TAMIL NADU ELECTRICITY REGULATORY COMMISSION

Draft Notification No. TNERC/SC/7 –……. dated .06.2021

(Comments invited by 29.07.2021)

(Except Wind/ Solar/ Bagasse/ Biomass Energy Generator in HT/EHT services)

The following draft of amendments to the Tamil Nadu Electricity Supply Code, which it is proposed to make in exercise of the powers conferred by section 181 read with section 50 of the Electricity Act, 2003 (Central Act 36 of 2003) and all other powers enabling it in this behalf, is hereby published for information of all persons likely to be affected thereby, as required by sub section (3) of section 181 of the said Act.

2. At present Harmonics is measured only in respect of bulk consumers (who avails supply at 33 kV or above level) as stipulated by the Commission vide order in T.P.No. 1 of 2017, dated 11-08-2017 based on the Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007.

3. Now the CEA has amended the said (Technical Standards for Connectivity to the Grid), Regulation 2007 vide (Technical standards for connectivity to the Grid) (Amendment) Regulations, 2019 to the effect that all the existing bulk consumers (Consumers drawing power at 33 kV or above level)

shall comply with the provisions of maintaining harmonics within the limit as prescribed in the latest IEEE 519-2014 standards.

Also the Central Electricity Authority has amended the (Technical Standards for Connectivity of the Distributed Generation Resources) Regulations, 2013 to include the consumers of below 33KV also to maintain the harmonics within prescribed limits and renamed the said Regulation as Technical Standards for connectivity below 33 kilovolts (Amendment) Regulations, 2019.

4. Consequent to the above set of amendments, the TANDEDCO filed a petition to the Commission to revise the methodology of measurements of harmonics and evolution of test results and also to obligate the consumers of both 33KV and above as well as consumers of below 33KV, to comply with the harmonics norms set by the revised regulations.

The petition was admitted on 25.08.2020 with a direction to TANGEDCO to webhost the petition in their website for inviting comments from stakeholders. Further, the petitioner Licensee was directed to carry out sample measurements of harmonics in various categories of services strictly in compliance of the amended regulations and revised standards and submit results to the Commission.

5. As the subject requires high technical expertise in the domain of Power Quality with knowledge of standards , practical experience in measurement of harmonics and analysis , a consultant team consisting of Dr.A.S.KANDASAMY, Emeritus Professor & SAC member of the Commission and Dr. K.R. VALLUVAN, Professor, Velalar College of Engineering and Technology, Erode, who possess wealth of knowledge , high expertise and exposure to the field of Harmonics and Power Quality over two decades were appointed by the Commission as Senior Consultants for formulating the directions to be issued by the Commission to the Licensee to adopt the methodologies of measurements as per latest regulations / standards, evolution of results, Interpretation on the measurement data received

from the Licensee, offer remarks on the issues of measurements raised by the Licensee , offer comments on the queries of stake holders on the webhosted proposal of the Licensee and to submit resultant recommendation to the Commission to make changes in Codes as per the amended Regulations and latest Standards.

6. The Licensee have conducted the sample measurements as directed by the Commission with amended Regulations / revised standards and submitted the results with report. The Consultants besides preparing a detailed thesis on the subject of harmonics have analyzed the test results of the Licensee, and submitted their contentions with recommendations to the Commission on the methodology of implementation with necessary changes in the Supply Codes.

7. The thesis compiled by the Senior Consultants that consists of five parts and 6th part containing three annexure is attached herewith. The draft amendment as recommended by the senior consultants is furnished as follows for comments of the stakeholders.

8. Notice is hereby given that the draft amendment will be taken into consideration after expiry of thirty days from the date of publication of this Notification in the TNERC website and that any objection or suggestion, which may be received from any person before the expiry of the aforesaid period, will be considered by the Commission.

9. Objection or suggestion, if any, should be addressed in duplicate along with a soft copy to the Secretary, Tamil Nadu Electricity Regulatory Commission, 4th Floor, SIDCO Corporate Office Building, Thiru Vi Ka Industrial Estate, Guindy, Chennai-600032 (email id- tnerc@nic.in).

AMENDMENTS

In the said Supply Code,-

(1) in regulation 4, in sub-regulation(1), for clause (iv), the following shall be substituted, namely:-

" Current Harmonic control a) Nonlinear loads change the sinusoidal nature of the ac power current (and consequently the ac voltage drops), thereby resulting in the flow of harmonic currents in the ac power system that can cause many ill-effects to the power system and to the consumer's installations. Hence the harmonic currents generated by the loads of bulk consumers/ consumers/ prosumers/ charging stations have to be brought within limits.

b) Both the CEA (Amendment) Regulations 2019 stipulate the same provision in respect of Current harmonics that "the limits of injection of current harmonics at the point of common coupling by the user, method of harmonic measurement and other such matters, shall be in accordance with the IEEE Std. 519-2014, as amended, from time to time".

c) Measurement of current distortion / harmonic currents shall be made at the point of common coupling (PCC) of the Installation of bulk consumers

at 33kV and above and consumers, prosumers, charging stations below 33kV.

d) Power quality meter complying with the IEC Standard 61000-4-30 edition 3.0 class A- shall be used.

e) The licensee shall use his portable power quality meter for one week for each consumer installation to measure the harmonic currents.

f) All three total demand distortion (TDD) values at 99^{th} percentile very short time (3s) value, 99^{th} percentile short time (10 min) value, 95^{th} percentile short time (10 min) value shall be measured and compared with the values specified in IEEE Std. The highest value among the above three shall be considered for levying penalty

g) If the measured values exceed the limits, a notice shall be issued to the bulk consumer/ consumer/prosumer/ charging station by the licensee to install adequate harmonic filters within 6 months. The notice shall also convey that in case of non- compliance, penalty at the rate mentioned in the following sub-regulation h) will be levied for the subsequent 12 months and there after supply to the service shall be disconnected in case of noncompliance even after the said 12 months.

h) A penalty of a maximum of 10% in steps of 1% increase will be levied on the monthly current consumption charges as shown below:

TDD excess % over and above the limit	***Penalty charge % on the monthly current consumption charges***
Up to 3%	*1%*
Above 3% up to 6%	*2%*
Above 6% up to 9%	*3%*
Above 9% up to 12%	*4%*
Above 12% up to 15%	*5%*
Above 15% up to 18%	*6%*
Above 18% up to 21%	*7%*
Above 21% up to 24%	*8%*
Above 24% up to 27%	*9%*
Above 27% up to 30%	*10%*
Above 31 %	*10%*

.

If the excess TDD over and above the limit involves decimals and if the decimal is from 0.1 to 0.4, the whole number may only be reckoned. If it is from 0.5 and 0.9, the next whole number will be reckoned.

i) The levying of penalty shall be stopped upon installation of filters by the consumer and testing by the licensee. If it is confirmed by testing that the harmonic currents are brought within the limits specified in the IEEE Standards, the penalty will be stopped from the date of intimation of the consumer to the effect that the installation of filters are fully completed and ready for testing by the Licensee. If the measured values exceed the limits, the penalty would continue. The Licensee shall issue a notice to the consumer forthwith to this effect. It is open to the consumer to rectify/re install the filters again and intimate the Licensee forthwith for re-testing before expiry of said 12 months.

j) Even after 12 months penalty period, if the consumer is not forth coming to install the required harmonic filters or unable to bring the values within prescribed limits, the Licensee shall issue a 30 days disconnection of supply notice to the consumer for non- compliance. If the consumer installs the filters and makes them ready for testing by the Licensee during the notice

period, the Licensee shall test before disconnection. If the measured values are within limits, the supply shall not be disconnected. However the penalty shall be levied till the date of intimation by the consumer to the effect that filters are installed and ready for testing. If the measured values exceed limits, supply to the service shall be disconnected by the Licensee after expiry of the original 30 days' disconnection notice period under report to the Commission.

k) During subsequent measurement by the licensee, if the current distortion limit as specified in IEEE standard is not maintained, the Licensee is at liberty to disconnect the supply to the consumer service by issuing 30 days' disconnection of supply notice under report to the Commission.

l) In case of new supply connectivity, a self-declaration by the applicant that adequate harmonic filters will be installed, shall be enclosed with the application requesting supply. The supply may be initially given and after 12 months the current distortion shall be measured and if it is found to be exceeding the limit, the supply to the consumer installation shall be straight away disconnected after issuing a 30 days' notice under report to the

Commission. The penalty applicable as stipulated in sub regulation h) shall be levied from the date of completion of said 12 months.

m) The licensee is at liberty to conduct current harmonic distortion measurement at any time at the consumer's installation to check as to whether the consumer is maintaining the current harmonic distortion within the limit.

n) This Regulation shall apply to all bulk consumers at 33kV and above and consumers, prosumers, charging stations of below 33kV voltage level except HT tariff IV (Lift Irrigation)" .

Enclosure: Consultants Report - 83 Pages

(By order of the Tamil Nadu Electricity Regulatory Commission)

(S.Chinnarajalu)
Secretary
Tamil Nadu Electricity Regulatory Commission

2021

HARMONIC CONTROL

REPORT SUBMITTED TO TNERC BY

Dr.A.S.KANDASAMY &
Dr.K.R.VALLUVAN

CONTENTS

PART 1

1.0 POWER QUALITY

A reasonable definition of quality of power can be “power made available at specified voltage and frequency without distortion of wave form or loss of symmetry and with minimum instances duration of variations beyond the specified limits or unscheduled interruptions.” From this definition, a few aspects would be clear:

1. It is generally accepted that any electrical parameter cannot remain constant and some variations will occur.
2. The term “Power Quality” has been used to describe the extent of variation of the voltage, current and frequency on the power system.
3. In brief, power quality is the characteristics of the electricity at a given point on an electrical system with respect to a set of specified parameters.

The electrical energy is a continuous flow. It cannot be conveniently stored and be put through quality assurance checks before it is used. The following are the power quality issues, each with different causes and effects and, of course, different cost implications.

1. Outages (Power interruption)
2. Surge
3. Under Voltage
4. Harmonics
5. Voltage sags
6. Voltage swells
7. Overvoltage

The above power quality issues are graphically illustrated below in fig. 1.1. From the graphical representation, it can be seen that :

1) Normal – voltage magnitude and frequency variations are within limits and waveform is sinusoidal.
2) Outage – no supply
3) Surge will last for a very few milliseconds,
4) Under voltage- voltage magnitude is lower than the specified limit.
5) HARMONICS

(a) Current waveform distortions (harmonic currents) due to the inherent characteristics of nonlinear loads (like electronic switching circuits, rectifiers, variable speed drives, welding sets, arc furnaces, induction furnaces, etc.)

(b) Voltage waveform distortion (harmonic voltages) due to harmonic current injections and the network impedance characteristics.

6) voltage sag will be for a few cycles,
7) voltage swell will be for a few cycles,
8) over voltage - voltage magnitude is higher than the specified limits.

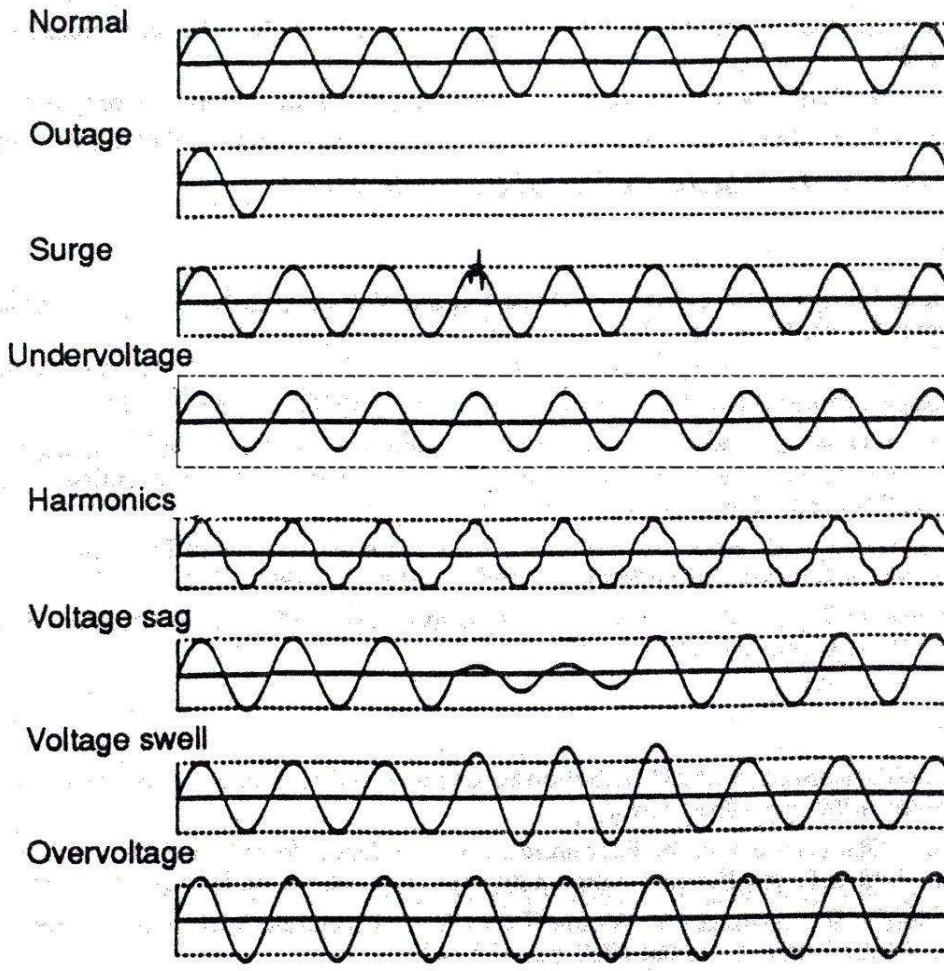

Fig 1.1. Power quality issues (from the book *Electricity – Theory and Practice* by Dr A.S. Kandasamy*)*

Thus, the power quality parameters can be divided into two categories, i.e.,

a) Steady state (or continuous) : Harmonics, frequency deviation, voltage unbalance, voltage fluctuations and flicker

b) Disturbances : outages, momentary interruptions, voltage Surges, voltage dips, voltage swell, transients.

1.1. Current and Voltage waveform Distortions

The worst among the power quality parameters are the current and voltage distortions and they are also a continuous phenomenon. They cause many ill-effects on the entire electrical network - from the point of generation (ie. from the nonlinear load) up to the point of electric supply source (ie. up to the generator). They also affect other loads connected to the same bus or grid.

IEEE Std.519-2014 gives the recommended practice and requirements for harmonic control in electric power systems. CEA (Amendment) regulations 2019 adopt this IEEE STANDARD for harmonic control.

