# Harmonic Measurement Procedure (MSEDCL Workshop, Aurangabad)

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International Copper Association India
Copper Alliance

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ASIA POWER QUALITY INITIATIVE

# What is Power Quality?

- Can be defined as:

  "Any power problem manifested in

  - Voltage,
  - Current,
  - or Frequency deviations

  that results in failure or poor performance of customer equipment"

# What are general clauses of power quality problems per IEC?

Voltage fluctuations (flicker)

Voltage dips, swells and interruptions

Voltage Imbalance (unbalance)

Power frequency variations

Induced low-frequency voltages

DC in ac networks

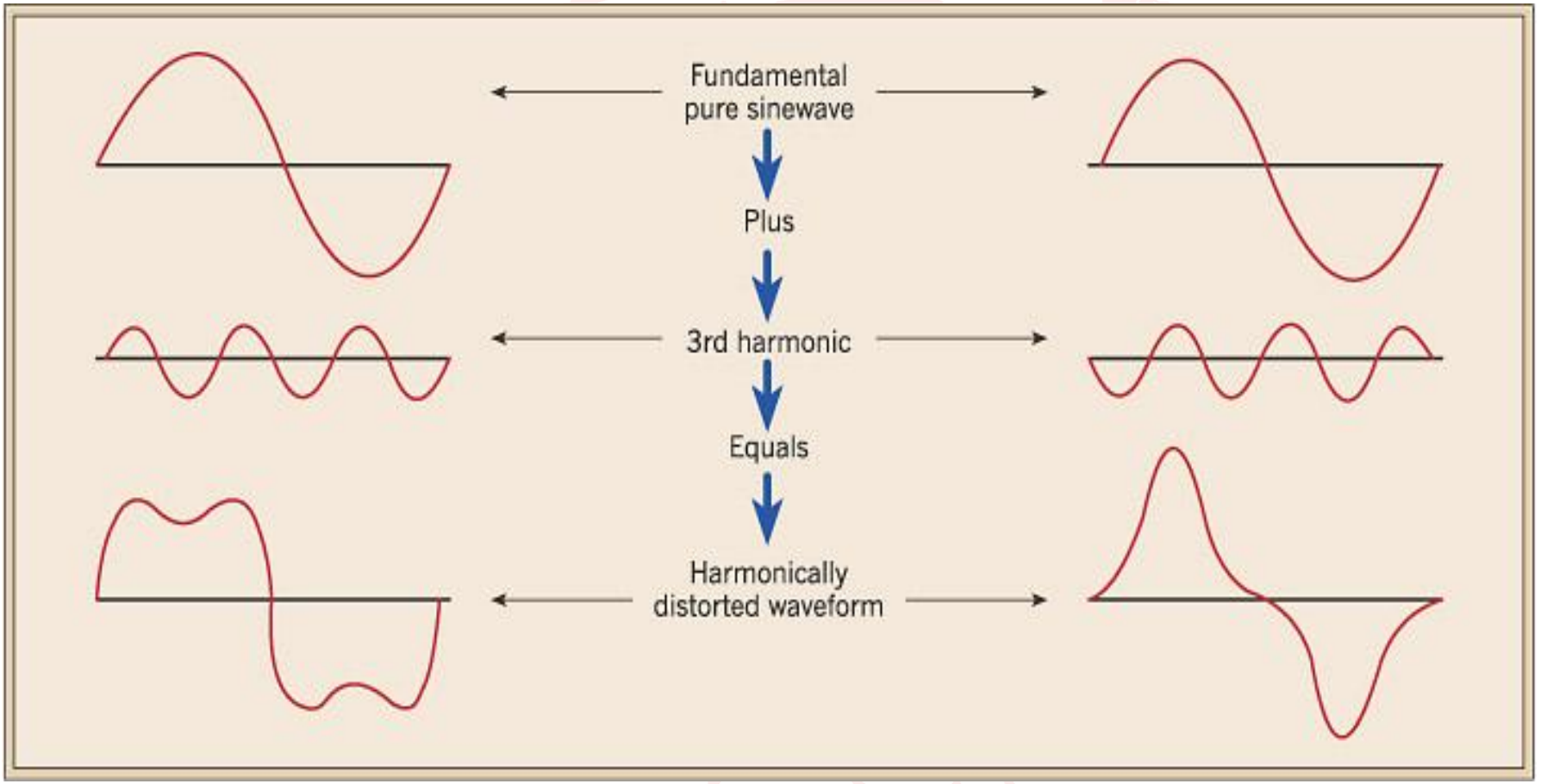
**Harmonics, inter-harmonics**

# What Are Harmonics?

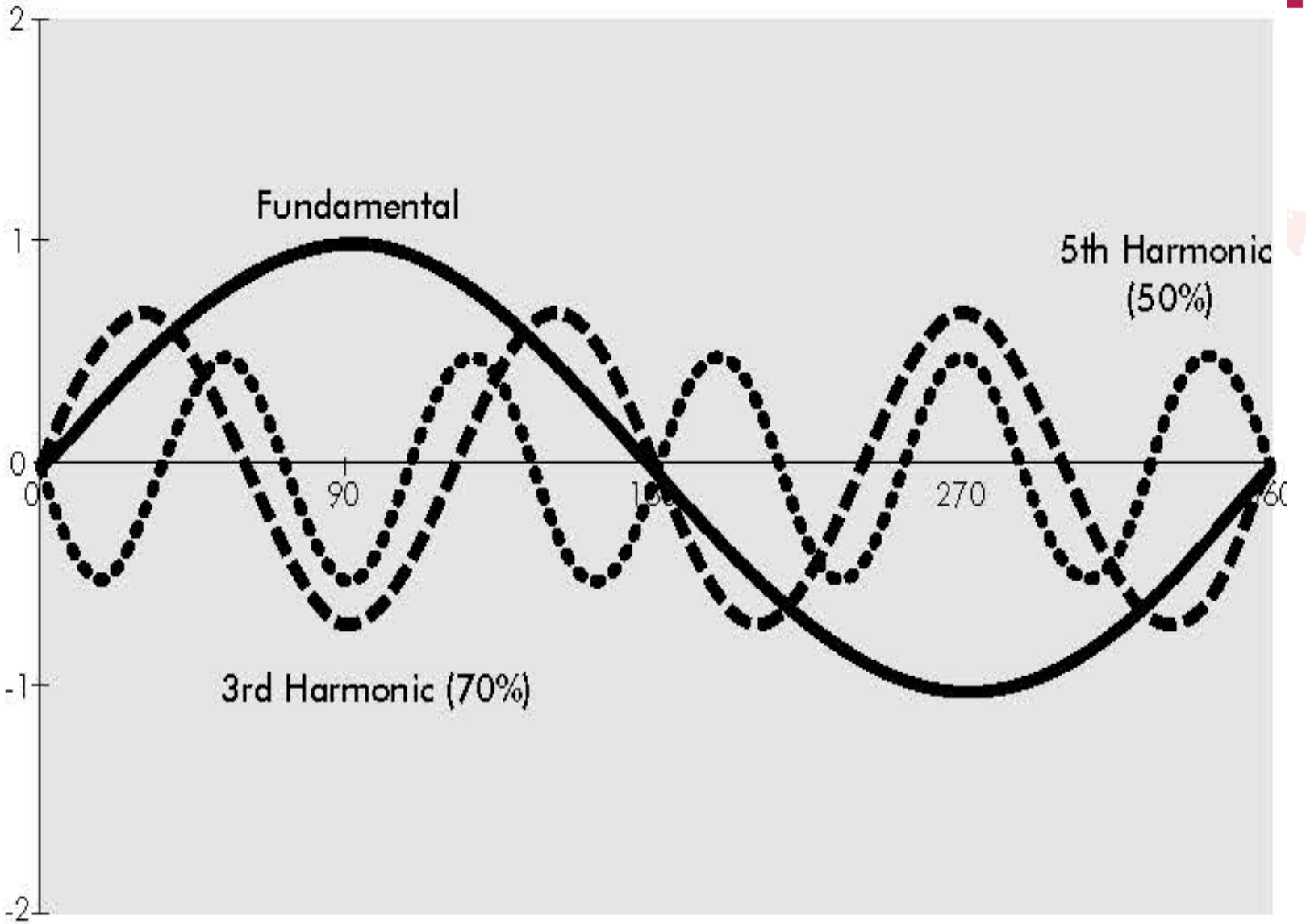
"A component frequency of a harmonic motion of an electromagnetic wave that is an integral multiple of the fundamental frequency"

- Fundamental frequency is 50 Hertz
  - 3rd Harmonic is 3 x 50Hz or *150Hz*
  - 5th Harmonic is 5 x 50Hz or *250Hz*, etc.
- Heard about non-characteristic harmonics & Sub-harmonics ?

