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# Assessment of Power Quality Indicators in Electrical Networks Connected to Distributed Generation Sources

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**Abstract.** This article is devoted to the assessment of power quality indicators in electrical networks connected to distributed generation sources. It discusses key parameters necessary to ensure power quality, such as voltage stability, frequency control, power flows, and harmonics. The article notes that distributed generators can inject power from various sources into the grid, which may lead to changes in network parameters. Therefore, it emphasizes the need for continuous monitoring of network quality. The article also presents the permissible normative values for voltage and current harmonic components. It concludes that, for reliable and stable operation of the power network, the output parameters of distributed generators must remain within established limits.
**Keywords:** distributed generation, power quality, voltage stability, frequency control, harmonic components, power flow, electrical network, energy sources.

The assessment of power quality indicators in electrical networks connected to distributed generation sources is an important process for determining the efficiency, reliability, and stability of energy production and distribution within the grid. Power quality indicators include parameters such as voltage stability, frequency control, power flow, and harmonics in the electrical energy. The integration of distributed generation sources into the network may lead to changes in power flows, voltage, and frequency parameters. Therefore, to ensure network quality and reliability, it is necessary to continuously monitor and assess power quality indicators. This process helps ensure optimal and stable grid operation.

When assessing power quality indicators in networks connected to distributed generation sources, primary attention is given to parameters such as voltage level, frequency stability, phase balance, harmonic distortions, power factor, and the distribution of power flows within the grid. Distributed generation sources—such as photovoltaic, wind, biomass, and others—inject power with different characteristics into the grid, making it more challenging to maintain power quality. Therefore, it is essential to use modern, high-precision technologies and methods to accurately evaluate and analyze these indicators. Such measurements serve as the basis for controlling, maintaining, and optimizing network operation.

The quality of electrical energy is measured by the voltage and frequency levels, as well as the distortion of their waveform. The quality deteriorates if any of the following parameters deviate significantly:

- Frequency deviates beyond the permissible range from the nominal 50 Hz;
- Voltage deviates from its nominal value;
- Voltage fluctuations exceed the permissible range;
- Voltage unbalance occurs, resulting in asymmetry or deviation from sinusoidal waveforms;
- Specific harmonic frequencies appear in the system;
- Voltage flicker occurs when fluctuation intensity exceeds allowable limits;
- High-frequency overvoltages arise in the distribution network.

For a distributed generation system to operate correctly, it must be synchronized with the distribution network. The parameters of the distribution network and the output parameters of the distributed generation system, along with their deviations, must remain within the established permissible limits; otherwise, the plant's operation is considered to be outside normal mode.

The permissible coefficients for voltage and current harmonic components are determined based on the characteristics of the power supply network, the nature of the connected loads, and practical experience.

The permissible values of voltage harmonic components are given **in** Table 1**:**

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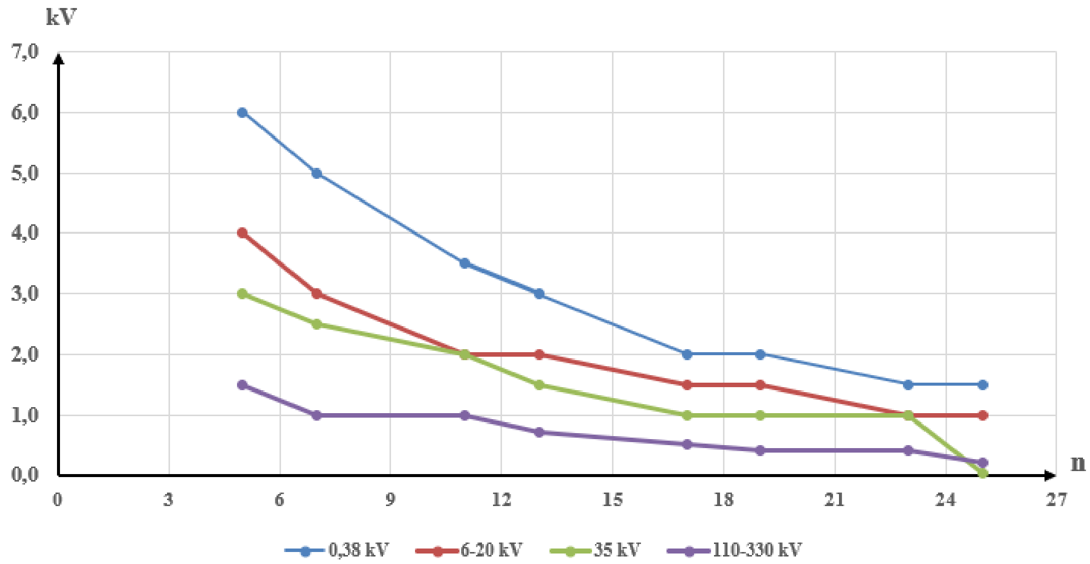
- *$n$ – harmonic order of the voltage component;
- for $n$ = 3 and $n$ = 9, the specified permissible values apply to single-phase power supply networks;
- for three-phase three-wire networks, these values are taken to be half of those shown in the table.