Clause 5 of IEEE STD 519- 2014 stipulates that,

"Because managing harmonics in a power system is considered a joint responsibility involving both end users and system owners or operators, harmonic limits are recommended for both voltages and currents. The recommended values in this clause are based on the fact that some level of voltage distortion is generally acceptable and both system owners or operators and users must work cooperatively to keep actual voltage distortion below acceptable levels. The underlying assumption of these limits is that by limiting harmonic current injections by users, voltage distortion can be kept below objectionable levels. In the event that limiting harmonic currents alone does not result in acceptable levels of voltage distortion, system owners or operators should take action to modify system characteristics so that voltage distortion levels are acceptable".

Consultants' submission:

Harmonic voltage control is a joint responsibility of the consumers and the licensee and both of them must work cooperatively to keep actual voltage distortion below objectionable levels. Hence the licensee cannot disown its responsibility and cooperation in managing the voltage distortion.

Generally, at the source point, the voltage harmonics are absent, as power flow progresses towards load end, voltage harmonics creep in due to the effect of current characteristics of non-linear loads reflecting on network impedances. The voltage harmonic distortion is thus mainly due to the current harmonic injection by its consumers to the system.

Voltage harmonics is generally expected to be managed by the licensee by

I. limiting the harmonic current interjections by the users in accordance with the Regulations

ii. the licensee shall take action to decrease the voltage distortion levels by modifying the supply system impedance characteristics as necessary.

That is why the voltage distortion is said to be a shared responsibility between the consumer and the supplier in the IEEE STANDARD.

Out of the power quality parameters, Current and voltage distortions (harmonics) will only be dealt in this Consultancy Report.

1.2. Harmonics - Definition

Harmonics are a mathematical way of describing distortion of a voltage or current waveform. The term harmonics refer to the components of a distorted waveform whose frequencies are integer multiples of the fundamental frequency.

Fourier Transform resolves a repetitive distorted waveform in terms of summation of many sinusoidal waveforms which are integer multiples (or harmonics) of the fundamental frequency.

1.3. Sources of harmonics

In an electric power system, an alternator (a generator) produces an alternating electromotive force (emf) or voltage / potential pressure to drive the free electrons (current) in a conductor to do a work.

The waveform of the voltage produced by the alternator is sinusoidal. When a sinusoidal waveform of voltage pressure is applied to a load to do a work (like heating, lighting. motoring, rectification etc.,), the resulting current waveform may be sinusoidal or may not be sinusoidal (i.e. distorted) depending upon the load characteristics (i.e. whether it is a ***linear*** *or* ***non- linear*** *load*).

Characteristic of linear loads

When a sinusoidal voltage is applied to a linear load, the current drawn by the load is in sinusoidal waveform. In other words, it is a load that draws instantaneously proportional current to the applied voltage, i.e., its impedance is constant along the whole alternating period.

An Alternator generates electromotive force (emf) which is a pure sinusoidal wave achieved by proper design and construction.

Examples for linear loads

When passive elements like a resistor or inductor or capacitor, (or their combinations as in motors, transformers, and lines) are applied with sinusoidal voltage from the alternator (active element), the current drawn by the passive elements is also sinusoidal. The question of current distortion does not arise. Hence no harmonics are generated in these linear loads.

Current waveforms in linear elements of resistor, inductor and capacitor are graphically shown below.

Resistor load

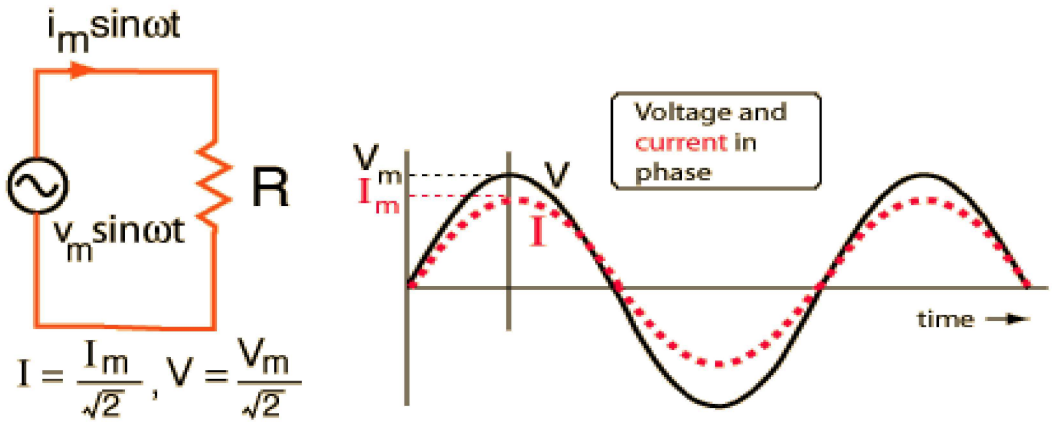

Fig. 1.2. A resistor connected to A.C. source and wave forms of voltage and current. Both the wave forms are sinusoidal.

Inductor load

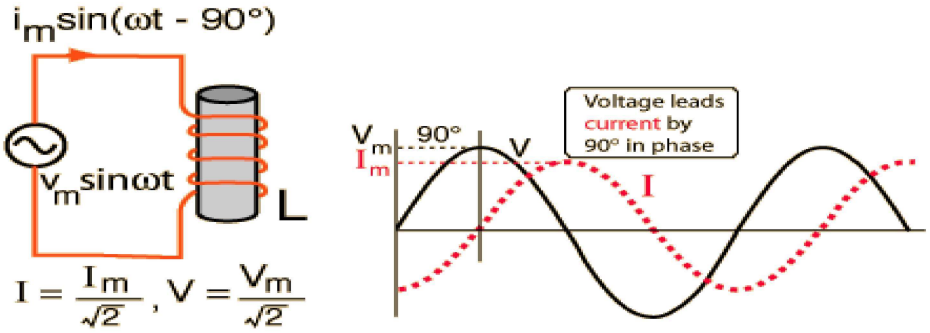

Fig.1.3. An inductor connected to A.C. source and the waveforms of voltage and current. Both wave forms are sinusoidal, but with phase difference (current is lagging behind voltage which causes lagging power factor).

Capacitor load

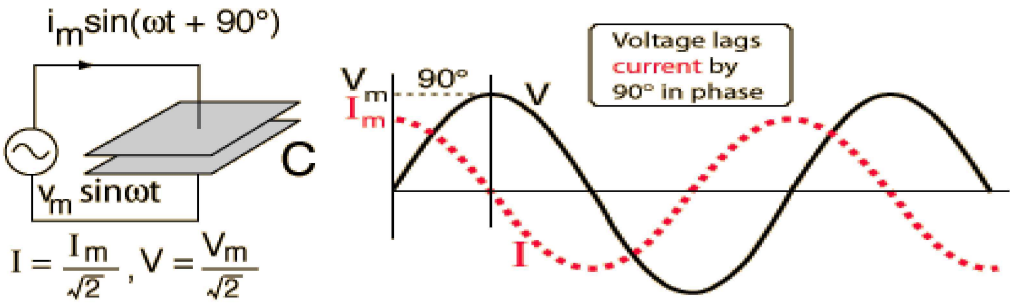

Fig.1.4. A capacitor connected to A.C. source and the voltage and current wave forms. Both the wave forms are sinusoidal, but with a phase difference (current is leading the voltage which causes leading power factor).

Characteristics of non- linear loads

The non- linear loads draw current in non-sinusoidal manner when applied with sinusoidal voltage. This kind of load does not have a constant relation current with respect to voltage along the alternating period In other words, non-linear loads change the sinusoidal nature of the load current (and consequently the voltage drop), thereby resulting in the flow of harmonic currents in the power system.

Non- linear loads

Examples for non-linear elements or loads are electronic components like diodes, , SCRs, switching circuits, UPS , inverters, electronic ballast for flourescent lamps, electronic fan regulators, SMPS, variable speed drives, CNC machines, induction furnaces, arc furnaces, welding sets, saturated transformers, etc.

When applied with sinusoidal voltage from the power system to these non- linear loads, the current drawn by them is NOT sinusoidal but distorted. These sources of current distortion are called harmonic generators. This are explained graphically as below.

Current Distortion In Non-Liner Loads.

Supply voltage

The supply voltages on all three phases of R (red), Y (yellow), B (blue) are sinusoidal as seen from the wave forms captured by Power Quality Analyser as shown in fig. 1.5.

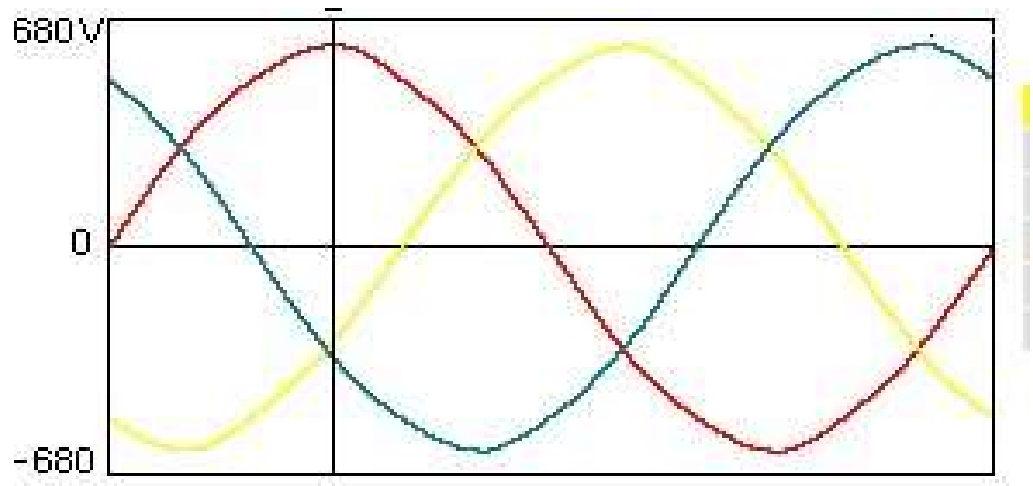

Fig. 1.5. The supply voltages on R, Y and B Phases. The wave shapes of voltages are sinusoidal.

Currents drawn by a non-linear load

Fig.1.6. below shows the load current waveforms of R, Y, B phases drawn by a non-linear load as captured by a Power Quality Analyser. The load currents are highly distorted.

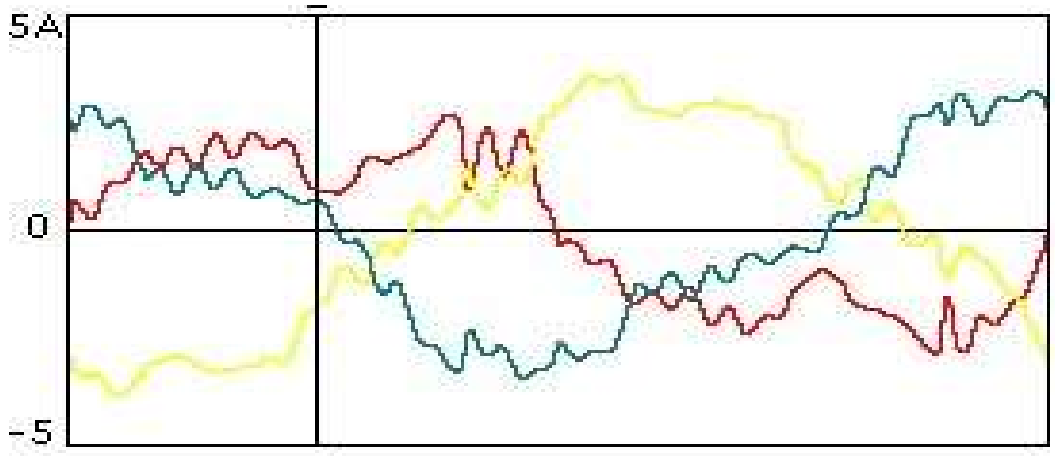

Fig. 1.6. Current waveforms drawn by a nonlinear load in R, Y and B Phases.

The distortions are physically present in the current wave forms of a network and they can be observed in an oscilloscope or a Power Quality Analyser. Using Fourier transform, the distorted wave shape is mathematically resolved into a number of sine waves. The resolved sine waves consist of one sine wave with the same frequency as that of the distorted wave (called the fundamental) and a number of sine waves whose frequencies are integer multiples of fundamental frequency with different amplitudes, called harmonics as shown in fig. 1.7. The distorted wave is split into harmonics to analyse their ill-effects on the power system as well as on the consumers' equipment.

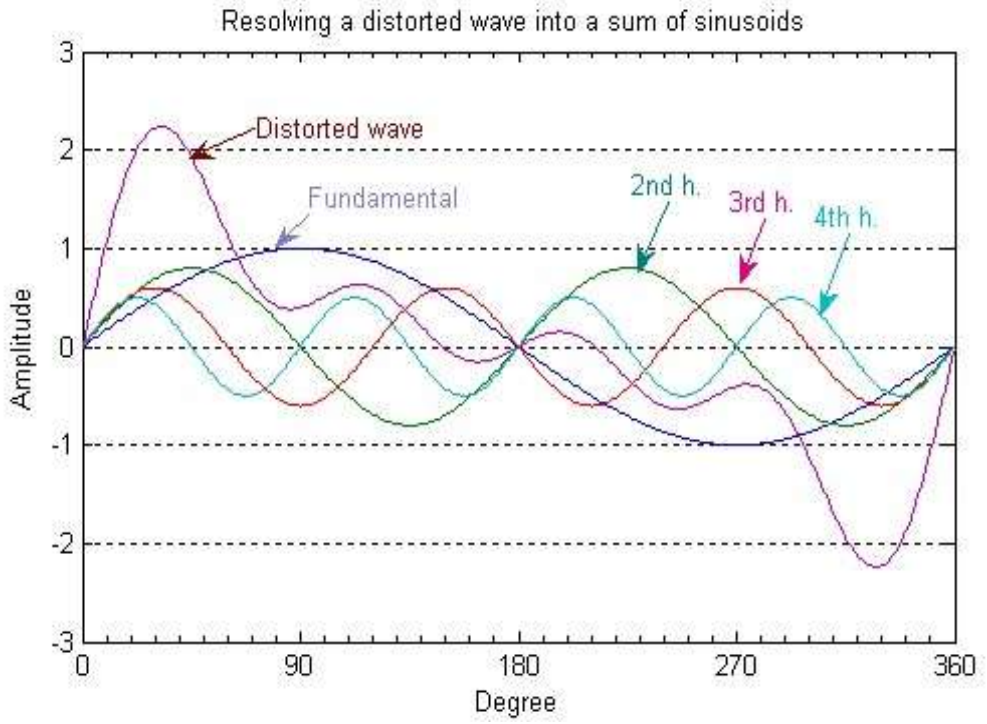

Fig.1.7. Distorted current wave form and the resolved fundamental and harmonics (up to 4th harmonic only shown for clarity)

Wave shown in pink colour is the distorted current wave in a single-phase nonlinear load when applied with a sinusoidal voltage. This distorted current wave is resolved into fundamental wave (shown in blue colour), 2nd harmonic (in green), 3rd harmonic (in red), 4th harmonic (in cyan). The figure shows up to 4th harmonic only for clarity. Using Fourier Transform, theoretically the distorted wave can be resolved into infinite number of harmonics; But in an electrical power system, the effects of harmonics beyond 50th are very insignificant. Hence IEEE 519-2014 Std limits the resolution to 50th harmonics.

