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From Editor's Desk

Dear fellow CEEAMA Members, Greetings!!!

It's indeed such a relief to have come out of the lockdown 4.0

It's almost like we have got our freedom back!

Last 10 weeks had been very depressing and disturbing to say the least. None of us had imagined that one day we will have this kind of a situation. In addition to causing huge economic loss to everyone, the pandemic has shaken up a lot of people psychologically as our social fabric was completely disturbed. In many ways it was worse than a War because in the war the enemy is visible. It has also exposed our poor health care system very badly and has also given a strong signal that as a country we need to spend much more on development of Hospitals & Laboratories. While the world is anxiously waiting for vaccine for Covid-19, all of us have to heavily rely on social distancing & good hygiene practices to protect ourselves.

Though the government has announced the economic package for MSMEs, it will take some time before its Positive impact can be felt. After the lockdown is lifted, we see that businesses are struggling to survive and we are not sure how our CEEAMA Members can be benefitted by Government Package. New norms are getting established at work places where health safety and precautions are paramount. We are in very uncertain times and no one really has a clue as to how and when revival will happen.

While we remain optimistic about future, the CEEAMA Governing Council announced webinar scheme which will allow associate members to showcase their products on line and also interact with Consultants. Many of you must have been taking benefit of these and all of you are encouraged to attend these Webinars. At the end of June, this scheme will be reviewed again and members will be kept updated about the development.

Best wishes for life after Unlock-down 1.0, stay safe and take precautions....

Editor Committee

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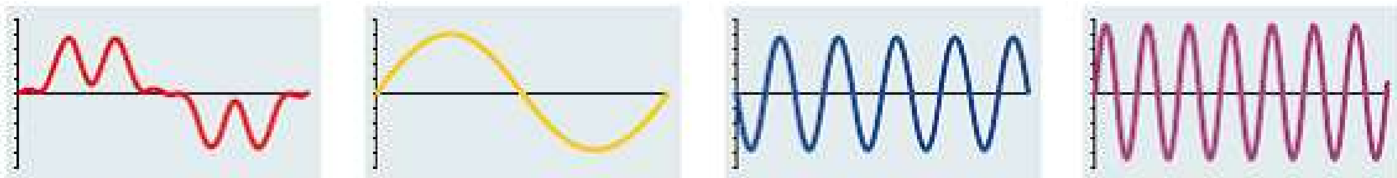
White Paper – Harmonics and their impact on kWh to kVAh billing

The electricity supply would, ideally, show a perfect sinusoidal voltage at every point of the power network. In reality it is almost impossible to accomplish such desirable conditions. Voltage and current waveforms deviate massively from a sinusoidal. These waveform deviations are described by the use of waveform distortion and usually called harmonic distortion.

A distorted waveform in general can be obtained by the superposition of sinusoidal waveforms of various frequencies and amplitudes. That means it can be “composed” from harmonic components. If any distorted waveform can be composed from harmonic components, any periodic waveform can also be decomposed into a sinusoid at fundamental frequency and a number of sinusoids at harmonic frequencies. The French mathematician Jean Baptiste Fourier was the first to demonstrate this technique. That’s why we call it today Fourier transformation. In this way, a superposition of perfectly sinusoidal waveforms can result in a distorted waveform. Conversely, a distorted waveform can always be represented as the superposition of a fundamental frequency waveform with other waveforms of different harmonic frequencies and amplitudes.

All periodical non-sinusoidal waveform can be represented as the sum of sine waves whose frequencies are integer multiples of the fundamental frequency, that we call harmonics.



Distorted wave | Fundamental wave 50 Hz | Hamonic wave 250 Hz | Harmonic wave 350 Hz

A good way to visualize the decomposition is the harmonic spectrum diagram depicting bars of varying magnitudes for different orders of harmonics.

Total Harmonic Distortion (THD) is a widely used notion in defining the level of harmonic content in alternating signals. This value is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency. This THD value is used for low, medium, and high voltage systems. Usually the current distortion is defined as THDi and the voltage distortion as THDv.

Total Harmonic Current (THC) is the accumulated currents of the orders 2 to 40 that contribute to the distortion of the current waveform. This value is particularly useful in determining the required characteristics for installation of modern active harmonic filters.

Total Harmonic Distortion of Current (THDi) indicates the total harmonic current distortion of the wave form. This value is defined as the ratio (in %) of the harmonic current to the fundamental (non-harmonic) current measured at a load point at the particular moment when the measurement is taken.

Voltage harmonics are the distortion of the voltage waveform. Likewise, current harmonics are the distortion of the current waveform. These distorted waveforms are difficult to quantify with a simple equation, thus a mathematical method is used (called a Fourier analysis) when discussing harmonics. This method determines the magnitude and frequency of many smaller sinusoidal waveforms that make up the distorted waveform seen at a facility. This allows the engineer to identify which are the most problematic individual harmonics and to provide corrective measures to reduce those harmonics.

