Pterra
CONSULTING

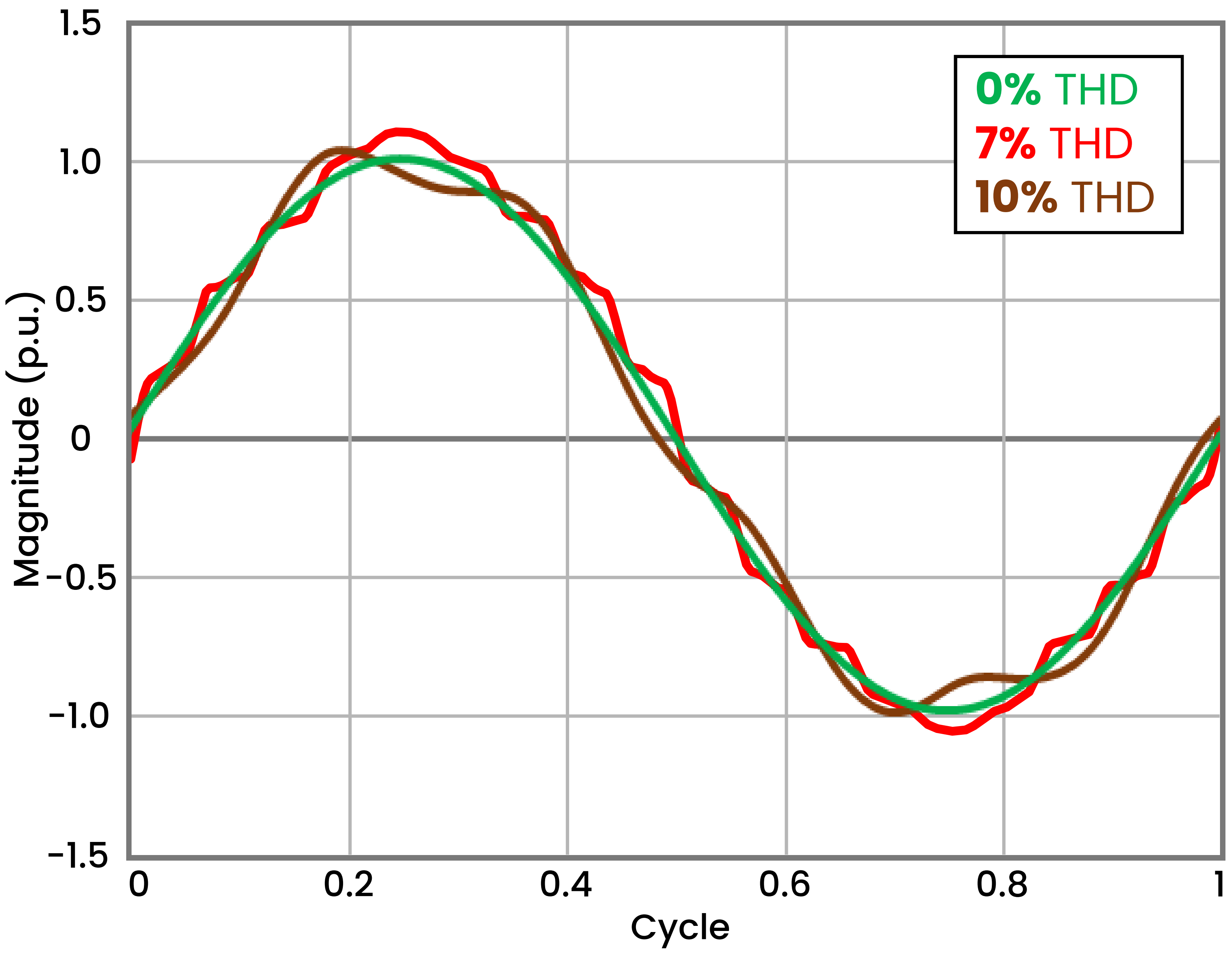
HARMONIC STUDY

Innovation
Independence
Leadership

Overview

Harmonics are a type of distortions that occur in AC power system, which affects both current and voltage waveforms. Harmonic distortions can be mathematically represented using the Fourier series, where the distorted waveform is expressed as the sum of the waveforms at fundamental frequency and at each harmonic order.