The main reason for resolving mathematically using Fourier Transform (ie. the distorted wave into fundamental and harmonics of different amplitudes and frequencies) is that solving the various issues using sine waves is mathematically easy rather than with the distorted wave.

Bar chart for current distortion

In the bar chart given in fig.1.8 below, the distorted current waves of three phases (R,Y and B) are resolved individually into fundamental and harmonics and shown in groups. The amplitude of each harmonic is shown as a bar whose

magnitude is expressed as a per cent value of the fundamental. Amplitude of Fundamental is normalised to 100% in Y axis. In X axis, the order of harmonics is indicated. 1 represents fundamental with the system frequency (50 Hz) ; 2 denotes 2nd order – i.e. harmonic component with a frequency of 2 × fundamental (i.e.100 Hz); 3 denotes 3rd order – i.e. harmonic component with a frequency of 3 × fundamental (i.e. 150 Hz), etc.

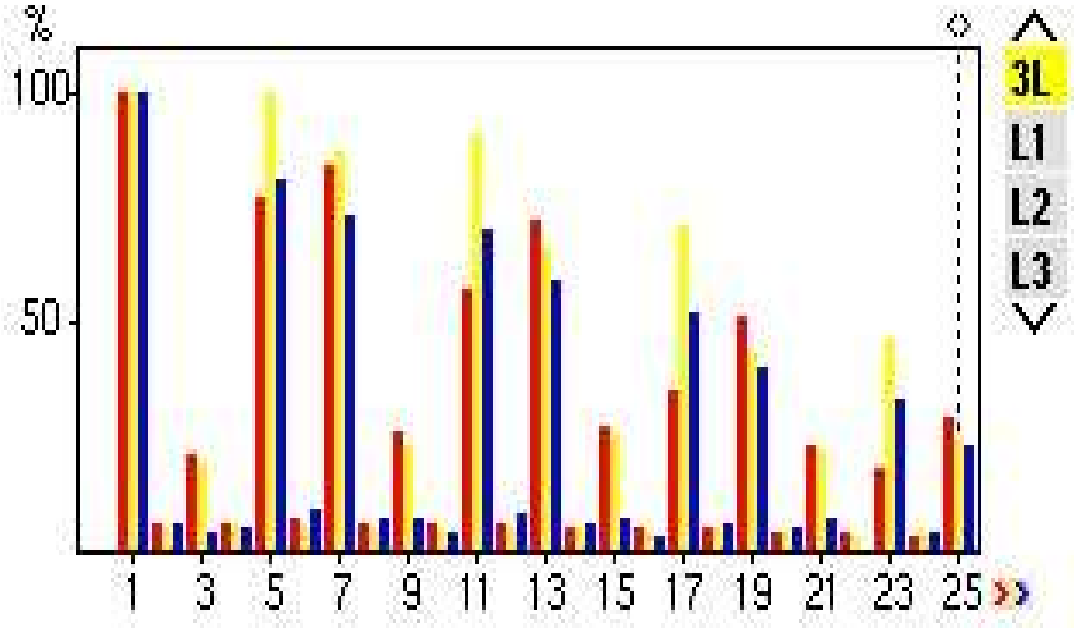

Fig. 1.8. The distorted current waveform resolved into fundamental and harmonics up to 25th order by the Power Quality Analyser. A PQA typically resolves up to 50th order ; but shows in 2 screens – from 1 to 25 in one screen and 26 to 50 in another screen for better viewing.

It can be seen that the magnitudes of 5th, 7th,11th, 13th ,17th, 19th , etc. (odd harmonics) are significant compared to that of the fundamental. The amplitudes of even harmonics (2nd, 4th , 6th , 8th ,10th,12th ,etc.) are negligible. The ***triplen* harmonics** (3rd ,9th ,15th ,21st ,etc.) are appreciable. The triplen harmonic currents are also to be dealt seriously since these currents add up and flow in the neutral conductor.

NOTE:

A distorted wave may be symmetrical or asymmetrical about the X axis. Symmetrical distorted wave has same wave form shape above and below the X axis as shown in

fig. 1.9. An Asymmetrical distorted wave has different wave form shape above and below the X axis as shown in fig. 1.10.

For symmetrical waveforms, only “odd” harmonics are present (multiples 3^{rd}, 5^{th}, 7^{th} ,11^{th} etc., of the fundamental frequency). For asymmetrical waveforms, apart from “odd” harmonics, “even” multiples of the fundamental frequency (viz.,2^{nd}, 4^{th}, 8^{th}, 10^{th} etc.) are also present. Also, DC components can appear in asymmetrical waveforms, which are represented as 0 (zero) Hz signals.

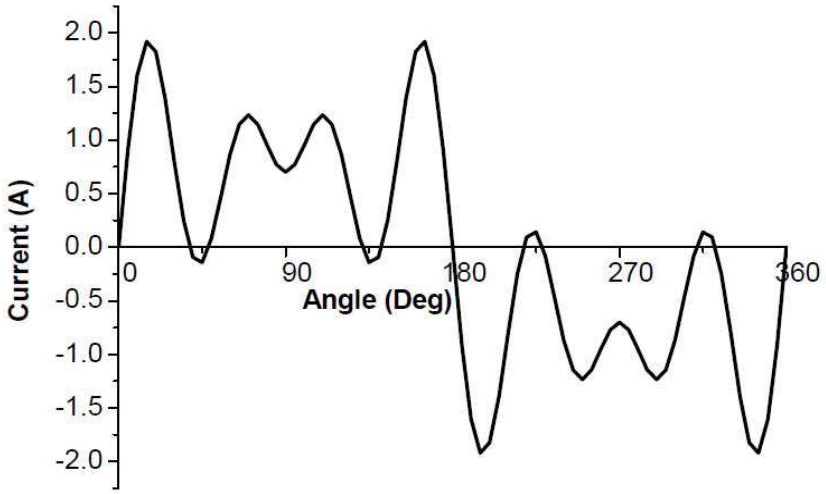

Fig.1.9. A symmetrical waveform

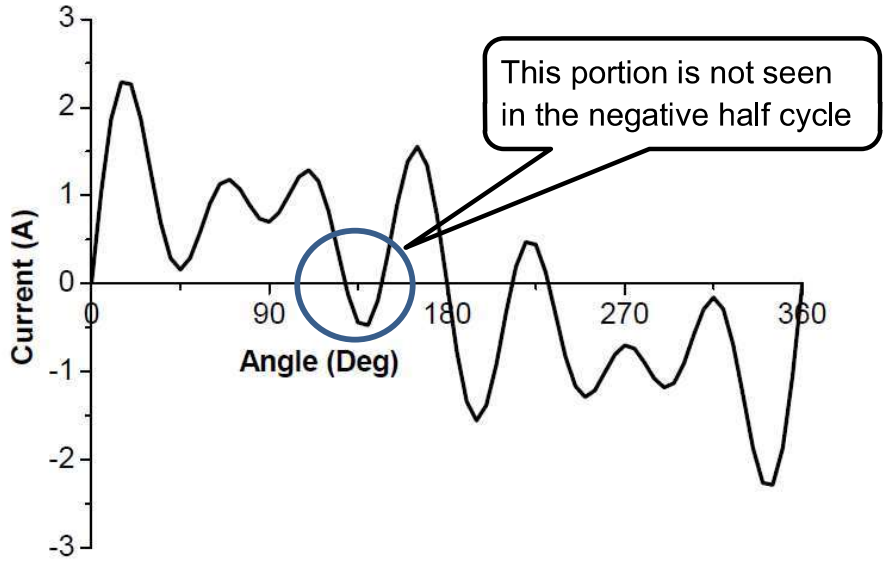

Fig.1.10. An asymmetrical waveform

Current Distortion / Harmonics currents – A Necessary Evil

In the past, majority of loads were linear loads; but due to the advent of power electronics based power converter systems and their exponential growth with techno-economic benefits and advantages, majority of loads connected to the electrical grid nowadays are non-linear. These non-linear loads are the sources of harmonics.

Harmonics in power systems are a recent phenomenon and they are caused by increasing number of non-linear loads like variable frequency drives, DC drives, battery charges, PCs, electronic ballasts, induction furnaces, static var compensators, UPS and so on. Though these non-linear loads generate harmonics causing many ill-effects on the power system and users' installation as well, the benefits and advantages from these non-linear loads are many. Harmonics generated by non-linear loads are evil but these non-linear loads are necessary because of their many benefits and advantages. Hence harmonics are called necessary evil. However, the ill-effects of harmonics have to be mitigated by installing filters. In practice, the current and voltage distortions are only to be reduced within permissible limits rather than entirely nullifying them.

This is because that electronically controlled equipment have some minimum harmonic generation even after embedding with filter. Though it is technically feasible to fully nullify the harmonics, it is not economically viable. Thus, there is a trade-off between keeping the harmonics within prescribed limits and the cost of installation of harmonic filters for fully nullifying them. Such minimum harmonics of all the equipment will thus be added and revealed in an installation. Further, the measurement errors due to ever varying loads, permissible instrument (CT, PT and meter) errors, etc. are all to be accounted for. Thus, the IEEE 519-2014 standard specifies the voltage and current distortion limits.

1.4. Harmonic currents – a POLLUTANT in power systems!

Harmonic currents generated by non -linear loads of consumers traverse back to the source and the high impedance of generators will transfer easily current harmonic distortion into voltage harmonic distortion on the generated voltage. The voltage drops along the power system due to flow of harmonic currents will

distort the supply voltage. The consumers will be supplied with distorted voltage supply; a **polluted supply**, instead of pure sinusoidal waveform of voltage. Such a power pollution is akin to air pollution caused by automobile emissions.

1.5. Ill effects of Harmonics in power systems

Harmonics are doing much havoc / many ill effects on the supply system and the consumers' installations; and they are increasing due to the ever-growing electronic power converters connected to the grid. They are described below:

1.Voltage distortion

Supply voltage distortion (voltage harmonics) caused by harmonic currents increases the transformer losses due to hysteresis and eddy currents and causes overstressing of the insulation material used. Voltage harmonics and inter-harmonics supplying lighting circuits can cause fluctuations of light intensity affecting the human eyes. The performance of electronic equipment / devices will be affected with distorted supply voltage. Service life of components and equipment under continuous distorted supply voltage will be reduced.

2. Additional KVA demand

Harmonic power increases the apparent power (kVA) drawn from the supply.

3,Lowering of Power factor

In view of harmonics generation by the non-linear loads, the power factor is to be redefined. When a linear load is inductive, load current lags the supply voltage. The angle between voltage and current is called displacement angle and the power factor is called *displacement power factor*. When the load is non-linear, harmonics are generated and consequently the displacement power factor is redefined as *distortion power factor*. Distortion power factor is a measure of how much the harmonic distortion of a load current additionally decreases the average power transferred to the load.

Harmonic Power increases the apparent power (kVA), while the "effective" real power (kW) at the fundamental frequency does not get benefit from that. Power factor $=\frac{kW}{kVA}$ is thus lowered as kVA increases. Consequently, the efficiency of the power system is reduced.

4.Over-sized power system

Higher load current due to addition of harmonic currents needs to be drawn from the source. Hence over-sized distribution circuits and de-rating of transformers are necessitated.

5 Increased power losses

The linear load current is the vector addition of *in-phase* real current and *reactive* current whereas the non-linear load current is made up of three currents i.e., in-phase current, reactive current and *currents due to harmonics*. As harmonic currents increase, I^2R losses also increase; as 'I' increases, losses increase in square.

6.Skin Effect

Skin effect in conductors is more predominant at higher frequencies of harmonic currents. Increased Skin Effect due to higher order harmonics causes *additional power losses or need for oversizing of conductors*.

7.Triplen harmonics and neutral conductor

In a 3-phase 4-Wire installation, Neutral conductor needs to be oversized to 200% to that of phase conductors to carry the triple-n harmonic currents.(i.e. 3^{rd},9^{th},15^{th}, 21^{st}, etc. order harmonics)

In a previous consultancy to TNEB (done in 2005) the consultants measured the current in the neutral conductor. Fig. 1.11. shows the currents in the three phase line conductors and the neutral conductor supplying a non-linear load. Ideally, there won't be a current in the neutral conductor in a 3P – 4W system. But due to harmonics, the triplen currents (i.e. currents of 3^{rd}, 9^{th}, 15^{th}, … harmonics) get added up and flow in neutral conductor. In fig. 1.11, we can observe that the neutral current is almost 100 % of line current.

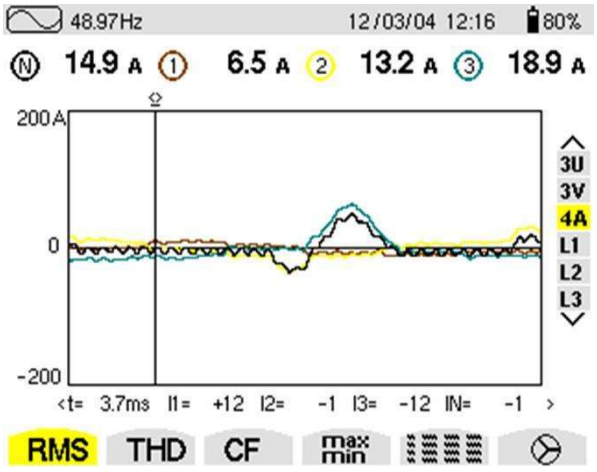

Fig. 1.11. A non-zero neutral current

8. Generators

Generators themselves can be affected by other harmonic sources (i.e. non- linear loads), in terms of efficiency reduction, overheating , etc. Further the high impedance of generators will transfer easily current harmonic distortion into voltage harmonic distortion on the generated voltage.

