Power quality analysis of the grid-connected PV system using microinverter

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Abstract. At present, small-scale grid-connected PV system is increasingly developed and used in many households. These small-scale PV system are often connected to grid using microinverter, because its advantages are low maintenance investment costs, ease of installation and operation and do not cause environmental pollution. The content of the article focuses on power quality analysis of the non-stored grid-connected PV system using microinverter. The research method in the paper is based on experiments on models and laboratory measurements. The analytical results will assess the power quality of grid-connected PV system using microinverter, thereby managers and operators to take measures to improve the power quality of the electrical system with grid-connected PV system.

1. Introduction
At present, small-scale grid-connected PV system is increasingly developed and used in many households. PV system often classifies into: off grid PV system, on grid PV system, on grid PV system with battery backup. On grid PV system or grid-connected PV system without battery backup has the advantage of low maintenance investment costs, easy installation and operation, and does not cause environmental pollution because it is not necessary to use batteries to electricity store, so it is increasingly used. The structure of grid-connected PV system includes PV panel, grid-connected inverter to convert direct current from PV panels into alternating current with the same frequency and phase of grid. Currently there are 3 types of technologies for grid-connected inverter including: string inverter (centralized inverter), microinverter (distributed inverter) and string inverter with optimal control circuit board for PV panel (Power Optimizer).

| № | Categories | Value | Note |
|---|------------|-------|------|
| 1 | Operating voltage | 187-242V | Largest and smallest in 2h±05% |
| 2 | Operating frequency | 49-51hz | ± 0.2 Hz |
| 3 | Voltage harmonics | THD ≤6,5% | Greatest value |
| 4 | Harmonic order 3 | H(3)≤3% | |
| 5 | Harmonic order 5 | H(5)≤3% | |
| 6 | Harmonic order 7 | H(7)≤3% | |
| 7 | Voltage flicker | P_{st} ≤0.9 | |
| 8 | P_{lt} ≤0.7 | |
| 9 | Power factor | PF≥0.9 | |

Microinverter has the advantage of being compact, installed under the PV panel, used for each PV panel. For large systems, microinverter will be paralleled and connected to grid. When grid-connected
implementation, PV system is necessary to ensure the power quality, in Vietnam power system, it must ensure that according to Circular 39/2015/TT-BCT with some basic criteria such as table 1 [1].

The power quality of grid-connected PV systems has many research projects. According to the document [2], a comparative analysis of total current harmonic distortion and the efficiency of PV power system when using different string inverters as: Sunnuy Boy 2400, Tauro PRM3, Sun Profi 2400, Ingecon Sun 2500, Soplete 2500. The paper [3] analyzed the power quality of four PV systems using the Sunny Tripower 15000TL-10 string inverters, and concluded that many grid-connected PV systems have a significant impact to the distribution grid when the output power of the system is small. The article [4] evaluated the power quality of a low voltage distribution system with PV system including 12 polycrystalline silicon modules SM-250PC8 and the Sunny Boy 3000 TL string inverter.

Grid-connected PV system using microinverter has been studied in the literature [5] [6]. However, the content of these works mainly refers to the construction of the PV grid structure using microinverter [5] or to improve the working reliability of this power system [6].

Thus, the upper analysis shows that grid-connected PV system using microinverter is increasingly used, but previous studies have not mentioned the power quality of this electrical system. Therefore, it is necessary to have a full analysis of the power quality of grid-connected PV system using microinverter which helps managers and operators to take measures to improve the power quality of the grid with PV system connection.

2. Research model and results

2.1. Building research model

Building a grid-connected PV system to study including two PV panels with 250Wp power and connecting through two MPPT microinverter 250W, with connection diagram as shown in Fig. 1, principle diagram in Fig. 2.

**Figure 1.** Research model of PV- microinverter system.

**Figure 2.** Grid-connected PV system configuration.

Data Acquisition and Control Interface 9063 device used to analyze the power quality of the system. Parameters of the two PV panels are given in table 2, parameters of MPPT microinverter in table 3.
Table 2. PV electrical specification.

| Properties | Value |
|------------|-------|
| $P_{mp}$ (W) | 250 |
| $V_{oc}$ (V) | 37,4 |
| $I_{sc}$ (A) | 8,83 |
| $V_{mp}$ (V) | 30,0 |
| $I_{mp}$ (A) | 8,33 |

Table 3. Parameters of microinverters.

| Properties         | Value                  |
|--------------------|------------------------|
| $P_{mp}$ (W)       | 250                    |
| $U_{in}$ (VDC)     | 22-45                  |
| $U_{out}$ (VAC)    | 190-260                |
| Output frequency   | 50/60 (auto)           |
| TDH                | <3%                    |
| Steady output efficiency | >90%                |
| MPPT range (VDC)   | 28-36                  |
| Power factor       | >97%                   |

PV panels are fixed at an tilt angle equal to the latitude of the installation location [7][8], in this study, it is mounted on an support system with an tilt angle of 16 ° to the south. Electricity power, what generated by solar panels, is fed directly to the distribution grid without storage. Measurements were made on September 18, 2018. With a sampling frequency of 1 minute every time, the data were measured at the two point of PV-microinverter systems and the grid at point of common coupling.

2.2. Results and discussions

The generation powers (P, Q) gives the result in fig. 3, fig. 4 and the power factor in fig. 5, the measurement result in a test day shows that the maximum power value is about 190W, at dark time, the system consumes an average amount of 0,7W. Corresponding energy generated for the first system is 590,72Wh, the second system is 575,32Wh, the highest output power is supplied from 9am to 3pm.

During the generation of PV-microinverter system, the maximum power factor 0,89, average 0,59. It is clear that the power factor tends to increase when the generation power increases, but this value is lower than the specified value, the power factor of the systems has not reached the standard power factor 0,9

![Figure 3. Generation power and energy from two PV–microinverter systems.](image-url)
The voltage value according to the time of day is obtained in fig. 6 and the voltage change according to the generation power in fig. 7. System voltage is not sinusoidal, appear harmonics, maximum value reaches 246V exceeding the allowed limit 242V in table 1. From fig. 7, the voltage value is not affected when the output power of the small capacity PV system is changed.

**Figure 4.** Generation reactive power from two PV–microinverter systems.

**Figure 5.** Power factor according to the generation power of two PV–microinverter systems

**Figure 6.** Voltage changes over time.

$U_1, U_2$ – voltages of first, second PV system, $U_3$ - Voltage at point of common coupling.
The harmonic voltage at point of common coupling is given in fig. 8, the result analyzing in box graph form of the voltage harmonics shown in fig. 9. Realizing that, the average value of voltage THD in a day is about 7.7%, sometime up to 14%, with 3rd-order component harmonics about 0.8%, 5th order about 2.5%, 7th order about 1%. Average value of THD exceeds the harmonic standard specified in table 1 is 6.5%.

Frequency analysis depends on the time and power of the PV-microinverter system shown in Figure 10. The observation shows that the frequency value is not affected by the generation power, the average of 50.22 Hz with the maximum value of 50.53 Hz, the minimum of 49.7 Hz, this result shows the guarantee of the frequency allowed limit.
3. Conclusion
Grid-connected PV system using microinverter is increasingly used in households. The analysis showed that in the operating process power quality of research PV system appeared the violation norms such as violations of the norm of voltage, harmonics norms. This reduces the power quality of power systems with connecting PV power sources. Therefore, it is necessary to have policies and solutions to manage and improve the power quality for power systems with connecting PV power sources.

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