Harmonic distortions are mainly caused by the utilization of power electronic-based equipment, such as inverters and VFDs. If not mitigated properly, harmonic distortions could shorten equipment life span, breaker mis-operation, and thermal overload.



Pterra delivers **independent, standards-based** harmonic assessments to verify system compliance and mitigate power quality risks under realistic operating conditions.

Typical Study Scope

Pterra will evaluate the following key aspects as part of the harmonic analysis.

Resonance Possibility

Identification of harmonic orders where resonance may occur in the network.

Stray Capacitance Effect

Assessment of cable and equipment capacitance contributions to harmonic behavior.

Harmonic Distortion Assessment

Quantification of harmonic distortion levels and comparison against applicable standards.

Mitigation and Filter Sizing

Design and sizing of harmonic filters or other corrective measures to ensure compliance.

Applicable Standards and Criteria

Harmonic distortion levels based on simulations conducted by Pterra will be compared to internationally recognized standards and utility practices.

IEEE Std. 519-2022
Standard for Harmonic Control in Electric Power Systems

IEEE Std. 1547-2018
Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces

IEEE Std. 2800-2018
Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems

IEC Std. 6100-3-6
Assessment of Emission Limits for the Connection of Distorting Installations to MV, HV and EHV Power Systems

IEEE/IEC/Utility-specific Harmonics Compliance Limits

Harmonic Parameters

IHD Individual Harmonic Distortion

IHD shows the magnitude of harmonic current that resides within a specific harmonic order. In general, higher harmonic order tend to have lower IHD value. This parameter is evaluated for both voltage and current distortions (IHD_V and IHD_I).

THD Total Harmonic Distortion

THD expresses the combined effect of all harmonics order as a single parameter. While both current and voltage possess a THD indices, only voltage total distortion (THD_V) is evaluated against compliance limits.

TDD Total Demand Distortion

TDD represents the total harmonic current distortion relative to the system's maximum demand load current (I_L). Unlike THD and IHD, which refer to an instantaneous measurement, TDD uses periodic measurement of a plant in a specific time period.

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Methodology

1 NETWORK MODELLING

The electrical network is represented in simulation software including transformers, cables, capacitor banks, and the Point of Interconnection (POI). This provides the baseline system model for harmonic analysis.

2 HARMONIC MODELLING

Harmonic sources such as inverters, VFDs, or other power-electronic equipment are modeled with their expected harmonic spectra. This step defines the distortion inputs that will interact with the network model.

3 HARMONIC ASSESSMENT

Perform frequency scans and harmonic load flow analyses to identify resonance points and calculate distortion levels. Results are directly compared against IEEE Std. 519-2022 or other applicable standards.

4 MITIGATION

If violations are detected, design and size harmonic filters or other corrective measures. The updated system model is re-assessed to confirm compliance.