9. Motors

Higher order harmonic currents increase iron losses and copper losses. Negative phase sequence (RBY instead of RYB) harmonic currents have the effect of force against torque rotation; consequently they can cause motor vibration, added heat, etc.

10. Transformers

Harmonics in transformers cause an increase in the iron and copper losses. Voltage distortion increases losses due to hysteresis and eddy currents and causes overstressing of the insulation material used. The primary effect of power line harmonics in transformer is, thus the additional heat generated.

Also, triplen harmonics in the neutral conductor of a Delta-Wye distribution transformer can dangerously overheat them. There is also a potential risk of resonance between transformer inductance and supplied capacitive loads, at the harmonic's frequencies.

Laminated transformers cores can also vibrate at certain harmonic frequencies, causing audible noise and overheat.

For all the effects described above, transformers need to be de-rated in the presence of harmonics, or specially designed to handle harmonics, identifying them by a rating parameter called "K factor", function of the harmonic's capability. The "k factor" transformers could be a more optimal solution (cost and weight), rather than de-rating (for example, can be designed with only oversizing neutral for triple harmonics).

Usage of K-rated transformers in power distribution components

A standard transformer is not designed for high harmonic currents produced by non-linear loads. It will overheat and fail prematurely when connected to these loads. When harmonics were introduced into electrical systems at levels that showed

detrimental effects, the industry responded by developing the K-rated transformer. K rated transformers are not used to handle harmonics, but they can handle the heat generated by harmonic currents and are very efficient when used under their K-factor value. Derating or k factor transformers invite additional capital investment reflecting on the fixed charges.

11. Circuit breakers and fuses

Since the thermal-magnetic tripping mechanism in circuit breakers responds proportionally to rms current, a highly distorted current signal (Irms much higher than the fundamental I_1) can cause unwanted MCB's tripping. This necessitates the oversizing of Circuit breakers. Also, circuit breakers, which are designed to interrupt current at zero current crossover, can meet several zero current crossovers within a fundamental period in the case of much distorted current; consequently, causing premature interruption of the circuit.

Similarly, in fuses, the higher the rms current, the higher the heating effect of that current; so the fuse will act faster. Moreover, higher order harmonics can cause skin-effect and proximity effect in the internal construction of the fuse; so additional unwanted overheating takes place in the fuse. Therefore, for the non-linear loads, it may be necessary to de-rate fuse selection.

12.Flicker

Voltage harmonics and inter-harmonics supplying lighting circuits can cause fluctuations of light intensity affecting the human eyes.

13. Other effects of the harmonics

The effects of harmonics are due to both current and voltage distortions, although current-produced effects are more likely to be seen in day-to-day performance. Voltage effects are more likely to degrade the insulation and hence shorten the life of the equipment. The following describes some of the common effects of harmonics:

- The protective relays will malfunction with harmonic currents and voltages present in the supply system.
- Digital circuits can be affected by misinterpretation of logical values in presence of harmonics.

- Memory losses, turn offs etc., will happen in electronic devices like computers in presence of harmonics.
- UPS may need to handle with high distorting loads, i.e., high current peaks may be over the range of the crest factor capacity of the UPS. In such case, the voltage distortion can further increase, if the inverter of the UPS is not capable enough.
- Increased losses within the equipment and associated cables, lines, etc.
- Pulsating and reduced torque in rotating equipment.
- Premature aging due to increased stress in the equipment insulation.
- Increased audible noise from rotating and static equipment.
- Mis-operation of equipment sensitive to waveforms.
- Substantial amplification of currents and voltages due to resonances.
- Communication interference due to inductive coupling between power and communication circuits.

1.6. POWER FACTOR VERSUS HARMONICS

It will be worth to compare power factor with harmonics as both reduce the efficiency of the power systems . Harmonics, in addition, are bringing other ill-effects as described above.

No.	Description	Power factor (lag)	Harmonics
1	Waveforms of voltage and current	Voltage and Current waveforms are sinusoidal	Distorted load current distorts the supply voltage waveform
2	Phase angle between voltage and current	Displacement PF .	Harmonics introduce additional phase shift between the voltage and current. True Power factor is to be redefined. True PF is less than the displacement PF.
3	Load current increases as power factor lowered i.e.harmonics increased	Apparent power kVA increased. Power losses in lines and transformers increased.	Additional apparent power kVA required. Additional power losses in lines and transformers.

4	Power quantity	Apparent power kVA increased as PF lowered.	Additional apparent power kVA required.
5	Power QUALITY	Supply voltage sine wave form not affected.	Supply voltage waveform distorted.
6	System efficiency	Reduced.	Additionally reduced.
7	Functioning of relays	Not affected.	Malfunctioning of relays.
8	Other consumers	Not affected.	Affected by getting distorted supply voltage.
9	Pollutant	Not a pollutant.	POLLUTANT.
10	CEA / State Regulation	Compensation for poor power factor.	Disconnection + Penalty (proposed)
11	ill- Effects	No ill-effects.	ill-effects are many.
12	Parties affected	i. Supplier ii. User	i. Supplier ii. User iii. Other users
13	Remedy	Installation of reactive power compensation equipment.	Installation of harmonic filters.

1.7. SUMMARY

Ill- effects of harmonic currents cannot be adequately estimated and compensated in terms of money. Remedy is either to altogether eliminate the harmonic if possible or minimize them within limits stated in standards.

As far as voltage harmonic distortion, it is a shared responsibility of the supplier (licensee) and the consumers (users). Current harmonic distortion of the non-linear loads of consumers distorts the supply voltage and the supplier network impedance characteristic also distorts the voltage. Licensee and the consumers should strive to mitigate the ill-effects of harmonics, rather than seeking / paying compensation. Further such compensation charge cannot be a perennial revenue to the licensee (supplier).

Penalty is proposed in our recommendation to induce the consumer for the early installation of harmonic filters. Penalty is proposed to be levied only after giving enough time (6months)) for installation of filters. Hence the question of levying penalty does not arise in case the consumer installs the filters within the 6 months' time given.

The licensee cannot claim compensation as it is not stipulated in the CEA Regulations 2019 which stipulates only the disconnection of supply for non-compliance of harmonic limit.

PART 2

IEEE, IEC STANDARDS AND CEA REGULATIONS ON HARMONICS

2.1. IEEE Std. 519- 2014 (revision of IEEE Std 519-1992)

In the introduction and clause1.2, it is stated that,

"The limits in this recommended practice represent a shared responsibility for harmonic control between system owners or operators and users. Users produce harmonic currents that flow through the system owner's or operator's system, which lead to voltage harmonics in the voltages supplied to other users. The amount of harmonic voltage distortion supplied to other users is a function of the aggregate effects of the harmonic current producing loads of all users and the impedance characteristics of the supply system.

Harmonic voltage distortion limits are provided to reduce the potential negative effects on user and system equipment. Maintaining harmonic voltages below these levels necessitates that

– All users limit their harmonic current emissions to reasonable values determined in an equitable manner based on the inherent ownership stake each user has in the supply system and

– Each system owner or operator takes action to decrease voltage distortion levels by modifying the supply system impedance characteristics as necessary".

Clause 2 of IEEE 519-2014 stipulates that,

"2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEC Standard 61000-4-7, General Guide on Harmonics and Inter-harmonics Measurement and Instrumentation, for Power Supply Systems and Equipment Connected Thereto.

IEC Standard 61000-4-30, Power Quality Measurement Methods".

Consultants' submission:

From the above, IEEE 519-2014 stipulates that the document of IEC 61000-4-30 is an indispensable for the application of IEEE 519-2014 and only the latest edition of the document IEC61000-4-30 shall be adopted.

Further IEC 61000-4-30 :2015 also reiterates to use the latest edition i.e., edition 3.

Page 7 of IEC 61000-4-30 :2015 is reproduced as below:

"INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMAGNETIC COMPATIBILITY (EMC) – Part 4-30: Testing and measurement techniques – Power quality measurement methods.

FOREWORD

6) All users should ensure that they have the latest edition of this publication.

9) This third edition during 2015 itself cancels and replaces the second edition published in 2008. The third edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) the measurement method for current, previously informative, is now normative with some changes;

b) the measurement method for RVC (rapid voltage change) has been added;

c) the measurement method for conducted emissions in the 2 kHz to 150 kHz range has been added in informative Annex C;

e) Class A and Class S measurement methods are defined and clarified, while Class B is moved to informative Annex E and considered for future removal".

CEA AMENDMENT REGULATION 2019, part IV paragraph 3 stipulates,

Voltage and Current Harmonics. - (i) The limits of voltage harmonics by the distribution licensee in its electricity system, the limits of injection of current harmonics by bulk consumers, point of harmonic measurement, i.e., point of

common coupling, method of harmonic measurement and other related matters, shall be in accordance with the IEEE 519-2014 standards, as amended from time to time.

(ii) Measuring and metering of harmonics shall be a continuous process with meters complying with provisions of IEC 61000-4-30 Class A.

Consultants' submission:

From the above it is evident that IEEE STD 519-2014 specifies the latest edition of IEC 61000-4-30 which in turn specifies the edition 3. CEA regulation 2019 adopts the above IEEE and IEC Standards.

What is the rule to be followed in respect any standard viz. Indian standards, IEEE, IEC etc.?

If any standard is revised, from the date of revision, only the revised or the latest one is legally acceptable and universally followed. This is also reiterated in CEA regulation above that…… IEEE 519-2014 standard, as amended from time to time

61000-4-30 edition 3 was issued 6 years back i.e., during 2015, which specifies the use of edition 3 only.

Will meter manufacturers now manufacture meter for the cancelled and replaced second revision and can able to get it certified from the standard lab based on the replaced edition?.

That is why CEA amendment regulations 2019 stipulates that "… shall be in accordance with the IEEE 519-2014 standards, as amended from time to time".

It is evident from the above that meter complying to the latest edition of 61000-4-30 is only to be used for measurement.

Hence in our consultative report, we use only the latest IEC 61000-4-30 edition 3 class A for power quality meter.

The proposed state regulation shall be in accordance with the CEA amendment regulation2019, revised IEEE 519-2014 and the latest edition (EDITION3) of IEC 61000-4-30 CLASS A.

2.2. Definitions as per IEEE Std 519-2014

2.2.1. 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.

2.2.2. Point of common coupling (PCC): Point on a public power supply system, electrically nearest to a particular load, at which other loads are, or could be, connected. The PCC is a point located upstream of the considered installation.

The measurement ONLY at PCC

Clause 5, para 2 of IEEE519:2014 Std. states that,

“

The recommended limits in this clause apply only at the point of common coupling and should not be applied to either individual pieces of equipment or at locations within a user’s facility. In most cases, harmonic voltages and currents at these locations could be found to be significantly greater than the limits recommended at the PCC due to the lack of diversity, cancellation, and other phenomena that tend to reduce the combined effects of multiple harmonic sources to levels below their algebraic summation.

”

PCC at the HV or LV side of transformer

Clause 1.2 , para 2 states that,

“

This recommended practice should be applied at interface points between system owners or operators and users in the power system. The limits in this recommended practice are intended for application at a point of common coupling (PCC) between the system owner or operator and a user, where the PCC is usually taken as the point in the power system closest to the user where the system owner or operator could offer service to another user. Frequently for service to industrial users (i.e., manufacturing plants) via a dedicated service transformer, the PCC is at the HV side of the transformer. For commercial users (office parks, shopping malls, etc.) supplied through a common service transformer, the PCC is commonly at the LV side of the service transformer.

”

2.2.3. Short-circuit ratio: At a particular location, the ratio of the available short-circuit current, in amperes, to the load current, in amperes.

2.2.4. Maximum demand load current (I_L) is arrived from the sum of the currents corresponding to the maximum demand during each of the twelve previous months divided by 12.

Explanatory note by the Consultants

Why correct ratio of maximum short-circuit current at PCC (I_{SC}) and the maximum demand load current (I_L) established at PCC ($=\frac{I_{SC}}{I_L}$) shall be adapted during measurements?

Maximum Short circuit current at PCC (I_{SC}) is arrived from the fault MVA at the PCC. The individual odd harmonic current limit and the TDD limit are to be taken from the corresponding voltage range current distortion limit table (of IEEE 519:2014 Std.) and against the corresponding short circuit current ratio of the table.

In case, values based on fault MVA at different locations other than PCC or different load currents other than Maximum demand load current - either for I_{SC} or for I_L or both - are used for arriving the short circuit current ratio, there is every possibility of referring to the row in current distortion limit table having higher permissible limits instead of the correct value of limits. However, such an error may not shift the row if the ratio arrived is not in close proximity between any two short -circuit ratios; for example, Table 2 of the IEEE 519:2014 Std., gives the limits for various short circuit ratios. For $I_{SC}/I_L < 20$, the value of TDD is given as 5%, whereas for I_{SC}/I_L 20<50, it is 8%; the variation is 3% between just less than 20 and 20.

2.2.5. Total demand distortion (TDD): TDD is 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 per cent of the maximum demand current. Harmonic components of order greater than 50 may be included when necessary.

$$TDD = \frac{\sqrt[2]{I_2^2 + I_3^2 + I_4^2 + ... + I_{50}^2}}{I_L} \qquad (2.1)$$

where I_2, I_3, I_4, …, I_{50} are 2nd, 3rd, 4th, …, 50th order harmonic currents and I_L is the maximum demand load current arrived as specified earlier.

Consultants note: Total demand distortion (TDD) refers to current distortion.

2.2.6. 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 per cent of the fundamental. Harmonic components of order greater than 50 may be included when necessary.

$$THD = \frac{\sqrt[2]{V_2^2 + V_3^2 + V_4^2 + ... + V_{50}^2}}{V_1} \qquad (2.2)$$

where V_2, V_3, V_4, …, V_{50} are 2nd, 3rd, 4th, …, 50th order harmonic voltages and V_1 is the fundamental component of the voltage.

Consultants note: Total harmonic distortion (THD) refers to voltage distortion.

2.3. Harmonic measurements

For the purposes of assessing harmonic levels for comparison with the recommended limits in this document, any instrument used should comply with the specifications of IEC 61000-4-7 and IEC 61000-4-30.

The relevant portions of the above IEC specifications are summarised in 2.3.1 through 2.3.2.

2.3.1 Measurement window width

The width of the measurement window used by digital instruments employing Discrete Fourier Transform techniques should be 10 cycles (200 ms) for 50 Hz power systems. With this window width, spectral components will be available every 5 Hz. For the purposes of the IEEE 519-2014 Standard, a harmonic component magnitude is considered to be the value at a centre frequency (50, 100, 150 etc.) combined with the two adjacent 5Hz bin values. The three values are combined into a single value that defines the harmonic magnitude for the particular centre frequency component.

