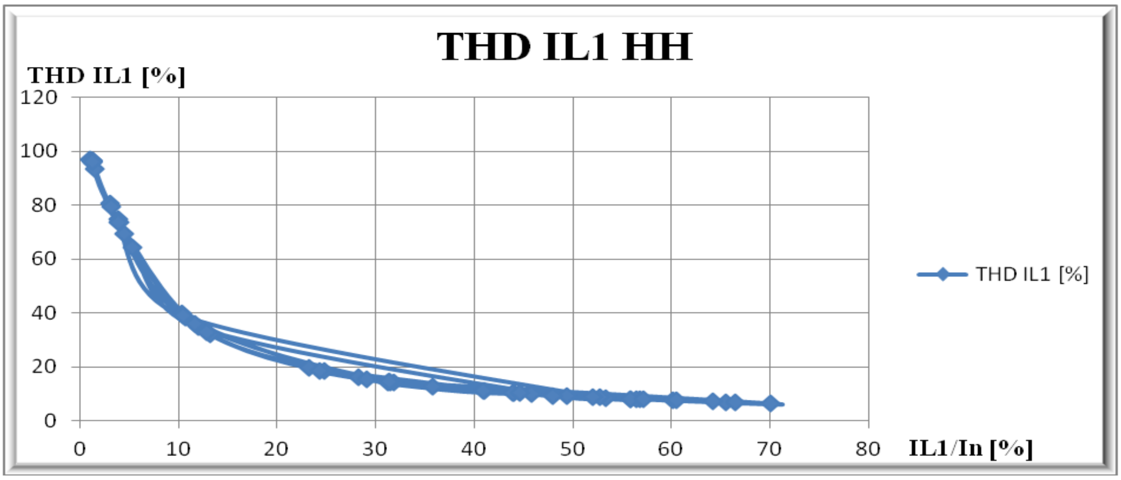

Figure 1

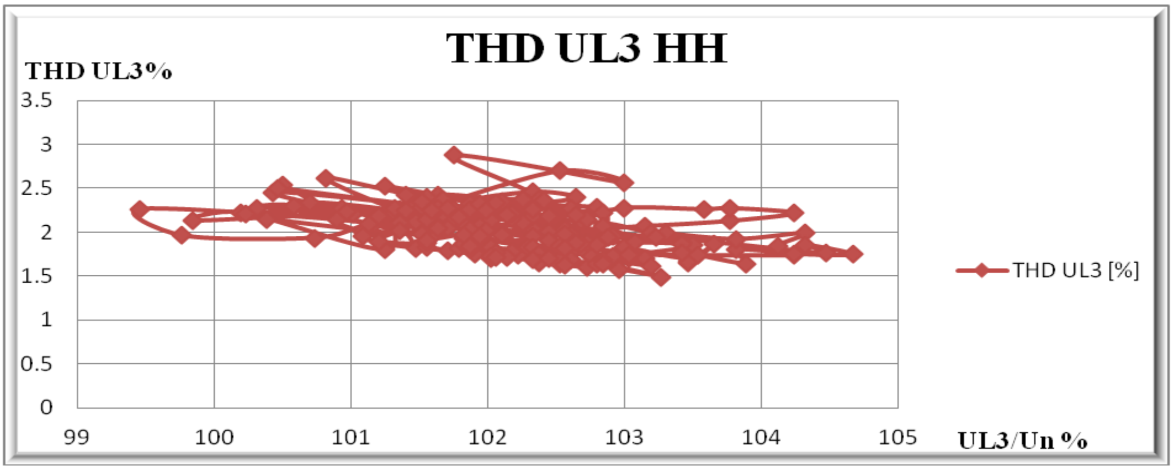

Figure 2

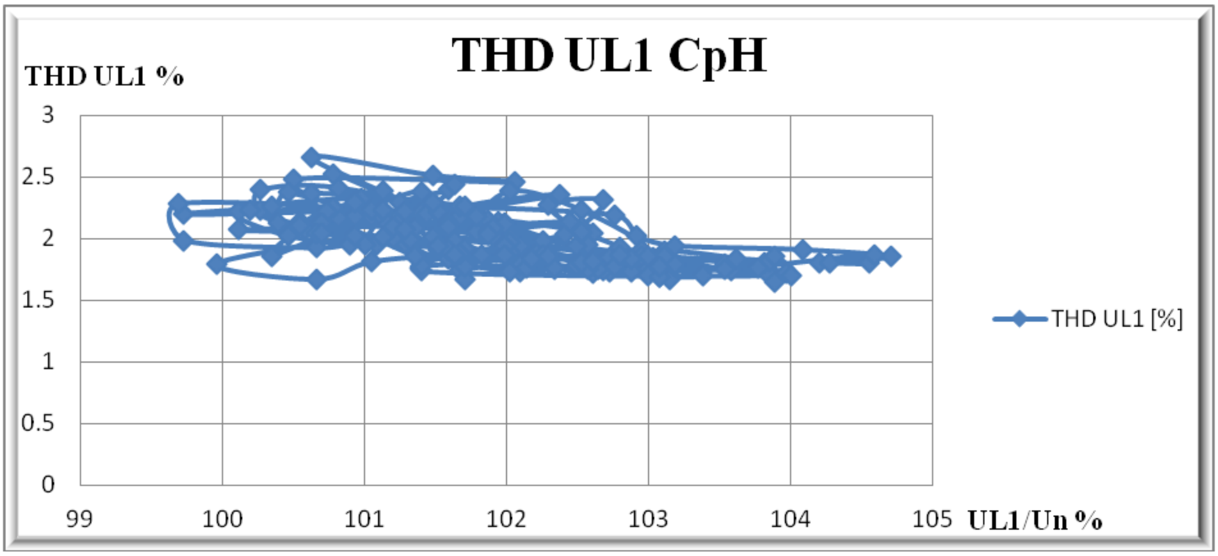

Figure 3

Measurements were carried out with regard to the power quality of ECO INVEST 1 OOD, a wind power plant (WPP) with a capacity of 1500 kW located in the village of Selanovtsi at 20kV. The tests results are shown in Figure 4 and Figure 5. The results from the measurements of the change in the harmonic distortion ratio in the electrical current, and from the percentage change in the electrical current in Phase I during the 168-hour measurement are shown in Figure 6. Figure 7 illustrates in percentage terms the relationship between the voltage of one of the phases and the asinusoidal voltage ratio. The results from the measurements of the other phases are identical. Indicators of power quality (voltage deviation and asinusoidal voltage ratio) in MV grids are within range [Figure 2, 3, 4]. By reducing the power production in standby power consumption of the power transformer with a capacity of 1600 kVA, the asinusoidal voltage ratios in MV grids reach 100% in each phase, i.e. they exceed the allowable values (Fig.9- 11) although the power transformer is of the Dyn5 connection type. The tests show that additional filters at 0,4 kV should be installed.