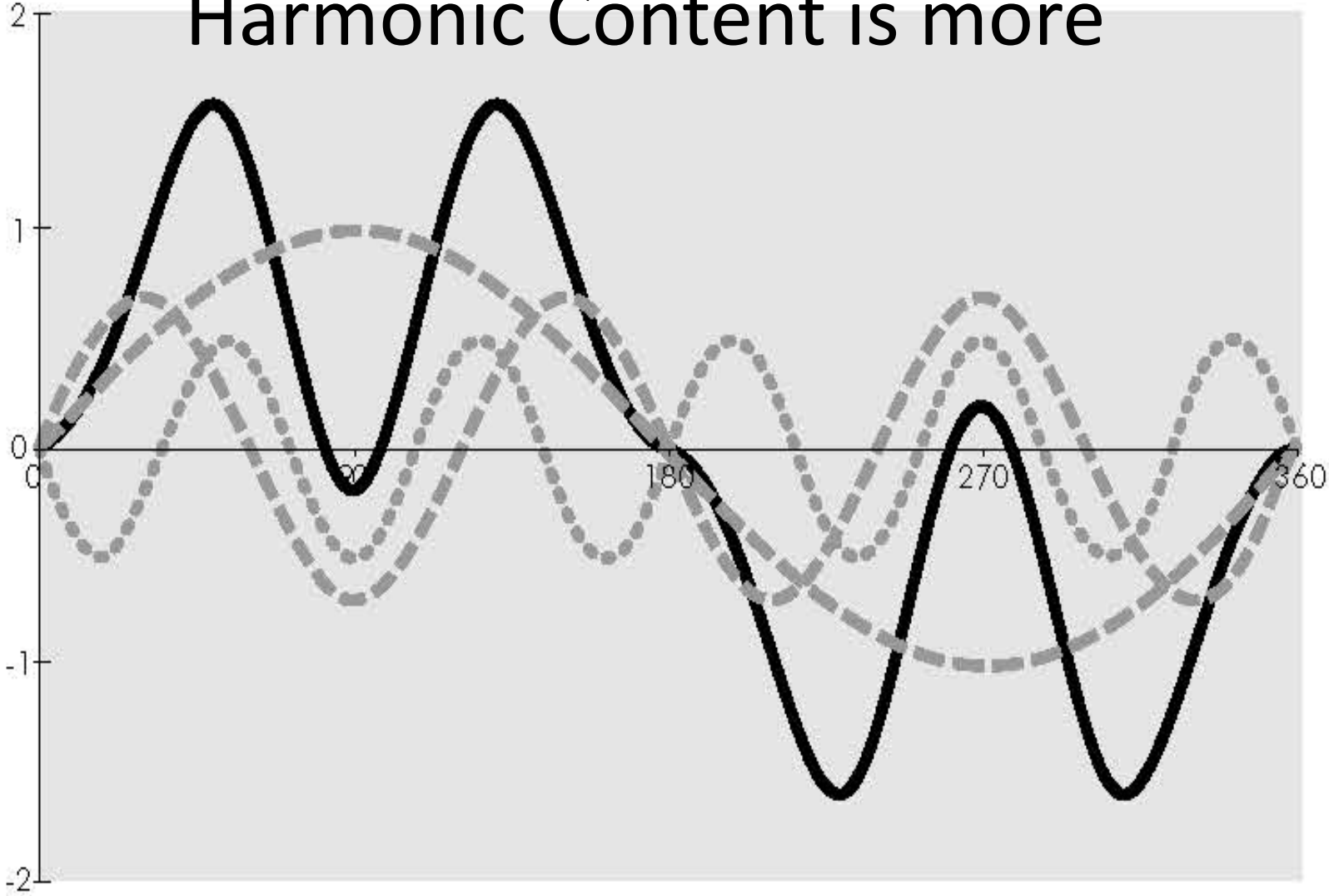
# Harmonics




The sum of the sinusoids created by harmonics can be analyzed using the Fourier series concept


2
1
0
-1
-2
0
90
270
Fundamental
5th Harmonic
(50%)
3rd Harmonic (70%)

# The distortion is more as the Harmonic Content is more



# Why harmonics are to be avoided?

- Harmonics are carried through the system from the source and can nearly **double** the amount of **current on the neutral conductor** in three phase four wire distribution systems.