2.3.2 Very short time harmonic measurements

Very short time harmonic values are assessed over a 3-second interval based on an aggregation of 15 consecutive 10 cycle windows for 50 Hz power systems. Individual

frequency components are aggregated on an rms calculation as shown in Equation (2.3) where *F* represents voltage (*V*) or current (*I*), *n* represents the harmonic order, and *i* is a simple counter. The subscript *vs* is used to denote "very short." In all cases, *F* represents an rms value.

$$F_{n.vs} = \sqrt{\frac{1}{15}\sum_{i=1}^{15} F_{n,i}^2}. \qquad (2.3)$$

The calculations are done up to 50th order (i.e. *n*=50) as per IEEE Std. 519:2014, Section 3 Definitions for TDD and THD.

Explanatory note by consultants:

The supply frequency of 50 Hz (50 cycles per second) means, 1 cycle = 20 ms.

∴10 cycles =200 ms =1 window width

Aggregation of 15 window width = 200 ms × 15 = 3000 ms = 3 second

Time aggregation or simply aggregation is the combination of several values of a given parameter (each determined over identical time intervals) to provide a value for a longer time interval.

One very short time measurement interval =3 second

The equations compute the square root mean (average) summation of individual harmonic component over 15 consecutive cycle windows width.

2.3.3. Statistical evaluation:

From the accumulation of 3 second interval value over period of one day (24 hours) the daily 99th percentile values of harmonics are derived.

2.3.4. Short time harmonic measurements

Short time harmonic values are assessed over a 10-minute interval based on an aggregation of 200 consecutive very short time values for a specific frequency component. The 200 values are aggregated based on an rms calculation as shown in Equation (2.4) where *F* represents voltage (*V*) or current (*I*), *n* represents the harmonic order, and *i* is a simple counter. The subscript *sh* is used to denote "short." In all cases, *F* represents an rms value.

$$F_{n.sh} = \sqrt{\frac{1}{200}\sum_{i=1}^{200} F_{(n,vs),i}^2} \qquad (2.4)$$

The calculations are done up to 50th order (i.e. *n*=50) as per IEEE Std. 519:2014, Section 3 Definitions for TDD and THD.

Explanatory note by consultants:

One very short time measurement interval =3 second .

Aggregation of 200 very short time measurement interval = 3 second × 200 = 600 second = 10-minute interval.

The equation is a square root mean (average) summation of individual very short time harmonic value over 200 consecutive very short time values for a specific frequency component.

2.3.5. Statistical evaluation:

Accumulation of 10-minute interval values over period of minimum one week.

weekly 99th and 95th percentile harmonic currents are extracted from the above.

2.4.Statistical evaluation

Very short and short time harmonic values should be accumulated over periods of one day and one week, respectively. For very short time harmonic measurements, the 99th percentile value (i.e., the value that is exceeded for 1% of the measurement period) should be calculated for each 24-hour period for comparison with the recommend limits in Clause 5. For short time harmonic measurements, the 95th and 99th percentile values (i.e., those values that are exceeded for 5% and 1% of the measurement period) should be calculated for each 7-day period for comparison with the recommended limits in Clause 5. These statistics should be used for both voltage and current harmonics with the exception that the 99th percentile short time value is not recommended for use with voltage harmonics.

(Refer IEC 6100-4-30:2015 – Annex. B – POWER QUALITY MEASUREMENT-monitoring period- B.5.2 page 59, ….; in contrast, for harmonics and steady state measurements , meaningful information may be captured in relatively short periods of time (minimum of one week).

2.5. Recommended harmonic voltage limits

At the PCC, *system owners or operators* should limit line-to-neutral voltage harmonics as follows:

– Daily 99th percentile very short time (3 s) values should be less than 1.5 times the values given in Table 1.

– Weekly 95th percentile short time (10 min) values should be less than the values given in Table 1.

All values should be in per cent of the rated power frequency voltage at the PCC. Table 1 applies to voltage harmonics whose frequencies are integer multiples of the power frequency.

Table 1. Daily 99th percentile very short time (3s) values should be less than the values in columns (3) and (5).

Bus voltage *V* at PCC	**Individual harmonic (%)**	**1.5 × value in column (2)**	**Total harmonic distortion THD (%)**	**1.5 × value in column (4)**
Column (1)	(2)	(3)	(4)	(5)
$V \leq 1.0$ kV	5.0	7.5	8.0	12%
1 kV$<V \leq$ 69 kV	3.0	4.5	5.0	7.5
69 kV$<V \leq$ 161 kV	1.5	2.25	2.5	3.75
161 kV $< V$	1.0	1.5	1.5	2.25

Consultants' Note:

Remarks for Daily 99th percentile:

In one day, ie. [(24 hrs × 60 min × 60 s) / 3 s] = 28.800 readings are recorded.

99th percentile value = the value that is exceeded for 1% of the measurement period.

99% of the readings = 99% of 28,800 = 28,512 readings.

ie. 28,512 readings arranged in a histogram shall be less than the values given in Table 1 column (3) and (5).

i.e. Only 1% of 28,800 = 288 readings can be more than the values given in Table 1.

Remarks for weekly 95th percentile:

In 1 week, ie. (7days × 24 hrs × 60 min) / 10min = 1,008 readings.

95th percentile value = the value that is exceeded for 5% of the measurement period.

95% of the readings = 95% of 1,008 = 957 readings.

ie. 957 readings arranged in a histogram shall be less than the values given in Table 1, column 2 and column 4.

i.e. Only 5% of 1,008 = 50 readings can be more than the values given in Table 1.

2.6. Recommended current distortion limits

1) Table 2 - Nominally rated for 120 V through 69 kV
2) Table 3 - Nominally rated above 69 kV through 161 kV
3) Table 4 - Nominally rated above161 kV

At the PCC, *users* should limit their harmonic currents as follows:

– Daily 99th percentile very short time (3 s) harmonic currents should be less than 2.0 times the values given in Tables 2, 3 and 4.

– Weekly 99th percentile short time (10 min) harmonic currents should be less than 1.5 times the values given in Tables 2, 3 and 4.

– Weekly 95th percentile short time (10 min) harmonic currents should be less than the values given in Tables 2, 3 and 4.

2.7. Recommendations for increasing harmonic current limits

It is recommended that the harmonic current values given in Table 2, Table 3, and Table 4 be increased by a multiplying factor when actions are taken by a user to reduce lower-order harmonics. The multipliers given in the second column of Table 5 are applicable when steps are taken to reduce the harmonic orders given in the first column.

Consultants' Note: multiplier applies to harmonic orders only; not for TDD.

2.8. Classes of meters in IEC 61000-4-30 EDITION 3.0

There are three types of meter viz., class A, B and S as per the above Standard.

"A" stands for "advanced" ,and "S" stands for "surveys"

Why class A type alone shall be used for our purpose ?

Class A Meter:

The value of the r.m.s. voltage is measured over 1 cycle , commencing at a fundamental zero crossing and refreshed each ***half- cycle.***

The value of the r.m.s current is measured over 1 cycle, commencing at a fundamental zero crossing on a voltage channel and refreshed each ***half- cycle.***

Class S Meter

The value of the r.m.s. voltage is measured over 1 cycle and refreshed each cycle.

Class B Meter

Class B instrument classified under this standard will be removed in the next edition of this standard.

Consultants' remark:

Class S and B meter shall not be used for our purpose and only class A meter shall be used as per CEA regulation.

Further Class A is used where precise measurements are necessary; e.g. contractual applications that may require resolving disputes, verifying compliance with standards, etc.

Power quality measurements, issues and guidelines shall be followed as per Annexure A of this standard.

2.9. INDIAN STANDARD

IS 14700 (Part 4/See 7): 2006 - ELECTROMAGNETIC COMPATIBILITY (EMC) - PART 4 TESTING AND MEASUREMENT TECHNIQUES Section 7 General Guide on Harmonies and interharmonics Measurements and instrumentation for Power Supply Systems and Equipment Connected Thereto is the Indian Standard applicable for this measurement which is a verbatim reproduction of IEC 61000-4-7 (2002). IEC 61000-4-7 has now been revised ; The Indian Std. is yet to be revised accordingly.

2.10. CEA REGULATIONS

The State regulations on harmonics shall be in accordance with the following amended CEA regulations.

2.10.1 ***The Central Electricity Authority (Technical Standards for Connectivity of the Distributed Generation Resources) Amendment Regulations, 2019 – Applicable to connectivity below 33 kV.***

The salient features in respect of current harmonics in the above regulations are:

"

The limits of injection of current harmonics at the point of common coupling by the user, method of harmonic measurement and other such matters, shall be in accordance with the IEEE 519-2014 standard, as amended, from time to time.

The measuring and metering of harmonics shall be a continuous process with power quality meters complying with provisions of IEC 6100-4-30 Class A.

Compliance of regulations:

(1) It shall be the responsibility of concerned licensee to ensure that before connectivity to the grid, all the provisions with regard to the connectivity stipulated in these regulations are complied with by the applicant.

(2) The user may be disconnected from the grid by the licensee for non-compliance of any provision of these regulations, under report by the licensee to the appropriate Electricity Regulatory Commission.

”

2.10.2. The Central Electricity Authority (Technical Standards for Connectivity to the Grid) (Amendment) Regulations, 2019 – Applicable to connectivity 33 kilovolt and above

The salient features in this regulations are:

“

Voltage and Current Harmonics. –

(i) The limits of voltage harmonics by the distribution licensee in its electricity system, the limits of injection of current harmonics by bulk consumers, point of harmonic measurement, i.e., point of common coupling, method of harmonic measurement and other related matters, shall be in accordance with the IEEE 519-2014 standards, as amended from time to time.

(ii) Measuring and metering of harmonics shall be a continuous process with meters complying with provisions of IEC 61000-4-30 Class A.

Compliance of regulations:

(1) The licensee shall ensure that before connectivity to the grid, all the provisions with regard to the connectivity specified under these regulations are complied with by the requester.

(2) The user may be disconnected from the Grid by the licensee for non-compliance of any provision of these regulations and any non-compliance of the provisions of these regulations shall be reported by the licensee or the State Load Dispatch Centre or the Regional Load Dispatch Centre, as the case may be, to the appropriate Commission

”

Consultants' Submission

In both the regulations i.e., applicable for both *' below 33kV '* and '*33kV and above'*, it is stipulated to follow the IEEE Std. 519-2014.

In the case of 'below 33kV' the regulation deals only with injection of current harmonics, whereas in the case of '33kV and above' the regulation deals with voltage and current harmonics.

In respect of voltage and / or injection of current harmonics, point of harmonic measurement, i.e., point of common coupling, method of harmonic measurement and other related matters, shall be in accordance with the IEEE 519-2014 standard, as amended from time to time.

2.11. History of IEEE 519-2014

In the United States, the Industry Applications Society (IAS) of the IEEE began a standards development project on harmonics in 1973. The first publication resulting from this project was IEEE Std 519-1981, entitled *IEEE Guide to Harmonic Control in Electrical Power Systems*. The IEEE publishes a hierarchy of Standards from the least to the most prescriptive, which are referred to as Guides, Recommended Practices, and Standards. In 1986, the Power Engineering Society (PES) joined the IAS to upgrade IEEE Std 519-1981 to the status of a Recommended Practice. In 1992, IEEE Std 519-1992, entitled IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems, was published. In 2014, IEEE Std 519 was revised by the PES Transmission and Distribution Committee. It is widely used by the utilities and by industrial, commercial and residential users in around the world. It has become the basis for all new power system designs and for the interface between the utilities and their customers.

The key prescriptions of IEEE Std 519-2014 are provided in Clause 5 (recommended harmonic limits). This clause addresses the harmonic current distortion and harmonic voltage distortion, respectively and with maintaining the power quality by both the supplier and the user.

The document also provides information on the following: **Interharmonic voltage limits based on flicker, Telephone influence factor, Guidelines for *I-T* product** and **Limits on commutation notches.**

IEEE Std 519-2014 primarily deals with integer harmonics. It discusses inter-harmonic limits based on flicker in informative Annex A. IEEE Std 519 emphasizes the two following points in applying the harmonic indices: The Point of Common Coupling or PCC between the supplier and the user and the ratio of the system short-circuit (SC) MVA and the maximum demand load MVA. On a public power supply system, the PCC is electrically nearest to a particular load, at which other loads are, or could be, connected. The SC ratio determines the total harmonic current distortion that can be injected into the system and allows higher limits for higher ratios. For current distortion limits, the fundamental current is calculated from the maximum demand load current, calculated over any 15-min or 30-min period and then averaged over the preceding12-month period. Note that the actual fundamental current at any particular time is likely to be less than the maximum demand fundamental current; so, the latter helps to reduce the THD percentage for any load less than the maximum demand load. However, this is not the general case, as actual harmonic current spectrums may vary based on the load currents.

PART 3
MEASUREMENTS

3.1. Guidance for Measurements

We have submitted to the Honourable Commission that the licensee may be asked to conduct representative sample measurements at field and furnish the measurement details to enable us to give our recommendation based on the measurements furnished by the licensee. Further, we have submitted the details required to be communicated for conducting measurements by the licensee. Accordingly, directions to the licensee to conduct sample measurements at Industries were issued by the TNERC in its daily order dated 06.10.2020, with the details submitted by us.

Directions to the licensee for conducting sample measurements

1. Measurements shall be made at the Point of Common Coupling (PCC) at the HV SIDE or the LV SIDE as cited in the IEEE 519-2014.

2.The maximum short circuit current at PCC and the maximum demand load current (as specified and arrived in the IEEE STANDARD) shall be furnished along with the detailed report.

3.The report shall contain measurement methodology, duration of measurement, measurement of individual harmonic from 5th to 50th, for arriving the multiplier so as to give relief in respect of the individual harmonics limited within 25% of the values specified against the individual harmonics. All these shall be as per the CEA Regulation read with IEEE STANDARD 519-2014.

4.The duration of measurement shall be strictly adhered to as per IEEE STANDARD, otherwise the current harmonic distortion value arrived by measurement may drift from the true value and lost the precision.

5. Measurement shall be done with a class A meter which will fully (not partially) complaint as per the specifications of both standards viz, IEC6100-4-7(edition 2.1)., IEC 6100-4-30(edition3.0). The existing meters may be connected in parallel and the recordings of both the meters shall be furnished. The difference between the

measurement suggested by TANGEDCO and CEA METHODOLOGY is to be studied in detail.