BASIC CONCEPTS

It is useful to define some terms about harmonics which are fundamental to interpret any measurement and study:

- **Fundamental frequency** (f_1): Frequency of the original wave (50/60 Hz)
- **Harmonic order (n)**: Integer given by the relation of the harmonic frequency with the fundamental frequency. With which the order the frequency of the harmonic is determined (Example: 5th Harmonic → 5•50 Hz = 250 Hz)
- **Fundamental component** (U_1 or I_1): Sinusoidal component, 1st order in the Fourier frequency series the same as the original periodical wave.
- **Harmonic component** (U_n or I_n): Sinusoidal component higher than one in the Fourier frequency series, integer multiple of the frequency source.
- **Individual distortion rate** (U_n% o I_n%): Relation in % between the efficient value of the voltage or current harmonic (U_n or I_n) and the effective value of the fundamental component (U_1 or I_1).

$$U_n\% = \frac{U_n}{U_1} \cdot 100 \qquad I_n\% = \frac{I_n}{I_1} \cdot 100$$

- **True RMS**: This is the square root of the sum of the squares of all the components which make up the wave.

$$U = \sqrt{U_1^2 + U_2^2 + U_3^2 + U_5^2 + \dots} \qquad I = \sqrt{I_1^2 + I_2^2 + I_3^2 + I_5^2 + \dots}$$

- **Harmonic residue**: Difference between the voltage or total current and the corresponding fundamental value.
- **Total harmonic distortion**: Relation between the efficient value of the voltage harmonic residue of the voltage and/or current and the value of the fundamental component.

$$\mathrm{THD}(U)\% = \frac{\sqrt{U_2^2 + U_3^2 + U_5^2 + \dots}}{U_1^2} \qquad \mathrm{THD}(I)\% = \frac{\sqrt{I_2^2 + I_3^2 + I_5^2 + \dots}}{I_1^2}$$

Harmonics are caused by non-linear loads. Nonlinear loads do not draw current sinusoidally from the utility. Examples of non-linear loads include VFDs, EC motors, LED lighting, photocopiers, computers, uninterruptible power supplies, televisions, and the majority of electronics that include a power supply. The most significant causes of harmonics in the building are typically non-linear, three-phase power, and the more power there is, the bigger the harmonic currents in the network will be.

Problems caused by harmonic distortion High levels of harmonic distortion in a facility can create a wide range of problems. Some of the problems that may be encountered are:

- Loss of capacity on energy distribution line
- Transformer overload and derating
- Conductor overload
- Voltage drops

- Increased System Losses on lines and machines
- Premature failure and reduced lifespan of devices often occurs when overheating is present, such as: Overheating of transformers, cables, circuit breakers and fuses - Overheating of motors that are powered directly across the line
- Nuisance trips of breakers and fuses due to the added heat and harmonic loading
- Unstable operation of backup generators
- Unstable operation of sensitive electronics that require a pure sinusoidal AC waveform
- Flickering lights
- Magnetic losses on electrical machines

Limits on harmonics – IEEE Std. 519 - 2014

IEEE Std. 519™-2014 is a standard developed for utility companies and their customers in order to limit harmonic content and provide all users with better power quality. Some of the key areas of the standard are detailed in the tables given below.

Dealing with harmonics may still be required, whether or not the goal is to meet IEEE 519 standards. In low-voltage systems (600 V or less), capacitors are typically the lowest impedance at harmonic frequencies, and experience very high RMS currents and increased heat which causes them to fail.

TABLE 1 – VOLTAGE DISTORTION LIMITS

Bus voltage *V* at PCC*	Individual harmonic (%)	Total harmonic distortion THD (%)
$V \leq 1.0$ kV	5.0	8.0
1 kV $< V \leq$ 69 kV	3.0	5.0
69 kV $< V \leq$ 161 kV	1.5	2.5
161 kV $< V$	1.0	1.5[1]

[1]High-voltage systems can have up to 2.0% THD where the cause is an HVDC terminal whose effects will have attenuated at points in the network where future users may be connected.

TABLE 2 – MAXIMUM HARMONIC CURRENT DISTORTION IN PERCENT OF I_L

Individual harmonic order (odd harmonics)[1, 2]

I_{SC}/I_L	$3 \leq h < 11$	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h < 50$	TDD
< 20[3]	4.0	2.0	1.5	0.6	0.3	5.0
20 < 50	7.0	3.5	2.5	1.0	0.5	8.0
50 < 100	10.0	4.5	4.0	1.5	0.7	12.0
100 < 1000	12.0	5.5	5.0	2.0	1.0	15.0
> 1000	15.0	7.0	6.0	2.5	1.4	20.0

[1]Even harmonics are limited to 25% of the odd harmonic limits above.
[2]Current distortions that result in a dc offset, e.g., half-wave converters, are not allowed.
[3]All power generation equipment is limited to these values of current distortion, regardless of actual I_{SC}/I_L.
where
I_{SC} = maximum short-circuit current at PCC
I_L = maximum demand load current (fundamental frequency component) at the PCC under normal load operating conditions

Harmonics have an economic impact during all phases of an installation's lifespan:

- First, there is the upfront cost of either sizing equipment to handle harmonics, or investing in harmonic mitigation in the first place.
- Secondly, there are the day-to-day added costs due to the inefficiency of the system.
- There are the costs due to premature failure of equipment.
- In a changed billing scenario, from kW to kVA, this poses additional expenses on account of increase in the apparent power, than the real power, and hence higher electricity bills.