- Distorted currents from harmonic-producing loads also **distort the voltage** as they pass through the system impedance. Therefore, a distorted voltage can be presented to other end users on the system.

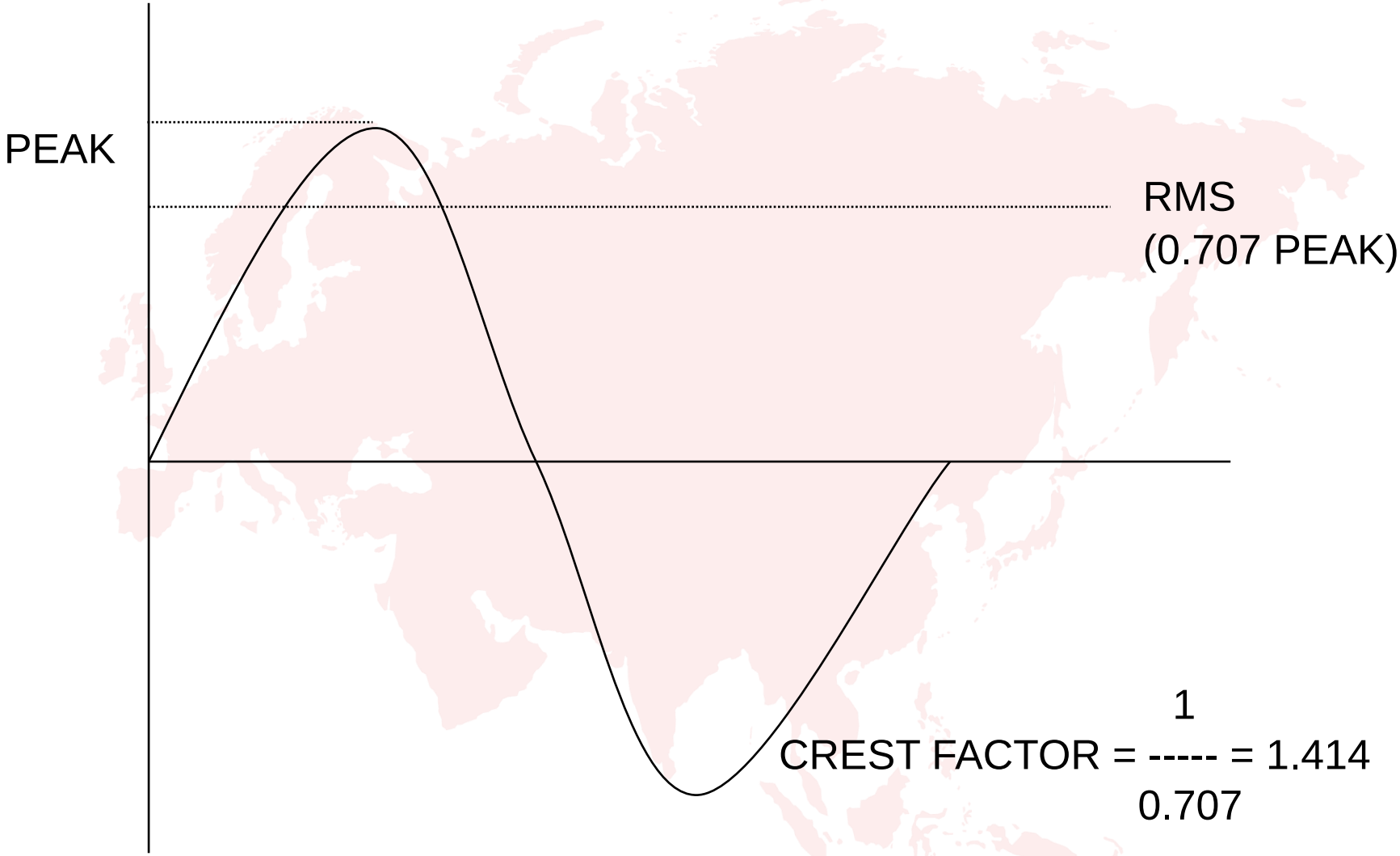
- Overall electrical system and power quality is affected by the introduction of harmonics.