6.Measurements shall be taken at least in two or more industries likely with more harmonic generation in each voltage level of 11 kV, 22 kV, 33kV, and EHT and especially measurement at electric traction, induction and arc furnaces and welding, IT parks, variable frequency drive loads etc., shall be done

7. The measurement shall be done when industry is working with a load current nearer to maximum demand average current arrived as per the IEEE definition to get a real representative current harmonic distortion value.

8.The measurement shall be done in the presence of the consumer or his authorised representative.

9. The report shall invariably mention the period of measurement, the meter details, like make, sl. No., compatibility with both the IEC STANDARDS, with its full specifications

10. The licensee shall be able to clarify any queries raised on measurement and its report

11. The report shall be in hard copy (in duplicate) and all measurements and loggings by the meter in soft form for analysis purpose.

Such a field measurement will help the Honourable Commission to take a proper decision.

TANGEDCO DISCUSSION ON MEASUREMENTS WITH THE CONSULTANTS ON 06.11.2020

In view of the directions given to the TANGEDCO by the TNERC, the TANGEDCO officials gave a presentation on measurements with the consultants on 06.11.2020 through video conference. The details of presentation and discussion thereon were submitted to the Honourable Commission vide the e-mail dated 08.11.2020. The same is also given vide Annex B .

During the discussion, the TANGEDCO was guided that,

i. Field measurements shall be done only with a meter complying with the latest editions of the IEC STANDARDS as per the IEEE 519-2014.

ii. The company, whose meter is used for measurement, shall produce a certificate of calibration with expiry date and ensure that the meter comply with the latest editions i.e.,6100-4-7 edition no. 2.1, and 6100-4-30 edition no. 3.0 2015-02

iii. Since the measurements are going to be a representative one, and be a basis for proper decision on harmonic control, measurements shall be carried on various categories of industries and various voltage levels.

iv. The duration of measurement shall be as per the IEEE STANDARD 519-2014.

v. The load current at the time of measurement shall be of maximum demand load current as defined in IEEE standard.

vi. The voltage and current harmonic distortions shall be measured only at the PCC as defined in IEEE.

vii. Details of input to the meter at the time of measurement, like voltage, power frequency, short circuit current and maximum demand load current at PCC may be reported.

viii. Whether the meter is able to display the non-compliance at the end of the measurement period and the limit arrived as per IEEE Tables.

ix. Where sample measurement is taken, it may be ascertained whether any of the consumer's equipment, motors etc., are already provided with filters, if so, the details obtained from the consumer may also be included in the report.

x. As directed by the Honourable Commission, the meter already used for arriving harmonics based on the old IEEE standard 519- 1992, may be put in conjunction with the meter confirming to the latest editions of IEC standards. The readings of both the meters may be furnished in the report.

3.2. Details of measurement and report of the licensee

We have received the TANGEDCO Report on 19.03.2021. The Summary of the measurements is tabulated in Table 3.1.

Analysis of the report and measurements by TANGEDCO

The licensee's recommendations / suggestions to use a meter not confirming to the latest IEC std, and adopting a lesser duration for measurement could not be considered for incorporation in the State regulation to be proposed as they may not result in accuracy and precision in the measurements. Further the above are not in accordance with the CEA's amendment regulations 2019 which is entirely based on revised IEEE Std 519- 2014, and the latest IEC 61000-4-30, edition 3 class A and will not sustain before law in case of disputes raised by consumers.

With progress in technology, the measuring techniques get improved leading to measurements with greater precision. The reason for amending the CEA regulations, revising international IEEE standard and revising IEC standards for meter specifications is to keep up with this progress.

As such, it is important to adopt only the amended regulations and the revised international standards cited above. Otherwise, the CEA amendments and revisions of international standards of IEEE and IEC are meaningless.

Further the meter manufacturer's recommendations / suggestions deviating from revised international standards, as cited in the TANGEDCO report, are in no way helpful to frame the state regulations.

The CEA amended regulations direct to measure the harmonics with a meter confirming to the latest IEC STD and disconnect the service if the measured harmonic level exceeds the limits specified in the revised IEEE STD.

The State regulation is necessitated to provide a detailed procedure in the implementation of amended CEA regulations 2019 and to remove certain hardships of consumers without changing the ultimate condition of disconnect the supply for non-compliance, as stipulated in the amended CEA regulations.

The hardship of consumers may be of the following:

1. Immediate disconnection of supply, soon after the harmonic measurements revealing excess harmonic content above the limits specified in IEEE std, will bring labour problems, recession in industrial growth, affecting essential services like Railway Traction, seeking remedy through court etc.

It therefore necessitates giving enough time for the consumer to install the harmonic filters required.

2. Even after enough time given, a few consumers will be reluctant to install the required filters for various reasons. To expedite the installation of filters, a penalty has to be imposed for certain period and not indefinitely.

After expiry of the penalty period, If the consumer is yet to install filters, supply has to be disconnected in accordance with the CEA amended regulations 2019.

These procedures are essential while a new technology is implemented.

3. Most of the industries generate current distortion / current harmonics only and will not cause other power quality parameters. In such cases, continuous measurement of current harmonics is not necessary and the cited international standards also stipulate that 7 days measurement is adequate in respect of harmonic distortion.

Further the CEA amended regulations stress to bring the current harmonics generated by consumers within limits.

The cost of a power quality meter confirming to the IEC standard 61000-4-30 edition 3 class A will be a few lakhs of rupess.

It is learnt that there are nearly 10,000 services in the licensee's jurisdiction.

The total cost of 10,000 metres will be about a few hundred crores of rupees.

If the entire NATION is taken into account, investment towards such meter will be huge and all consumers may not able to afford to purchase such costly meter.

Further Indigenous meters are not available at present.

In these circumstances an alternate solution is recommended to overcome this in PART 4 - Recommendations of the consultancy report.

3.3. TANGEDCO's MEASUREMENT OF HARMONIC DISTORTION IN HT AND EHT SERVICES

In all cases, the voltage harmonic distortion is below the specified limit.

Measurement of current harmonic distortion in HT and EHT services are tabulated in Table 3.1.

In the licensee's (TANGEDCO) reply to SIMA, it is stated that TANGEDCO is proposing to measure only the TDD. This aspect is considered in the draft State regulation.

Quantum of Penalty proposed:

The data is not adequate and hence it is difficult to distribute the proposed maximum penalty of 10% above the excess current distortion over and above the limit , based on measurement details.

General remarks on the above measurements:

1. Incomplete measurement in certain cases
2. Measurement at PCC NOT confirmed
3. Short circuit current calculated at upstream SS transformer, instead of at PCC
4. Load current during measurement in certain cases is low compared to the maximum demand load current
5. Instrument transformers' accuracy class as mandated by IEC STD to additionally connect the power quality meter with associated wiring etc. is not mentioned.
6. POWER QUALITY METER Test certificate and calibration certificate details are nor ascertained by the Licensee.

Table 3.1.

Sl No.	Consumer / Description	TATA Communications	Brakes India	CMRL, KOYAMBEDU	SIMPSON	BHARATI AIRTEL	JR SMELTERS	SAIL	SOUTHERN RAILWAY , AVADI
1	System nominally rated voltage to installation in **kV**	11	33	110	11	11	11	230	110
2	Maximum Short circuit current (A) at PCC, I_{SC}	6290 at upstream ss transformer	4378 at upstream ss transformer	4560 at upstream ss transformer	8476 at upstream ss transformer	8661 at upstream ss transformer	8400 at upstream ss transformer	6860	29933.86
3	Maximum demand load current (A) (As defined in IEEE Std) - I_L	233.44	55.13	42.96 **Arrived from 7 months average**	40.20	132.45	145.57	86.7356	72.90
4	Load current during measurement (A)	218.504 (93.60 % of I_L)	35.29 (64.01 % I_L)	34.33 (79.91 % of I_L)	22.17 (55.14% of I_L)	132.45 (**exactly the same value as I_L above !?**)	99.61 (68.42 % of I_L)	36.36 (41.92 % of I_L)	103.417 **(141.86 %of I_L)**
5	Ratio $\frac{I_{SC}}{I_L}$	27	79	106	210	65	58	79	411
6	IEEE TABLE No. and row corresponding to ratio of I_{SC}/I_L	2, 2nd row	2 3rd row	3 4th row	2 4th row	2 3rd row	2 3rd row	4 3rd row	3 4th row
7	% TDD LIMIT read from the IEEE TABLE	8.0	12.0	7.5	15.0	12.0	12.0	3.75	7.5
8	Meter used complies with IEC 61000-4-30 **edition 3.0** class A (Note: Required statement is **Yes or No)**	Reported as confirming to technical suitability as per IEEE 519-2014, except 3s data results in the report **Not fully compliant. Note: For meter specification,**	Reported as confirming to technical suitability as per IEEE 519-2014 **Note: For meter specification, compliance to the IEC STD to be referred.**	Reported as confirming to technical suitability as per IEEE 519-2014 **Note: For meter specifications, compliance to the IEC STD to be referred.**	Reported as confirming to technical suitability as per IEEE 519-2014, except 3s data results in the report **Not fully compliant. Note: For meter specifications, compliance to the IEC STD to be referred** Refer remarks at page 150 of TANGEDCO report	Reported as confirming to technical suitability as per IEEE 519-2014 **Note: For meter specifications, compliance to the IEC STD to be referred.**	Reported as confirming to technical suitability as per IEEE 519-2014, **Note: For meter specifications, compliance to the IEC STD to be referred**	Reported as confirming to technical suitability as per IEEE 519-2014 **Note: For meter specifications, compliance to the IEC STD to be referred .**	Reported as confirming to technical suitability as per IEEE 519-2014, except 3s data results in the report **Not fully compliant. Note: For meter**

		compliance to the IEC STD to be referred. Refer remarks at page 56 of TANGEDCO report							**specifications, compliance to the IEC STD to be referred .**
9	Verification of the Meter Test certificate for confirming to the specifications of above IEC STD and calibration certificate from the standard lab and the expiry date	**Neither reported nor copy of certificates submitted by the company**	**Neither reported nor copy of certificates submitted by the company**	**Neither reported nor copy of certificates submitted by the company**	**Neither reported nor copy of certificates submitted by the company**	**Neither reported nor copy of certificates submitted by the company**	**Neither reported nor copy of certificates not submitted by the company**	**Neither reported nor copy of certificates submitted by the company**	**Neither reported nor copy of certificates submitted by the company**
10	CTs and PTs accuracy class mandated by IEC 6100-4-30 Class A	**Not confirmed**	**Not confirmed**	**Not confirmed**	**Not confirmed**	**Not confirmed**	**Not confirmed**	**Not confirmed**	**Not confirmed**
11	Measurement at PCC (As defined in IEEE Std)	**Not mentioned**	**Not mentioned**	**Not mentioned**	**Not mentioned**	**Not mentioned**	**Not mentioned**	**Not mentioned**	**Not mentioned**
12	Duration of measurement i)One day for very short time harmonic currents and ii)one-week short time harmonic currents as per IEEE Std	Adopted	Adopted	Adopted	adopted	adopted	adopted	adopted	adopted
13	TDD -Measured **Daily 99TH** percentile **very** short time (3 sec) less	**Not measured**	Within limit / PASS	Within limit / PASS	**Not measured**	Within limit /PASS	**Reported - result incomplete,** and failed	Within limit /PASS	**Not measured**

	than 2 times the value as in sl.no.6								
14	TDD-Measured weekly 99TH percentile short time (10 min) less than 1.5 times the value as in sl.no.6	**Not measured**	Within limit/ PASS	Within limit/ PASS	**Not measured**	Within limit /PASS		FAIL	**Not measured**
15	TDD-Measured weekly 95TH percentile short time (10 min) less than the value as in sl.no.6	Within limit -Pass	Within limit/ PASS	exceeding the limit / FAIL	Within limits /PASS	Within limit /PASS		FAIL	FAIL
16	%THD at PCC Measured Daily 99th percentile very short time (3 s) Weekly 95th percentile short time(10 min)	**Not measured** PASS	Within limit /PASS Within limit / PASS	Within limit /PASS Within limit / PASS	**Not measured** Within limit/ PASS	Within limit/ PASS Within limit/ PASS	PASS	PASS PASS	**Not measured** FAIL
17	**Remarks**	**i.Meter not fully compliant** **ii.Incomplete measurement** **iii. Deficiency –** words in **BOLD** are concern	**i. Deficiency –** words in **BOLD** are concern	i. short circuit ratio 106 is in close proximity between the ratio values of 2nd and 3rd rows. ii. If the correct values of short circuit current at PCC and 12 months average instead of 7 months average is taken, the ratio may be just below 100. In that case the limit is reduced from 7.5% to 6%,	i. Incomplete measurement ii. **Deficiency –** words in **BOLD** are concern	**I. Deficiency –** words in **BOLD** are concern	Refer note on page 207 of the TANGEDCO's report	**I. Deficiency –** words in **BOLD** are concern	**i.Incomplete measurement.** **ii.Deficiency –** words in **BOLD** are concern Refer remarks in TANGEDCO's report in Page 264.

PART 4

RECOMMENDATIONS

1.Central Electricity Authority (Technical Standards for Connectivity of the Distributed Generation Resources) Amendment Regulations 2019,

Regulation 4 (3) stipulates that,

"these regulations shall apply to all generating companies, or persons owning distributed generation resources, charging stations, prosumers or persons who are connected to or seeking connectivity with the electricity system below 33 kV voltage level.

Regulation 11 A stipulates that,

"Standards for charging station, prosumer or a person connected or seeking connectivity to the electricity system sub-regulation (2)(2) stipulates that "*the limits of injection of current harmonics at the point of common coupling by the user, method of harmonic measurement and other such matters, shall be in accordance with the IEEE 519-2014 standard, as amended, from time to time".*

2.The Central Electricity Authority (Technical Standards for Connectivity to the Grid) (Amendment) Regulations, 2019

Part IV paragraph (3) stipulates that,

"Voltage and Current Harmonics. - (i) The limits of voltage harmonics by the distribution licensee in its electricity system, *the limits of injection of current harmonics by bulk consumers, point of harmonic measurement, i.e., point of common coupling, method of harmonic measurement and other related matters, shall be in accordance with the IEEE 519-2014 standards, as amended from time to time".*

According to regulation 2, "Definitions (8), Bulk consumer means a consumer who avails supply at voltage of 33kV or above".

Consultants' note:

Both the above amended CEA regulations stipulate the same provisos in respect of the limits of injection of current harmonics, method of harmonic measurement and

other related matters, which shall be in accordance with the IEEE 519-2014 standards, as amended from time to time.

Hence common recommendations for both the regulations are given below.