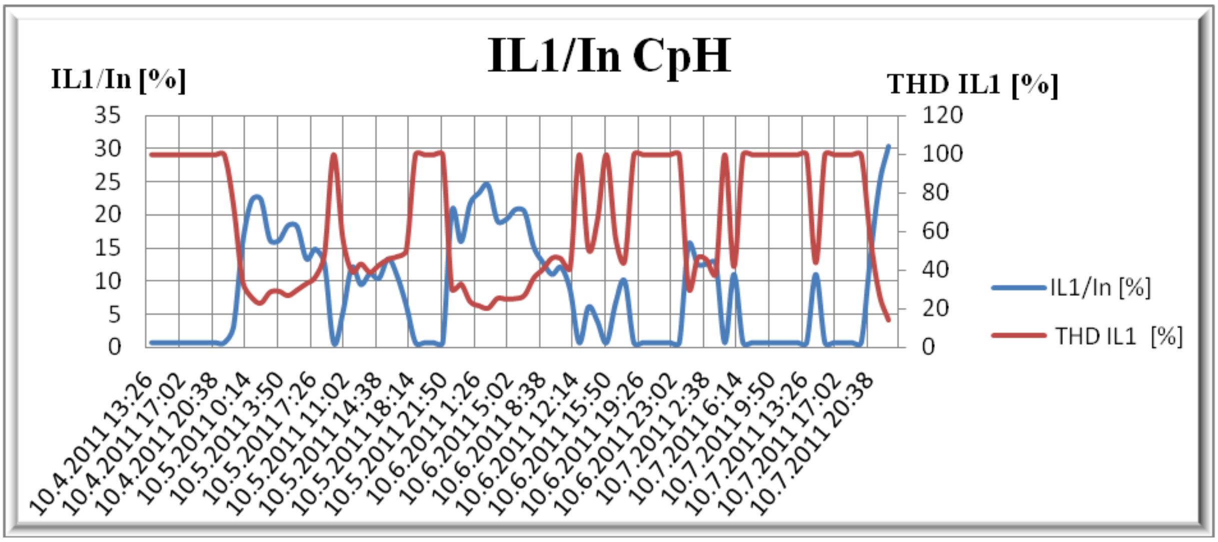

Figure 4

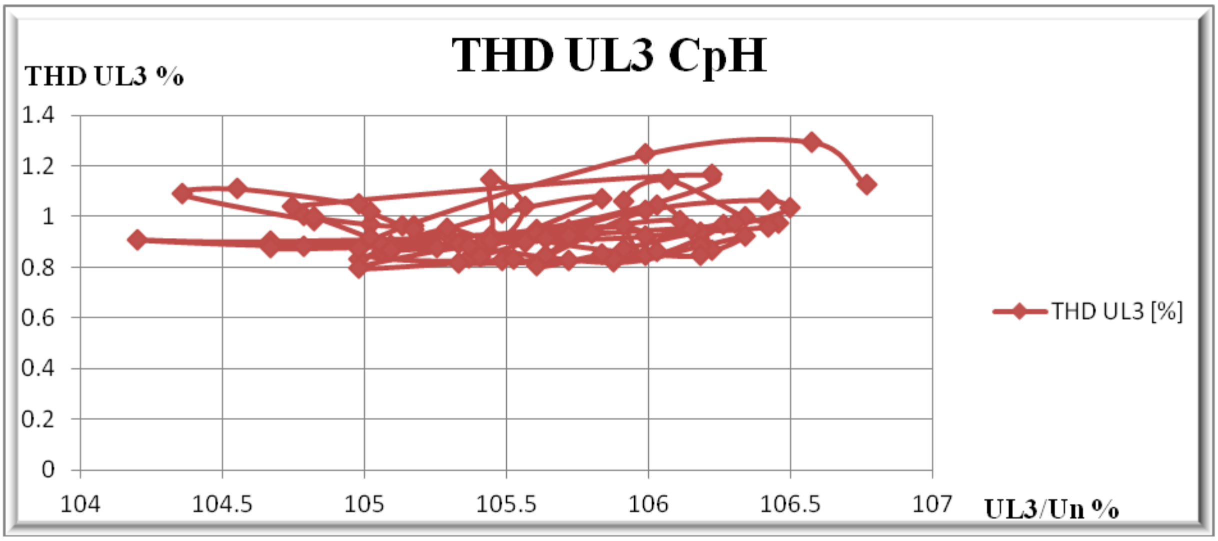

Figure 5

Measurements were carried out with regard to the power quality of a small photovoltaic power plant with a capacity of 30 kWp located in the village of Piperkovo, connected at 0,4kV. The results from the measurements of the change in the harmonic distortion ratio in the electrical current are shown in Figure 8, as per the percentage change in the electrical current in Phase I. For the other two phases, the results are identical. Fig. 7 illustrates in percentage terms the relationship between the voltage of one of the phases and the asinusoidal voltage ratio. From the provided graphs, it can be seen that the power quality indicators (voltage deviation and asinusoidal voltage ratio) in LV grids are within normal. By reducing the production of electricity, with the electricity consumption generated from the inverters in a standby mode, the asinusoidal voltage ratio at 400V for this three-phase photovoltaic power plant with a capacity of 30 kWp reach 98 % in each phase, i.e. they exceed the allowable limits (Figure 6).