# Simplest Way of Measurement

## Crest Factor:

If on a quick spot measurement, if the crest factor is found more than 1.41 then, harmonics may be present in the waveform. If the crest factor is 1.8 or more, then high distortion would be present.

# Crest Factor




$$\text{CREST FACTOR} = \frac{1}{0.707} = 1.414$$

# True Power Factor

## Power factor:

- The power factor (also termed as Displacement power factor) is defined as the ratio of Real power (KW) to apparent power (KVA).
- In Harmonic environment we have Displacement power factor (cos ϕ) and Total or True power factor (Displacement and Distortion inclusive)
- So if the True power factor is different from the Displacement power factor (Cos ϕ) then, significant harmonics may be present in the load.
- True or total power factor will be less than the displacement power factor.

# Effects of Harmonics

- Distorted Voltage
- Overheated Transformers and Motors
  - Increases Hysteresis (magnetization) losses in steel and iron cores of transformers, motor and magnetic trip units of circuit breakers (Equipment inefficiencies and overheating)
- Heating of Neutral Conductors
  - Skin Effect → Increased amount of current flowing on the outside of conductors (overheating)
- Low Voltage at End Loads
- High Neutral to Ground Voltages at End Loads

# Effects of Harmonics (cont)

- Operation Problems of Relays and Circuit Breakers
  - Thermal/Magnetic Trip Circuit Breakers
    - Fuses & bimetal strips respond to True RMS
    - Harmonic currents increase eddy current losses in the core steel of the metallic strip.
  - Electronic Trip Circuit Breakers
    - Magnitude and phase angle(s) of harmonic current(s) in relationship to the fundamental current can cause:
      - Overprotection when: Peak current sensing > True RMS
      - Under protection when: Peak current sensing < True RMS

# Total Demand Distortion

- Current harmonic limits in IEEE do not use common harmonic definitions

  - TDD ( Total Demand Distortion)
    - Not THD ( Total Harmonic Distortion)
  - Individual harmonics in % of $I_L$
    - Not in % of $I_1$ (fundamental)

- Majority of the Harmonics meters measure THD as a % of $I_1$

# Total Demand Distortion

TDD and THD definitions are similar
– Only difference is the denominator

$$THD_I = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + I_5^2 + \ldots}}{I_1}$$

$$TDD_I = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + I_5^2 + \ldots}}{I_L}$$

# Harmonic Limits Specified by CEA

CEA (Technical standards for connectivity to the grid) regulations 2007 published in the gazette 09-03-2007 prescribes limits applicable to consumers.

Voltage and current Harmonics Limits:

- The total Harmonic Distortion for voltage at the connection point shall not exceed 5% with no individual harmonic higher than 3%.
- The Total Harmonic Distortion for current drawn from the transmission system at the connection point shall not exceed 8%.

# Instrumentation:

Portable Power Quality Analyzer of class A type. (Based on IEC 61000 Part 4-7 & IEC 61000 Part 4-30 and suitable for current TDD measurement as per IEEE 519)

- **Class A**

  This class is used where precise measurements are necessary, for example, for contractual applications that may require resolving disputes, verifying compliance with standards, etc. Any measurements of a parameter carried out with two different instruments complying with the requirements of Class A, when measuring the same signals, will produce matching results within the specified uncertainty for that parameter.

# Point of Evaluation : (Based on IEC 61000-3-6)

- The Point of Evaluation shall be at the Point of Common Coupling or at the control room for measurement convenience due to longer period of measurement and safety of the measuring equipments. When measurement is undertaken at the control room it shall be at the PCC voltage.

**3.17**
**point of common coupling (PCC)**
point in the public supply system, which is electrically closest to the installation concerned, at which other installations are, or could be, connected. The PCC is a point located upstream of the considered installation

**3.19**
**point of evaluation (POE)**
point on a public power supply system where the emission levels of a given installation are to be assessed against the emission limits. This point can be the point of common coupling (PCC) or the point of connection (POC) or any other point specified by the system operator or owner or agreed upon

# Will the PCC measurement be sufficient for the customer to take remedial action?

Although applying IEEE Std 519 limits at the transformer primary is allowed, good engineering practice should include consideration of the secondary side voltage distortion. Voltage distortion will always be higher downstream near the harmonic generating loads and therefore, meeting IEEE Std 519 limits at the PCC will not necessarily ensure that voltage distortion is less than 5% throughout the power distribution system.