DRAFT REGULATION

CONSULTANTS NOTE:

The heading of IEEE 519-2014 is "IEEE RECOMMENDED PRACTICE AND REQUIREMENTS FOR HARMONIC CONTROL IN ELECTRIC POWER SYSTEMS"

It is clear that that this standard deals only the harmonic control, one of the many power quality parameters.

CEA AMENDMENT 2019 REGULATIONS 2019 ADOPT ONLY THIS IEEE STD.

The heading of regulation to be drafted shall be current harmonic control.

CURRENT HARMONIC CONTROL

1.CEA (Amendment) Regulations 2019 stipulate that the limits of injection of current harmonics by bulk consumers, point of harmonic measurement, i.e., point of common coupling, method of harmonic measurement and other related matters, shall be in accordance with the IEEE 519-2014 standards, as amended from time to time".

2.Injection of current harmonics by installations of bulk consumers/ consumers/prosumers/charging stations shall be measured at the Point of Common Coupling (PCC) as defined in the IEEE Standard 519-2014.

3.Meter used for measurement shall comply with the IEC standard 6100-4-30, edition.3.0. class A.

(detailed note is given in part 2 for adoption of edition 3 only)

4.The measured current distortion shall be compared with the current distortion (TDD) limits specified in the respective table of IEEE Std 519-2014.

5. If the measured current distortion (TDD) is exceeded the limit, the consumer should be informed about the exceeded limit and directed to provide the required filters within 6 months, failing which *penalty* will be imposed for the subsequent 12

months or till such time filters are installed and harmonics are brought within specified limit.

EXPLANATION: PENALTY PHILOSOPHY

Harmonic current is a pollutant power quality parameter. The pollutant is to be curbed or limited by way of imposing penalty etc., through a law or regulation.

Penalty is a punishment for violating a law, rule, regulation or a contract. Imposing a penalty is to expedite the installation of filters by the consumer so as to get a quality power by all the consumers including him and also to mitigate the ill-effects caused to the network of the licensee. Therefore, the penalty should not be construed as a compensation towards the damage caused by the ill-effects of current distortion and the penalty shall not be treated as a perennial revenue to the licensee but for early correction. Penalty is different from compensation.

In case, the consumers install filters at the earliest (with in a maximum period of 6 months given), the question of paying penalty dose not arise.

6. Even after the expiry of 12 months penalty period, if the consumer is not forthcoming to install the filters required to bring the current distortion within the permissible limit applicable to him, the licensee is entitled to disconnect the service after reporting the fact to the Commission as per the direction of CEA REGULATION 2019, as electricity power pollution cannot be indefinitely allowed to continue by imposing compensation as in other cases like poor power factor.

7. A penalty of a maximum of 10% in steps of 1% increase will be levied on the current consumption charges as shown below.

TDD excess % over and above the limit	Penalty charge % on the monthly current consumption charges
Up to 3%	1%
Up to 6%	2%
Up to 9%	3%
Up to 12%	4%
Up to 15%	5%
Up to 18%	6%
Up to 21%	7%

Up to 24%	8%
Up to 27%	9%
Up to 30%	10%
Above 31 %	10%

If the excess TDD over and above the limit involves decimals and if the decimal is between 0.1 to 0.4, the whole number may only be reckoned. If it is between 0.5 and 0.9, the next whole number will be reckoned.

Explanation:

For 3.15, 3.43, 3.49, the whole number i.e. 3 is to be reckoned

For 3.51, and 3.92 , the next whole number i,e, 4 is to be reckoned.

The prayer of TANGEDCO is to levy penalty only in respect of current distortion (TDD) excess over the limit and not on any individual harmonic component excess over the limit specified. Hence Penalty towards TDD alone is included in the draft State regulation.

TDD values at

1) 99th percentile very short time (3s) value.

2) 99th percentile short time (10 min) value.

3) 95th percentile short time (10 min) value

shall be measured and compared with the values specified in IEEE Std. The highest value among the above three shall be considered for levying penalty.

SIMA PROPOSAL ON COMPENSATION CHARGES (taken from TANGEDCO report)

Deviation of TDD as against IEEE 519-2014 Std	Energy compensation charges
Exceeding 20% above limit	2%
Exceeding 30% above limit	4%
Exceeding 40% above limit	6%

Exceeding 50% above limit	8 %
Exceeding more 50% above limit	10% maximum

Consultants' comment:

The charges are not evenly distributed.

For example:

1% exceeding the limit, energy compensation charge is 2%

20% exceeding the limit, energy compensation charge is also same i.e., 2%

A flat charge of 2% for a wide slab i.e., from 1% to 20% exceeding the limit is not commensurable and invite criticism. Hence not acceptable.

8.The levying of penalty shall be stopped as soon as the consumer provides filters and measurement by the licensee indicates that the current harmonic distortion is brought within the permissible limit.

9. If the consumer installs the filters within the notice period of 6 months, the question of penalty dose not arise at all.

10. If the consumer fails to provide adequate filters within 6 months, penalty charges will be levied for subsequent 12 months only. Thereafter, a 30 days' disconnection notice shall be served on the consumer for non- compliance, after duly reporting the fact to the Commission.

11. Harmonics is a subtle subject and industries will avail the advantages of the electronic based technology as and when it grows. It requires some time for the consumer to adapt the new technology (involving of measurement, design, manufacture, installation of harmonic filters and conformity test). So, we consider that the above procedure and time frame are essential and may be acceptable to all the parties concerned.

12. In case of subsequent measurement by the licensee if the limit is not maintained on account of new additions and/ or alterations, or defects in the filters/ filtering circuit, the licensee is at liberty to proceed to disconnect the service by issuing 30 days' disconnection of supply notice after reporting the fact to the Commission. The fees prescribed by the Commission to test for conformity by the licensee is to be borne by the consumer in case the current distortion limit is exceeded.

A regulation to the distribution code for the conformity testing fee to be collected is to be added after obtaining an estimation from the licensee.

13. Current distortion by the consumers affect the supply voltage to distort to a major extent, and the impedance characteristics of the network are also causing voltage distortion to some extent but not appreciable; as seen from the sample measurements by TANGEDCO at the PCC, the voltage harmonic distortion is within limits.

14. It is stated in CEA Regulations that disconnection of supply is only stipulated for non- compliance. The intention of the CEA regulation may be that quality power shall be attained as early as possible. But it is practically not possible to disconnect supply to a service straight away after the measurement of current harmonic distortion. There is some room for the Honourable Commission to adapt a procedure in between the measurement and disconnection. However, we also ultimately propose to disconnect the supply to the service after giving enough time to adapt the new technology of providing passive and/or active filters after measurement, design, manufacturing, installing and testing. Resorting to direct disconnection for the existing industrial services will bring many hardships especially on labourers. Essential services like Railway traction cannot be disconnected just immediately after measuring and finding the limits are exceeded. Further the industrial growth will also be hampered. Hence it may not the aim of the CEA also, but a quality power at the earliest. Hence, we are in no way distracting or devaluing the aim of CEA regulation.

15. For new services, a Self-declaration by the consumer that adequate filters will be provided to bring the current distortion within limits may be obtained in the application requesting supply. The supply may be initially given and after 12 months, (this period is required to find out the maximum demand load current as defined in the IEEE STD) , the harmonic current distortion may be measured to ensure whether

it is within the permissible limit. If it is exceeded, supply to the service may be straight away disconnected after issuing a 30 days' disconnection of supply notice after reporting the fact to the Commission. In such a situation, new industries will initially procure equipment with harmonic filters only. This is an added advantage to the industries as the cost of equipment with harmonic filters is less than the cost of equipment plus cost of filters subsequently procured and added. In European and USA, countries all electronic equipment is manufactured with harmonic filters to comply with the IEEE Standard.

16. It is stipulated in CEA Regulations that "the measuring and metering of harmonics shall be a continuous process with power quality meters complying with the IEC 6100-4-30 Class A"

In this connection we submit the following points for Honourable Commission's consideration

A continuous process of measuring and metering with power quality meters is essential for continuous monitoring of power quality disturbance parameters like outages, momentary interruptions, momentary or transient over voltage or surges, voltage dips and voltage swell, frequency deviation, voltage unbalance, voltage fluctuations and flicker.

Some of the disturbance parameters are solely due to the licensee's power system problem. A few of them are solely due to consumer installations. Rest of them are jointly due to both of them.

Further the licensee's prayer is for injection of current harmonics by the consumers.

For power quality steady state parameters like HARMONICS i.e., voltage and current distortions, measurement period is indicated for a week only in IEC 6100-4-30 , 2015, B.5.2. The measurement process in respect of industries having emissions of harmonics alone is a one-time one-week measurement only. Hence CONTINUOUS MEASUREMENT IS NOT NECESSARY JUST FOR MEASURING CURRENT DISTORTION.

As the proposed State Regulation is exclusively meant for current distortion by the consumer's non-linear loads, continuous measurement of current distortion is not

necessary as the cost of the meter according to the latest IEC specifications is very costly and the consumers may not be able to afford the high cost.

Further the current distortion need not be measured continuously as in the case of power factor. Once the required filters are provided there may not arise a situation for variation of current distortion unless there is variation/ alteration of loads. In the case of power factor, it is one among other billing quantities like maximum demand and energy (these quantities are continuously varying with changing loads and duration). To measure all these parameters, one meter is enough. Further the measurement of current distortion once done, subsequent measurement may not be required unless there is alteration/ addition of loads.

Our humble suggestion / submission in this regard is that the testing procedure by the licensee for annual calibration of meters meant for monthly billing with standard meters possessed by the licensee may be adapted for current distortion measurement. Further in the past, the licensee was adapting one-time measurement of harmonics only with their own meters.

It is learnt that there are nearly 10,000 HT and EHT services in Tamilnadu. The cost of one meter confirming to the latest edition of IEC standard, measuring all power quality parameters will be about 9 lakhs of rupees; then the total expenditure on meters will be nearly nine hundred crores of rupees in respect of Tamilnadu alone. If the entire Nation is taken and installation of the power quality meter in each and every HT and EHT services as per the CEA regulation, it will be very high. At present indigenous make power quality meters as per the standard is not available. Meters are to be only imported; hence it will hamper the industrial growth and there will be unnecessary drain of foreign exchange reserves.

With a few harmonic analyser recorder / loggers of portable type, the licensee can make measurements on all services in a phased manner. In the past, the licensee was able to carry out the harmonic measurements only with 42 meters in respect of services fed with 33kV and above as per the old CEA regulations and TNERC tariff order.

Of course, such a special meter installation on a permanent basis is essential at the distribution licensee's network at appropriate/strategic locations to monitor and

control the various disturbances occurring in the licensee's network as per CEA regulation.

17. Both the CEA (Amendment) Regulations 2019 for 33kV and above and below 33kV are identical in respect of injection of harmonic currents. Hence a common regulation for current harmonic control is drafted in accordance with our recommendations for substitution to the supply code and tariff order, submitted in Part 5 to the Honourable Commission's kind perusal and consideration.

18. DELETION OF CLAUSE ON HARMONICS IN TARIFF SCHEDULE OF T.P. NO. 1 OF 2017

Consequent to the substitution to the Regulation 4 (1) (iv) of Tamilnadu Electricity Supply Code as above, the clause 6.1.1.2 (Harmonics) of T.P. No. 1 of 2017 may be deleted for the following reasons.

i. The relevant CEA Regulations on harmonics stipulate only disconnection of supply for non-compliance/ violation. As such no tariff /compensation is involved and the question of bringing this under tariff schedule will not arise.
ii. Two categories of cases arise, one for the existing services, the other for the new services to be connected to the grid and two different procedures are proposed for these two categories; i.e., for existing services, it involves giving time for installation of filters and in case if the consumer fails to install the filters within the time given, levying of penalty is imposed for twelve months and thereafter disconnection is resorted for non- compliance. In respect of new services, the installation shall be provided with adequate filters before availing supply. On measurement, if the non-compliance is detected, the supply to the service is straight away disconnected without resorting to levy of penalty and supply will be resumed only after compliance.

iii. Imposing penalty for non-compliance of current distortion limit does not fall under tariff schedule as it is not a perennial revenue to the licensee and is also different from levying compensation towards low power factor.

iv. The non-compliance of current distortion within the specified limit is also a violation and it is analogous to the various violations covered in the supply code. Such violations and their remedies are covered only in the supply code and did not brought under the tariff schedule.

v. It is therefore proper to place the subject matter of harmonics under the supply code alone.

However, if the clause 6.1.1.2(harmonics) of T.P. No. 1 of 2017 is to be retained, this may be substituted with,

“Tamilnadu Electricity Supply Code, clause 4 (1) (iv) current harmonic control is applicable”.

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PART 5

Draft Amendment Regulations

The existing regulation 4 (1) (iv) of Tamilnadu Electricity Supply Code may be substituted with the following:

"4 (1) (iv) Current Harmonic control

a) Nonlinear loads change the sinusoidal nature of the ac power current (and consequently the ac voltage drops), thereby resulting in the flow of harmonic currents in the ac power system that can cause many ill-effects to the power system and to the consumers' installations. Hence the harmonic currents generated by the loads of bulk consumers/ consumers/ prosumers/ charging stations have to be brought within limits.

b) Both the CEA (Amendment) Regulations 2019 stipulate the same provision in respect of Current harmonics that "the limits of injection of current harmonics at the point of common coupling by the user, method of harmonic measurement and other such matters, shall be in accordance with the IEEE Std. 519-2014, as amended, from time to time".

c) *Measurement of current distortion / harmonic currents shall be made at the point of common coupling (PCC) of the Installation of bulk consumers at 33kV and above and consumers, prosumers, charging stations below 33kV.*

d) Power quality meter complying to the IEC Standard 61000-4-30 edition 3.0 class A- shall be used.

e) The licensee shall use his portable power quality meter for one week for each consumer installation to measure the harmonic currents.

*f) All three total demand distortion (*TDD) values at 99th percentile very short time (3s) value, 99th percentile short time (10 min) value,95th percentile short time (10 min) value shall be measured and compared with the values specified in IEEE Std. The highest value among the above three shall be considered for levying penalty

g) If the measured values are exceeded the limits, a notice shall be issued to the bulk consumer/ consumer/prosumer/ charging station by the licensee to install adequate harmonic filters within 6 months. The notice shall also convey that in case

of non- compliance, penalty at the rate mentioned in h) sub-regulation will be levied for the subsequent 12 months and there after supply to the service shall be disconnected for noncompliance.

h) A penalty of a maximum of 10% in steps of 1% increase will be levied on the monthly current consumption charges as shown below.

