

# Harmonic Analyzer

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## 1 Description

This device is a post processing tool for the analysis of harmonics in power systems with EMTP. This device calculates current and voltage harmonics from Steady-state and Time-domain simulations results. Additionally, harmonic levels are compared with limits recommended by IEEE and IEC standards. Options are available to export harmonic levels to files compatible with Microsoft Excel and other tools (comma-separated values).

This device is available in both 1-phase and 3-phase versions.

## 2 Prerequisites

### 2.1 Python

Python™ is required to use this device. The following packages are required as well:

- Matplotlib
- Numpy
- Scipy

Refer to the documentation of the “Scripting\Python” device to learn how to install and set-up Python™ and the required packages.

## 3 Definitions

For the purposes of this document and the usage of this device, the following terms and definitions from the *IEEE Standards Dictionary Online* apply.

- **Harmonics (component):** A component of order greater than one of the Fourier series of a periodic quantity. For example, in a 60 Hz system, the harmonic order 3, also known as the “third harmonic,” is 180 Hz.
- **Interharmonic (component):** A frequency component of a periodic quantity that is not an integer multiple of the frequency at which the supply system is operating (e.g., 50 Hz or 60 Hz).
- **Maximum Demand Load Current:** This current value is established at the point of common coupling and should be taken as the sum of the currents corresponding to the maximum demand during each of the twelve previous months divided by 12.

- **Total Demand Distortion (TDD):** The ratio of the root mean square of the harmonic content, considering harmonic components up to the 50th order and specifically excluding interharmonics, expressed as a percent of the maximum demand current. Harmonic components of order greater than 50 may be included when necessary.
- **Total Harmonic Distortion (THD):** The ratio of the root mean square of the harmonic content, considering harmonic components up to the 50th order and specifically excluding interharmonics, expressed as a percent of the fundamental. Harmonic components of order greater than 50 may be included when necessary.
- **Total Harmonic Current (THC)<sup>1</sup>:** The root mean square of the harmonic content, considering harmonic components up to the 50th order and specifically excluding interharmonics.

## 4 Parameters

- **Standard:** Three harmonic emission limit standards are available in the current version of the tool: “IEEE 519-2014”, “IEC 61000-3-2” and “IEC 61000-2-4”
- **Data-source:** If “Time-domain” is selected, voltage and current harmonics are calculated using Fast-Fourier Transform (see section 5 for more details). If “Steady-state” is selected, harmonics components are simply read from Harmonic Steady-State results.
- **Power Frequency:** 50Hz or 60Hz.
- **Assume balanced network:** When checked, only one phase is analysed (Three-phase network only).
- **T<sub>START</sub>:** When calculating time-domain harmonics, simulation results between 0s and T<sub>START</sub> are discarded.
- **T<sub>END</sub>:** When calculating time-domain harmonics, simulation results between T<sub>END</sub> and the last time point are discarded. Use 1E15 to evaluate harmonics on the entire simulation time window.

### 4.1 IEEE 519-2014 Parameters

- **Base Voltage:** Rated voltage of the system. Used to determine harmonic distortion limits.
- **Maximum demand load current (I<sub>L</sub>):** This current value is established at the point of common coupling and should be taken as the sum of the currents corresponding to the maximum demand during each of the twelve previous months divided by 12. Used to calculate the TDD as per IEEE 519-2014.
- **Power Generation Equipment:** All power generation equipment is limited to specific values of current distortion, regardless of the short-circuit current.
- **Maximum short-circuit current (I<sub>sc</sub>):** The ratio between the short-circuit current (I<sub>sc</sub>) and the demand load current (I<sub>L</sub>) determines current distortion limits (IEEE 519-2014).

### 4.2 IEC 61000-3-2 Parameters

- **Equipment Class:** Equipment are classified as follows
  - Class A:
    - Balanced three-phase equipment
    - Household appliances, excluding equipment identified by Class D
    - Tools excluding portable tools
    - Dimmers for incandescent lamps
    - Audio equipment
    - Everything else that is not classified as B, C or D
  - Class B
    - Portable tools
    - Arc welding equipment which is not professional equipment

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<sup>1</sup> The definition of THC is not from the *IEEE Standards Dictionary Online*. This value is particularly useful in determining the required characteristics for installation of modern active harmonic filters.

- Class C:
  - Lighting equipment
- Class D:
  - Personal computers and personal computer monitors
  - Television receivers
  - Note: Equipment must have power level 75W up to and not exceeding 600W
- **Circuit Power factor:** The circuit power factor is required to calculate the third harmonic limit current emission for class C equipment.
- **Class D Current Limit:** Two set of limits are specified for Class D equipment: “Permissible harmonic current per Watt (mA/W)” and “Permissible harmonic current (A)”.
- **Active Power:** The active power of the circuit under test is required to calculate the class D current limits in “mA/W”.

### 4.3 IEC 61000-2-4 Parameters

- **Equipment Class: Equipment are classified as follows**
  - Class 1: Industrial environment intended for power supply to sensitive electronic units
  - Class 2: Normal industrial environment. Usual limits for public networks.
  - Class 3: Deteriorated industrial environment (generally due to the presence of transducers). Not suitable for power supply to sensitive units.

## 5 Harmonic calculation

A method inspired by IEC 61000-4-7 is used to calculate harmonics (time-domain). A FFT is first performed for each signal. The output of the FFT is then grouped to be the sum of squared intermediate lines between two adjacent harmonics according to the equations below:

$$G_{g,n}^2 = \frac{C_{k-5}^2}{2} + \sum_{i=4}^4 C_{k+i}^2 + \frac{C_{k+5}^2}{2} \quad \{50 \text{ Hz system}\}$$

$$G_{g,n}^2 = \frac{C_{k-6}^2}{2} + \sum_{i=5}^5 C_{k+i}^2 + \frac{C_{k+6}^2}{2} \quad \{60 \text{ Hz system}\}$$

In these equations,  $C_{k+i}$  is the RMS value of the spectral component corresponding to an output bin of the FFT, and  $G_{g,n}$  is the resulting RMS value of the harmonic. See IEC 61000-4-7 or contact [support@emtp-software.com](mailto:support@emtp-software.com) for more details.

For better accuracy, it is recommended to calculate harmonics of periodic signals. The observation window width shall be 10 (50 Hz systems) or 12 (60 Hz systems) periods (approx. 200ms).