Table 1. Permissible Values of n-th Order Voltage Harmonic Components (%)

| n / Unom<br>Odd harmonics (not divisible by 3) | 0.38 kV | 6–20 kV | 35 kV | 110–330 kV |
|---|---|---|---|---|
| n = 5 | 6.0 | 4.0 | 3.0 | 1.5 |
| n = 7 | 5.0 | 3.0 | 2.5 | 1.0 |
| n = 11 | 3.5 | 2.0 | 2.0 | 1.0 |
| n = 13 | 3.0 | 2.0 | 1.5 | 0.7 |
| n = 17 | 2.0 | 1.5 | 1.0 | 0.5 |
| n = 19 | 2.0 | 1.5 | 1.0 | 0.4 |
| n = 23 | 1.5 | 1.0 | 1.0 | 0.4 |
| n = 25 | 1.5 | 1.0 | 0.4 | 0.2 |
| n > 25 | 0.2% or calculated according to the formula 25/n | | | |




**Graph of the values of odd voltage harmonic components (not divisible by 3)**

| n / $U_{nom}$ (odd harmonics divisible by 3) | 0.38 kV | 6–20 kV | 35 kV | 110–330 kV |
|---|---|---|---|---|
| n = 3 | 5.0 | 3.0 | 3.0 | 1.5 |
| n = 9 | 1.5 | 1.0 | 1.0 | 0.4 |
| n = 15 | 0.3 | 0.3 | 0.3 | 0.3 |
| n = 21 | 0.2 | 0.2 | 0.2 | 0.2 |
| n > 21 | 0.2 | 0.2 | 0.2 | 0.2 |