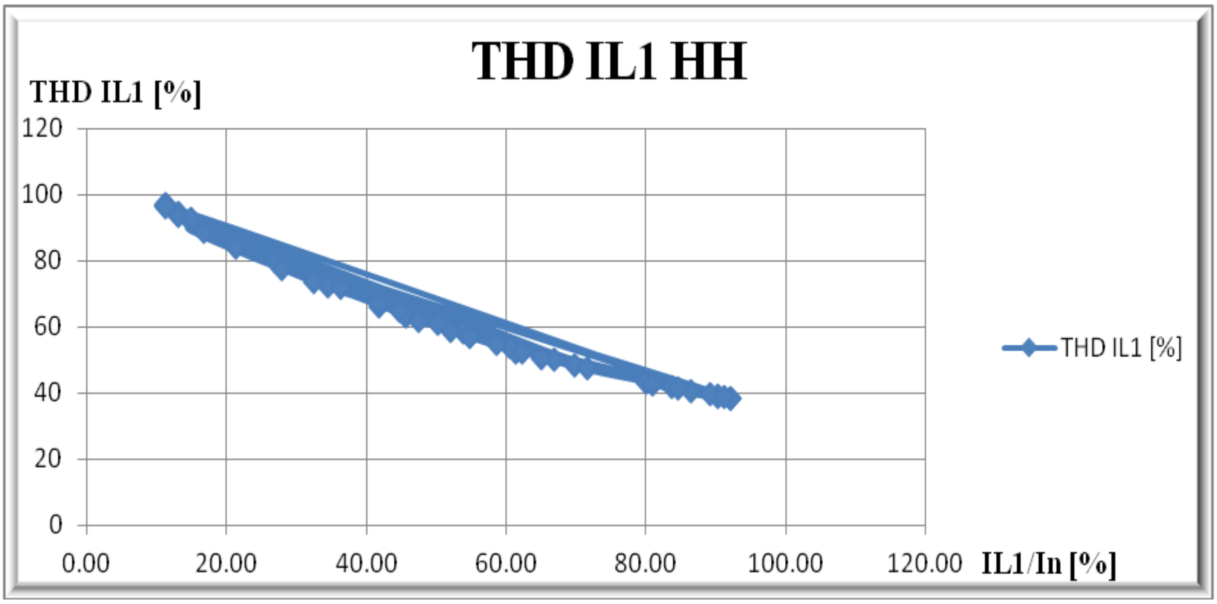

Figure 6

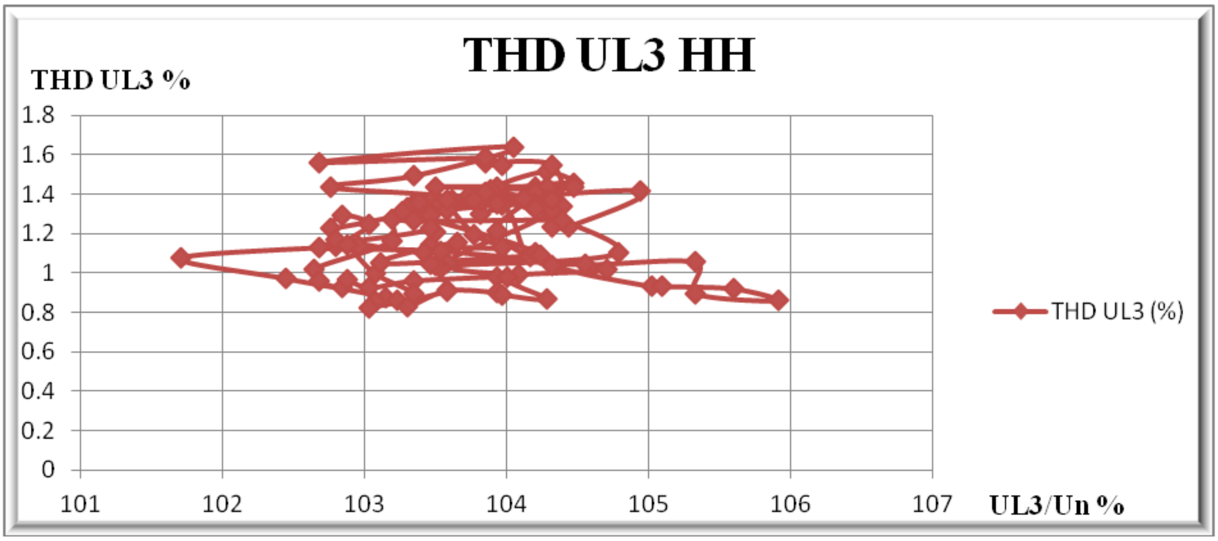

Figure 7

Measurements were carried out with regard to the power quality of a small photovoltaic power plant with a capacity of 12 kWp, located in the village of Stob, Kocherinovo Municipality, and connected at 0,4kV. [1, 2] Fig. 7 shows the change in the asinusoidal voltage ratio in Phase I as per the load indicated in percentages. The other phases are identical, depending on the operating time. Fig. 9 illustrates the change in the produced active power and the power factor during the operation of the small power plant. Fig. 10 shows the changes in the harmonics 3, 5, 7, 9 depending on the operating time.