# Duration of Measurement (Based on IEC 61000-4-30)

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- The duration of measurements shall be as below:

The period shall be sufficient to capture at least two operating cycles of the largest harmonic producing equipment. If the harmonic level is caused by the summation of several items of equipment, the period shall be at least one operating shift (normally 8 hours).

In order to compare the level of harmonic emissions from a customer's installation with the emission limits, the minimum measurement period should be one week. However, shorter measurement periods might be needed for assessing emissions under specific conditions. Such shorter periods should represent the expected operation over the longer assessment period (i.e. a week). In any case, the measurement period shall be of sufficient duration to capture the highest level of harmonic emissions which is expected to occur. If the harmonic level is dominated by one large item of equipment, the period should be sufficient to capture at least two complete operating cycles of this equipment. If the harmonic level is caused by the summation of several items of equipment, the period should be at least one operating shift.

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# Load at the time of measurement

The measurement shall be undertaken while the industries are operating at 75% or more of their average maximum demand for past 12 months or the number of months for which they were in service, if the service period is less than one year.

What happened if the measurement is taken at lower load?

| | Current (amps) | | Current Harmonics (amps) | | | | | |
|---|---|---|---|---|---|---|---|---|
| Load | RMS | 60 Hz | 5th | 7th | 11th | 13th | $I_{THD}$ | $I_{TDD}$ |
| Full | 233 | 182 | 118 | 80 | 12 | 12 | 79% | 79% |
| 75% | 187 | 142 | 96 | 70 | 15 | 7 | 86% | 65% |
| 50% | 134 | 96 | 69 | 54 | 17 | 5 | 96% | 48% |
| 25% | 67 | 43 | 33 | 29 | 14 | 9 | 120% | 30% |

Figure 3: Current measurements on a 150HP, 6-pulse VFD with no harmonic treatment

# What are all the parameters to be measured?

The Total harmonic currents in Amps and the individual and total harmonic voltages, as a percentage of fundamental voltage shall be measured in all phases for every 10 minutes for the above mentioned measurement period.

## Why aggregation of 10 minutes be given here?

The following measurement aggregations apply:

- **Class A**

  The basic measurement time interval for parameter magnitudes (supply voltage, harmonics, interharmonics and unbalance) shall be a 10-cycle time interval for a 50 Hz power system or 12-cycle time interval for a 60 Hz power system.

  The 10/12-cycle measurement shall be re-synchronized at every RTC 10 min tick. See Figure 2.

# What next after measurement?

From the value of Total Harmonic Currents (RSS) in absolute values, the individual and total harmonic voltages (RSS) as percent of fundamental voltage, recorded at 10 minutes interval for the entire duration of measurement, 95% probability value will be arrived as per clause B.6.1 of IEC 61000-4-30, and the values of the phase having the maximum 95% value will be reported as the respective harmonic levels of the service for the measurement period.

**B.6 Statistical analysis of the measured data**

various possible numbers may be chosen as the most useful summary value: maximum value, 99 % value, 95 % value, average value, minimum value, etc. In many references, the 95 % probability value has been found to be useful.

# Current Harmonics

The 95% value of the total harmonic currents (average value of the harmonic current in RSS measured during every 10 minutes interval of the measurement duration) in absolute value, is divided by $I_L$ (The load current $I_L$ is to be calculated as given in the note below) to arrive at the maximum harmonic current distortion in percent of $I_L$ (TDD) at the POE. This will be the percentage $I_{THD}$ for the service. The calculated value is compared with limit value defined in CEA, which is 8%.

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*Note:*

**In the case of arc furnace industries or industries having one or two harmonic rich continuous process loads (which does not have other substantial loads) the calculation of $I_L$ shall be based on their sanctioned load.**

**For all other industries, the $I_L$ shall be calculated based on average demand for past 12 month or the no. of months for in service if less than one year.**

# Voltage Harmonics

- The 95% value of the Individual Voltage Distortion and the Total Voltage Distortion (THD) as a percentage of fundamental voltage is noted.
- The measured value is compared with the limit values and checked if it has exceeded the limit values defined in CEA, which is 5% for total harmonics and 3% for individual harmonics.

**Periodicity**

Measurements to be carried out once in twelve months or as per requirements in specific cases.