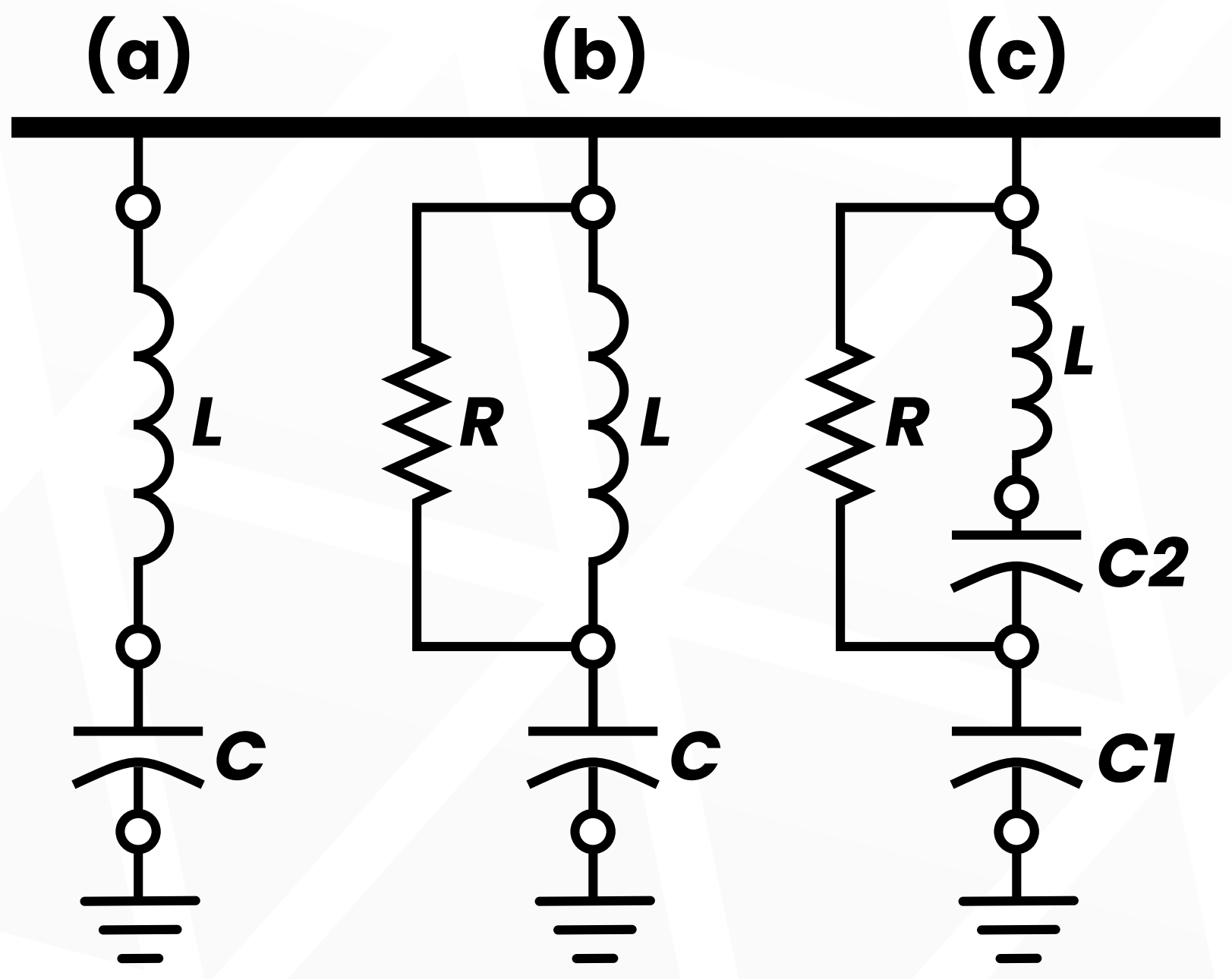
Planning vs. Mitigation Study

The scope and accuracy of harmonic studies depend on the stage of the project. In the planning phase, when the project is still under construction or only available in blueprints, the analysis relies on modelled data, manufacturer specifications, and conservative assumptions. A steady-state solution is typically assumed, with the highest peak load demand taken as the operating condition to ensure worst-case evaluation.

In contrast, a mitigation study is conducted once the project is interconnected and operational. At this stage, historic and direct measurements of both voltage and current harmonic distortions can be collected over a defined time period. These measurements enable a more accurate assessment of system performance and support the design of corrective measures, such as harmonic filters, when necessary.

Harmonic Filters

Harmonic distortion violations are mitigated by installing harmonic filters. The choice of filter configuration depends on both the magnitude of distortion and the harmonic order at which the violation occurs. The three common filter types are: **Notch Filter *(a)***, also known as single-tuned filter; **High-Pass Filter *(b)***; and **C-Type High-Pass Filter *(c)***. Each filter type offers distinct advantages and limitations.



	Main Purpose	Filtering Effectiveness at Tuning Frequency	Typical Application	Quality Factor (Q)	Fundamental Frequency Losses	Filter Cost
Notch Filter	Trap a specific harmonic order	Very high (strong, selective filtering)	Targeted mitigation of specific harmonic (e.g., 5th, 7th)	High Q factor	Very low	Lowest
High-Pass Filter (HPF)	Attenuate higher-order harmonics	Lower than notch filter	Systems with high-order harmonics and resonance risk	Low Q factor (high damping)	Low	Higher than Notch Filter
C-Type HPF	Attenuate higher-order harmonics with low fundamental losses	Lower than notch filter	Large drive systems where interharmonics and losses are critical	Low Q factor with improved efficiency	Near zero	Highest