The third harmonic – in a minimal load mode – has the highest level. By reducing the production of electricity, with the electricity consumption generated from the inverters in a standby mode, the asinusoidal voltage ratios at 400V for this three-phase photovoltaic power plant with a capacity of 12 kWp reach 95% in each phase, i.e. they exceed many times the allowable limits (Figure 8). In a standby mode, the inverters consume reactive power and are sources of harmonic distortion. In the low voltage grid – with a voltage deviation below or over the allowable values – the harmonic distortion ratio increases, but remains within acceptable limits (Figure 11, 12). In the third phase, the situation is identical.

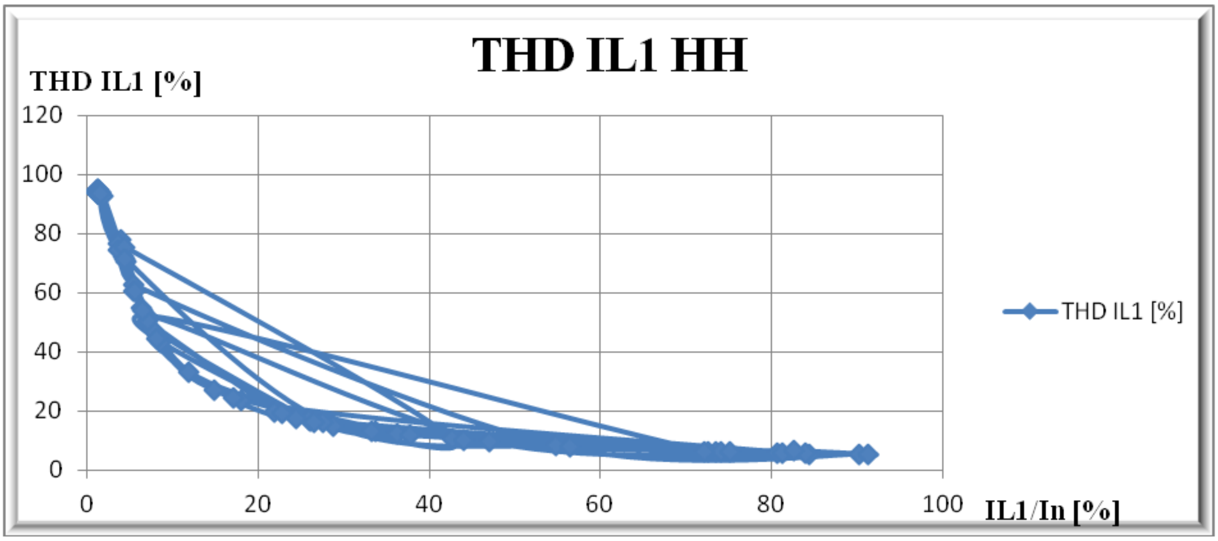

Figure 8

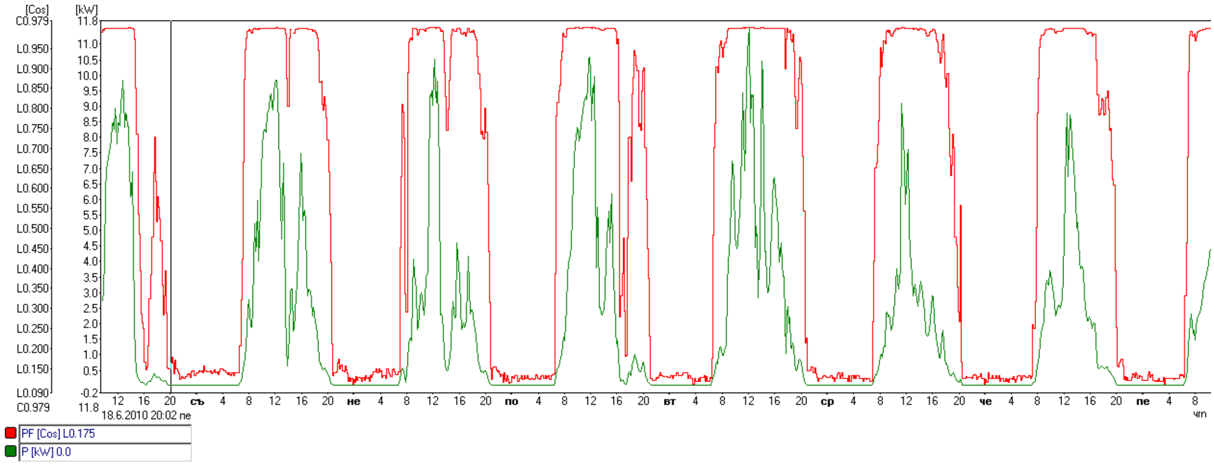

Figure 9

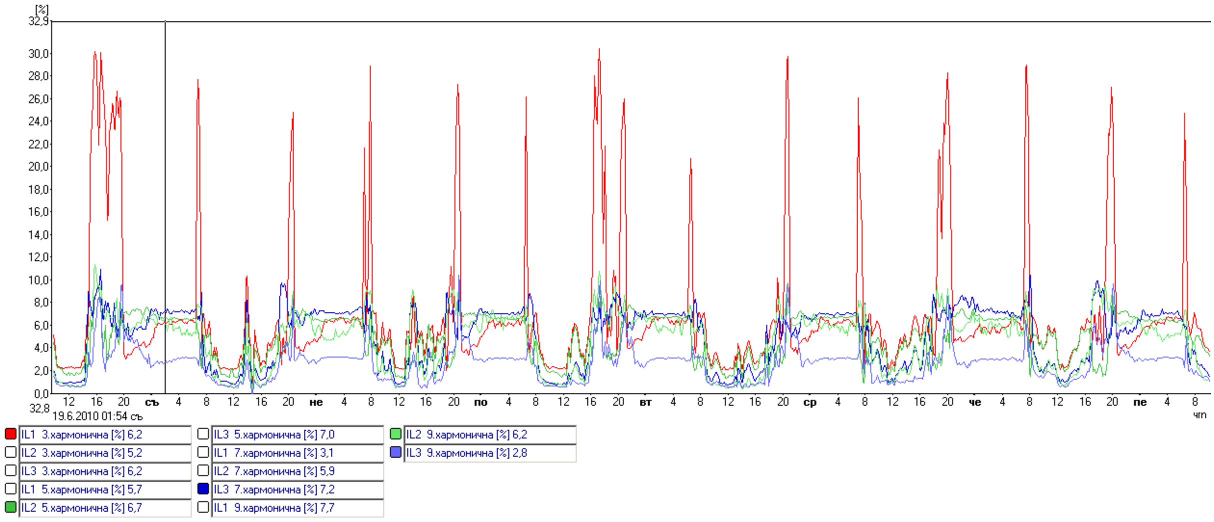