Dealing with harmonics in the changed billing scenario (from kW to kVA)

One way to deal with harmonics is to simply oversize portions of the electrical infrastructure within a building. Transformers and wire size may be upsized to handle the added harmonic content and heat. Backup generators also need to be oversized in systems with significant harmonic loading. There are multiple aspects to generator sizing. The generator has to be capable of handling the added harmonic current. Also, the generator's voltage regulator has to be capable of handling the voltage distortion without causing unstable operation.

An alternative to paying for oversized equipment would be to invest in products that create less harmonics. Having built a power system over a number of years, this may not be possible in existing installations and hence innovative ideas need to be provided to mitigate harmonics and avoid excessive electricity bills as one migrates from kW to kVA billing. It shall be noted that the kVA billing will account for the distortion Power Factor also, in addition to the displacement power factor which was being addressed during kW billing regime. A brief comparison of Displacement and Distortion Power Factors is provided in the table below:

Displacement and Distortion Power Factor Comparison.

Linear Loads, Displacement Power Factor	Non-Linear Loads, Distortion Power Factor
• Linear loads do not change the shape of the current waveform, but may change the phase angle between voltage and current.	• With a non-linear load, the current is drawn from the utility in pulses which may occur multiple times per electrical cycle.
• Power factor correction for linear loads can be achieved by adding capacitance to offset the inductive effect of the motors and re-align current with voltage.	• Non-linear loads create harmonic currents at higher frequencies in addition to the original current frequency.
• In linear circuits, the sinusoidal currents and voltages are of one frequency. The displacement power factor arises only from the difference in phase between the current and voltage.	• Power factor correction can be achieved using filters designed to pass only line frequency (50 or 60Hz), reducing harmonic current, and making the non-linear device now look like a linear load.
	• Distortion power factor is a measure of how much the harmonic distortion of a load current decreases the efficiency of the power transferred to the load.

Approaching harmonic mitigation to reduce excessive billing

For existing installations, a harmonic spectrum needs to be captured on an instrument capable of analysing harmonics and provide outputs through interfaces on the voltage and current spectra in addition to active, reactive, apparent power, frequency etc. in various time domains. This detection of existing harmonics forms the basis of mitigation and hence the checking of IEEE 519 limits at the 'Point of Common Coupling'.

Appropriate solutions such as Tuned Filter, Active Harmonic Filter, Static Var Compensator, Hybrid solution (Fixed + Active Filter) or a further complex solution depending on the existing harmonic spectrum can be worked out. With indicative budgetary pricing and payback period calculations, and the filter manufacturing time consideration, a project can be planned for implementation.

The system shall be well maintained and periodically overhauled so that the equipment provides years of long service.

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By , Mr. Chidambar Joshi

LFM 128

Maitriser Technologies Private Limited

Importance of maintaining Zero Neutral Current in Hospitals

Introduction:

Hospitals in cities are well equipped with electrical gadgets, have an electrical staff available round the clock. Ever imagined the status of hospitals in towns, which cater to the poor and needy?. This case study involves a Hospital run by trust for poor patients in Madikere (Coorg), Karnataka. Ashwini Hospital in Madikere, decided to equip their hospital with Dialysis machine to cater for the poor patients. Dialysis facility were available only in cities and the poor had to travel far for seeking this facility.

Case Study in Detail:

With funds contributed by philanthropists , and other organisation, during 2016, Ashwini Hospital set up a new ward and got the Dialysis machines erected. The OEM had insisted provision of UPS in addition to normal power supply. So UPS was also provided. Before connecting the equipment OEM carried out detail checks on the power supply. They were shocked to find neutral current flowing in the system.

They refused to connect their equipment till the neutral current in the system was zero.

Solution:

SOS was sent to me, as I had solved many of their Electrical issues. When the problem was projected to me. I visited the hospital and was shocked to find the Neutral current almost equal to phase current. With sufficient balancing of load between the phases neutral current was reduced but not to a value zero.

The only solution available was to introduce a Delta Star isolating transformer. Star connection with neutral was exclusive for Dialysis machine.

Accordingly a 3 phase Delta Star 10KVA 415V isolating transformer was procured and introduced in the circuit.

With this setup, the dialysis equipment was made functional and patients received treatment.

By: A V Prasanna