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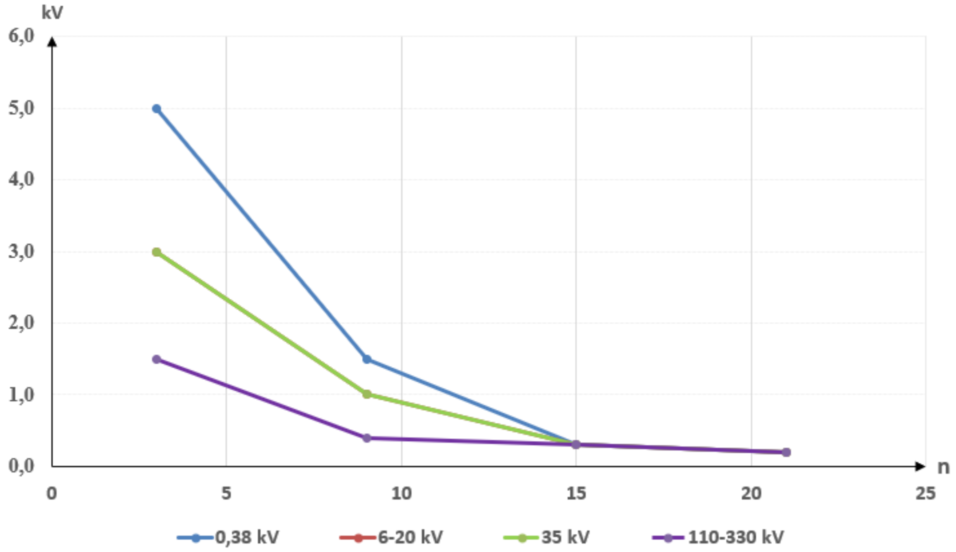
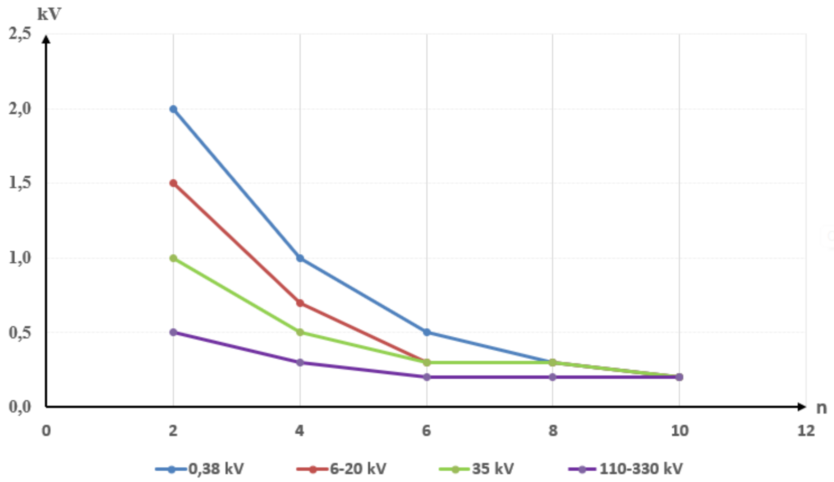



**Graph of the values of odd voltage harmonic components (divisible by 3)**

| n / $U_{nom}$ (Even harmonics) | 0.38 kV | 6–20 kV | 35 kV | 110–330 kV |
|---|---|---|---|---|
| n = 2 | 2.0 | 1.5 | 1.0 | 0.5 |
| n = 4 | 1.0 | 0.7 | 0.5 | 0.3 |
| n = 6 | 0.5 | 0.3 | 0.3 | 0.2 |
| n = 8 | 0.3 | 0.3 | 0.3 | 0.2 |
| n = 10 | 0.2 | 0.2 | 0.2 | 0.2 |




**Graph of the values of even voltage harmonic components**

For n = 3 and n = 9, the values indicated apply to single-phase networks; in three-phase three-wire networks, these values are taken to be half of those shown. If n > 25, the value is calculated as 0.2% or according to the formula 25/n.

Power quality is the degree to which the current and voltage delivered to consumers in electrical networks correspond to the standard specified parameters. If power quality does not meet the required standards, equipment will not operate normally, leading to production losses or malfunctions.

Compliance with power quality requirements ensures:

- reliable operation of electrical equipment;
- continuity of production processes;
- extended service life of equipment;
- energy efficiency and economic effectiveness.

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The parameters of the distribution network, the output parameters of the distributed generation sources, and their permissible deviation values must be specified in the documentation governing the connection of distributed generation sources.

Distributed generation sources must monitor all deviations in the parameters of the electrical energy they produce and take appropriate measures to maintain these parameters within their normal values, thereby ensuring synchronization between the distributed generation sources and the distribution network. If the parameters exceed the established permissible values, the situation is regarded as a violation of normal operating conditions.

**Conclusion**

The assessment of power quality indicators in electrical networks connected to distributed generation sources plays a vital role in ensuring the stable and reliable operation of modern power systems. As noted in this article, the key factors affecting power quality—voltage stability, frequency, power flows, and harmonic components—must be continuously monitored and analyzed.

Exceeding the permissible values of harmonics, deviations in voltage from the nominal, or frequency fluctuations lead to improper operation of electrical equipment. Therefore, distributed generation sources must operate fully synchronized with the grid and within the established parameter limits.

Based on the analysis and tables presented in this article, it is concluded that ensuring power quality requires compliance with legislative and technical requirements and the use of high-precision monitoring and assessment methods. This will contribute not only to the efficient operation of power networks but also to the long-term service life of equipment and to energy efficiency.

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