Figure 10

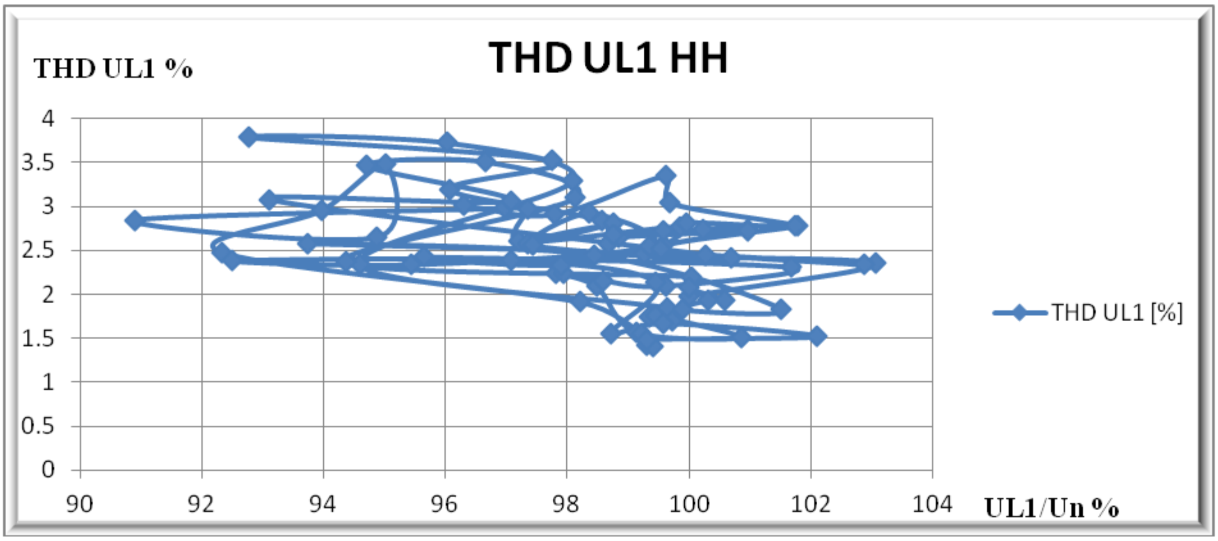

Figure 11

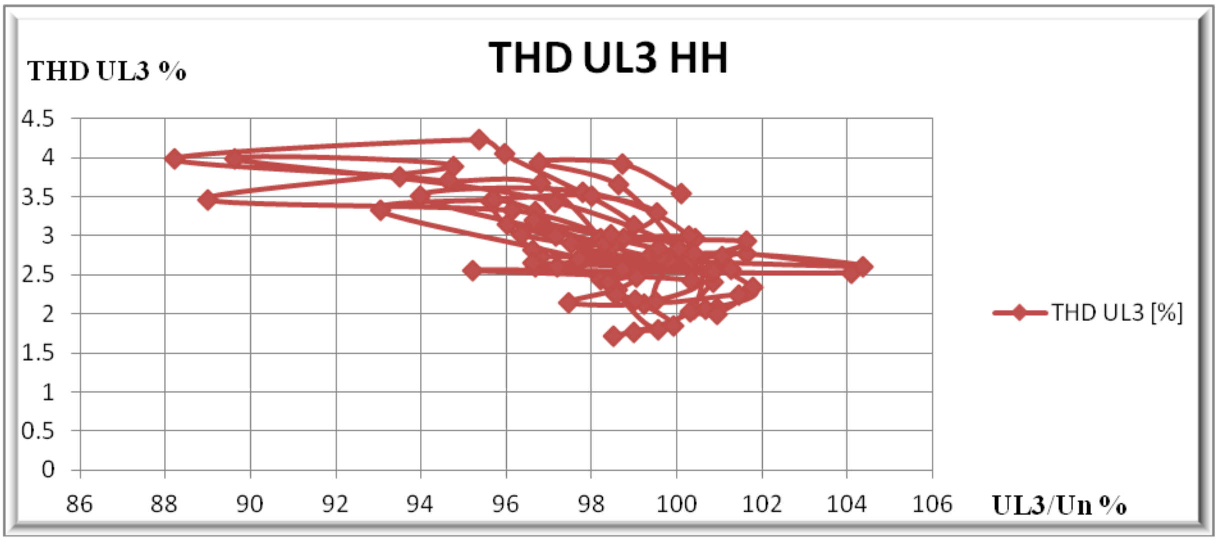

Figure 12

To improve the electromagnetic compatibility of photovoltaic generating systems in a night mode, retrofitting of adaptive filters would be required.

CONCLUSION

Recently, the introduction of distributed power generation into low and medium-voltage power grids has been increasing at accelerated rates due to higher purchase prices of the electricity produced. Until now, quality tests of the energy generated by small power plants that use renewable energy resources have been sporadically conducted. For the purpose of this paper, some measurements of the electromagnetic compatibility parameters of a wind farm and several photovoltaic plants with different capacity, connected to both MV and LV grids, were taken. The tests were performed with a network analyzer. They showed that most small power plants, operating at maximum output, meet the requirements of regulatory documents. However, two photovoltaic power plants with a capacity of 12 kW make an exception. They generate high levels of current harmonics at nominal production. In a standby mode, all the photovoltaic power plants (connected to LV and MV grids) generate reactive power and some increased content of current harmonics. time, some additional adaptive filters should be installed to limit the level of harmonic current pollution, or they should be switched off. However, in order to satisfy those power plants' needs during this period of time, they should have their own on-site transformer installed.

ACKNOWLEDGEMENT

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