TDD excess % over and above the limit	Penalty charge % on the monthly current consumption charges
Up to 3%	1%
Up to 6%	2%
Up to 9%	3%
Up to 12%	4%
Up to 15%	5%
Up to 18%	6%
Up to 21%	7%
Up to 24%	8%
Up to 27%	9%
Up to 30%	10%
Above 31 %	10%

If the excess TDD over and above the limit involves decimals and if the decimal is between 0.1 to 0.4, the whole number may only be reckoned. If it is between 0.5 and 0.9, the next whole number will be reckoned.

i) The levying of penalty shall be stopped as soon as the consumer provides filters and after confirmation by the licensee that the harmonic currents are brought within the limits specified in the IEEE Std.

j) Even after 12 months penalty period, if the consumer is not forth coming to install the required harmonic filters, the licensee shall issue a 30 days disconnection of supply notice to the consumer for non- compliance. Supply to the service shall be disconnected by the licensee after expiry of the 30 days' disconnection notice period under report to the Commission.

k) During subsequent measurement by the licensee, if the current distortion limit as specified in IEEE Std., is not maintained, the licensee is at liberty to disconnect the supply to the consumer service by issuing 30 days' disconnection of supply notice under report to the Commission.

l) In case of new supply connectivity, a self-declaration by the applicant that adequate harmonic filters will be installed, shall be enclosed with the application requesting supply. The supply may be initially given and after 12 months the current distortion shall be measured and if it is found to be exceeded the limit, the supply to the consumer installation shall be straight away disconnected after issuing a 30 days' notice under report to the Commission.

m) The licensee is at liberty to conduct current harmonic distortion measurement at any time at the consumer's installation to check as to whether the consumer is maintaining the current harmonic distortion within the limit.

n) This Regulation shall apply to all bulk consumers at 33kV and above and consumers, prosumers, charging stations of below 33kV voltage level except HT tariff IV (Lift Irrigation)

TARIFF ORDER

Clause 6.1.1.2(harmonics) of T.P. No. 1 of 2017 may be deleted(refer the recommendations) or if necessary may be substituted with,

"Tamilnadu Electricity Supply Code, clause 4 (1) (iv) current harmonic control is applicable".

ANNEX A

Miscellaneous petition No. 22 of 2020 dated 25th August 2020 filed by TANGEDCO Ltd before the Honourable Tamilnadu Electricity Regulatory Commission (TNERC)

Consultants' comments on TANGEDCO'S Miscellaneous Petition No. 22 of 2020 and Stakeholders' comments thereon:

TANGEDCO proposed in its petition that "this petition is preferred by the petitioner consequent to the amendments made to the following Regulations on 06.02.2019 by the CEA.

The amended CEA Regulations 2019 for 33 kV and above, and for below 33kV stipulate as below:

In respect of amended CEA Regulation 2019 for 33 kV and above, both the voltage and current harmonics are covered. The relevant portions in respect of harmonics are reproduced as below.

"(3) Voltage and Current Harmonics. - (i) The limits of voltage harmonics by the distribution licensee in its electricity system, the limits of injection of current harmonics by bulk consumers, point of harmonic measurement, i.e., point of common coupling, method of harmonic measurement and other related matters, shall be in accordance with the IEEE 519-2014 standards, as amended from time to time.

(ii) Measuring and metering of harmonics shall be a continuous process with meters complying with provisions of IEC 61000-4-30 Class A".

In respect of amended CEA Regulation 2019 for below 33 kV, only current harmonics are covered. The relevant portions in respect of harmonics are reproduced as below:

"the limits of injection of current harmonics at the point of common coupling by the user, method of harmonic measurement and other such matters, shall be in accordance with the IEEE 519-2014 standard, as amended, from time to time.

The measuring and metering of harmonics shall be a continuous process with power quality meters complying with provisions of IEC 61000-4-30 class A".

1). The licensee states that "this petition is preferred by the petitioner consequent to the amendments made to the following Regulations on 06.02.2019 by the CEA"
Further the licensee's prayer is for the levy of compensation towards injection of current harmonics by the installations fed with supply below 33kV consequent to the amended CEA Regulation 2019.

The consultants would therefore confine their comments with respect to the two amended CEA Regulations 2019 and the injection of current harmonics by the consumers / users.

2) Both the amended CEA Regulations 2019 (one for 33kv and above, the other for below 33kv) stipulate to follow the IEEE 519-2014 standard, as amended from time to time.

In view of the above,

the suggestion of stakeholder viz., PQ WELFARE CONSORTIUM "to adopt 4 categories of system voltage levels as per IEEE Std 519-2014" is not necessary as the CEA has adapted the revised IEEE Std as it is and hence the CEA Regulation is naturally to be followed.

3) the stakeholder's statement is that "in case of voltage harmonics beyond limits at PCC, the consumer should not be penalised with compensation charges".

In this connection, we have to point out that IEEE standard 519-2014 stipulates that voltage distortion (not only at PCC, but everywhere of the network) is a shared responsibility between the consumer and the supplier and the amended CEA

Regulation 2019 for 33kv and above, states “The limits of voltage harmonics by the distribution licensee in its electricity system”.

Further there is no mention about the voltage distortion in the CEA Regulation 2019 for below 33 kV supply.

The injection of current harmonics produced by the consumer loads produce supply voltage distortion in a major way. The injection of current harmonics by the consumers is the cause and supply voltage distortion are the (ill) effects. If the cause is reduced, the ill-effects will automatically be reduced. Further, the impedance characteristics of the supply system will also be a cause for distorting the supply voltage. That is why the voltage distortion is said to be a shared responsibility between the consumer and the supplier in the IEEE Std.

However there is no provision in the CEA Regulations about the limits of harmonic voltages applicable to consumers.

The stakeholders cautioning that “the consumer should not be penalised for voltage distortion” is therefore unnecessary.

4) The Honourable TNERC order T.P.No. 1 of 2017 dated 11-08-2017 has specified to adapt the permissible limits for harmonics as specified by CEA (i.e., CEA Regulation 2007). Now the CEA Regulation has been amended in 2019 by adapting the revised IEEE standard 519-2014. As per the amended CEA Regulations 2019, measurement methodology, specifications for measuring meter, measurement duration, permissible limits are entirely changed in accordance with the revised IEEE Std. 519-2014. In these circumstances, the stakeholder’s suggestion that “TANGEDCO should not follow existing methodology for measuring for bulk consumers” is a valid point.

Further the TANGEDCO’S methodology for measuring the current distortion will not sustain before law as the amended CEA Regulations 2019 issued on 06.02.2019; before the claim of the petition, and stipulate to follow the methodology as per the revised IEEE Std 519-2014.

For para 9 (2) of TANGEDCO proposal, the above explanation holds good.

5) Since the TANGEDCO's prayer is for current harmonic distortion by the consumers, the matters such as power factor maintenance by the consumers as well by the supplier, and other power quality parameters like voltage fluctuations, flicker, unbalance voltage etc., are not discussed.

6) The stakeholder's comments on adapting a flat rate of compensation on all levels of current distortion beyond the permissible limit, can not be accepted as higjher pollution is to be penalised at a higher rate of penalty .

The stakeholder's suggestion that "the consumer should not be levied with compensation charges for exceeding limits by a marginal value (say 3% above limits)".

The IEEE has already permitted the harmonic distortion to certain limits on various grounds as explained in part I. The aim shall be to bring the current harmonics within the permissible limits and not to enhance it. The Standards and Regulations are striving to mitigate the ill-effects of the current distortion at the earliest and not to provide revenue to the licensee by way of compensation or enhance the limit as requested by the stake holder.

The consumers should come forward to reduce the current harmonics within the permissible limits at the earliest and to ensure a quality power to all.

Hence the stakeholder's suggestion to enhance the limit beyond the limit specified in the IEEE Std is not acceptable.

7) The stakeholder's suggestion that the compensation charges should be levied for energy charges part alone and not on the demand charge (which is the other part of two-part tariff).

We have to state as below:

Current distortion by non-linear loads of consumers, increase the total current drawn from the source more than the required fundamental load current. In view of this, higher alternator (generator) capacity, oversized transformers (otherwise de-rated transformer capacity), oversized transmission and sub-transmission line conductors etc. are required to accommodate the increased current due to harmonics . Further in view of increased current, iron and copper losses in equipment are increased; hence heat dissipation increases. Consequently the fair life of the equipment as specified in the ACT is reduced and new equipment are to be procured. For all this, additional capital is to be incurred by the licensee. This reflects on the fixed charges; the one part of two-part tariff i.e., demand charges.

Therefore, the contention of the stakeholders is not correct. Further we are recommending only penalty and not compensation which has got no bearing on the tariff structure. (kindly refer the penalty philosophy in part 1).

8) IEEE Std 519-2014 gave the normative references vide its section 2.
“the following referenced documents are indispensable for the application of this document”

The indispensable documents are,

IEC Standard 6100-4-7
IEC Standard 6100-4-30.

No other standards are quoted in respect of harmonics.

TANGEDCO quoting IEC /TR 6100-3-6 for point of evaluation and duration of measurement is not at all relevant as far as the document viz., IEEE Std 519-2014; the Standard the CEA has adapted without any deviation in its amendment.

The contention of stakeholder’s comments to adapt for point of evaluation at PCC (point of common coupling) and duration of measurement for one week as per IEEE Std 519-2014 is in accordance with the CEA’s Regulations 2019.

9) Maximum demand load current is defined in the IEEE that “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.

Further, it is stated in the tables 2, 3, and 4 of IEEE Std. 519- 2014,

I_L = maximum demand load current (fundamental frequency component) at PCC under normal load operating conditions.

TANGEDCO has chosen I_L as 75% of the average maximum demand current.

10) The stakeholder’s comment is that the measurement should be conducted for a period of one week with loads as available at PCC.

If measurements are taken with loads as available at PCC as suggested by the stakeholders, and in case, the load is very low during the measurement period, and then the measurement may not reveal the real content of the current distortion at normal load operating condition.

In this connection we submit our comments as below:
Why correct short -circuit ratio (= I_{SC}/I_L) shall be adapted?
The location referred in the above definition is PCC.

Short- circuit ratio is the ratio between short circuit current (I_{SC})and the maximum demand load current (I_L) established at the PCC. Short circuit current (I_{SC}) is arrived from the fault MVA at the PCC.

Maximum demand load current (I_L) is arrived from the sum of the currents corresponding to the maximum demand during each of the twelve previous months divided by 12.

The individual odd harmonics current limits and the TDD limit are to be taken from the corresponding voltage range - current distortion limit table of IEEE 519-2014 Std. and against the corresponding short circuit current ratio row of the table.

In case, wrong values based on fault MVA at different locations other than PCC or different load currents other than Maximum demand load current either for I_{SC} or for I_L or both are used for arriving the short circuit current ratio, then, there is every possibility of shifting the row having higher permissible limits and deviating from the correct value of limits.

However, such an error may not shift the row if the ratio arrived is not in close proximity between any two rows. When the ratio is in close proximity between any two rows, correct values arrived at PCC have to be substituted in the short circuit current ratio.

It is therefore submitted that, unless measurements are taken under normal load operating conditions which will establish maximum demand load current at PCC, correct value of current distortion cannot be arrived and compared with the measured value.

The above is illustrated with an example:

Suppose if I_L is taken as per the suggestion of stake holder which naturally will be much lesser than the one defined in IEEE, then the ratio may be 20, instead of less than 20 for the maximum demand load current. In that case, the TDD limit will get shifted to 8% from 5% which would be the correct TDD value as per table 2 of IEEE. In this case the industry may be either exempted knowingly or unknowingly from the harmonic control or the penalty rate proposed in the Draft Regulation may get reduced.

11) TANGEDCO's proposal 9(3)(B)(iv) is not in accordance with the IEEE Std 519-2014.

TANGEDCO's proposal 9(3)(B) based on IEC 6100-3-6 is as below:
TANGEDCO quoting IEC /TR 6100-3-6 for point of evaluation and duration of measurement is not at all relevant as far as the document viz., IEEE Std 519-2014 is concerned.

As per the TANGEDCOS's proposal, the point of evaluation shall be " at the control room for measurement convenience due to longer period of measurement and safety of the measuring equipment" .

Further, clause 5 of IEEE Std. 519-2014 stipulates that "the recommended limits in this clause apply ONLY at the point of common coupling and should not be applied to either individual pieces of equipment or at locations within a user's facility. In most cases, harmonic voltages and currents at these locations could be found to be significantly greater than the limits recommended at the PCC due to the lack of diversity, cancellation, and other phenomena that tend to reduce the combined effects of multiple harmonic sources to levels below their algebraic summation".

The proposal of TANGEDCO to prefer the point of measurement at the control room instead of at PCC and the reasons quoted for this are not acceptable. In practice, the meter meant for energy billing is placed only at the PCC in the open yard (inside consumer's premises) at the measuring CT and PT. The question of inconvenience and safety shall not arise.

TANGEDCO, the licensee, proposes its own methodology so far adapted in measurement, duration of measurement, point of measurement etc., after the notification of the subject matter vide the national apex body CEA's amended Regulations 2019 which specifies to follow the procedures stipulated in standards of the international technical apex bodies of IEEE and IEC.

Hence the Licensee's proposal to adapt its own methodology as in the past cannot be entertained after the notification of the amended CEA Regulations 2019.

12) The stakeholder's comment / suggestion to introduce an incentive in mitigating the harmonic ill-effects cannot be accepted for the reasons below:

i. Harmonic generation from one consumer's non- linear loads is a pollutant causing much havoc to the licensee's power system and other consumers' installations connected to the network.

ii. A considerable pollution is already permitted by way of specifying limits say 8% or so.

iii. Pollution mitigation by a consumer is not an improvement to the licensee's power system as that of power factor and it only reduces the ill -effects caused by the consumer to the licensee's network and others.

iv. The CEA Regulations 2019 do not specify any incentive - penalty mechanism for the harmonics.

Further in our recommendations, for those consumers coming forward to install the filters within the time given, the question of penalty does not arise.

Current harmonic injection / harmonic current emissions by consumers' non-linear loads and voltage distortion by the licensee's system impedance characteristics have since been covered in the amended CEA regulations 2019.

Forum of Regulators have approved a Model Power Quality Regulations including one of the power quality parameters viz., harmonics on 24.08.2018 prior to the notification of the amended CEA Regulations 2019.

CONCLUSION:

The LICENSEE'S prayer for inclusion of services fed with below 33kV along with 33kV and above is to be considered and the provisions in respect of harmonics vide clause 6.1.1.2 of T.P. No. 1 of 2017 are to be amended in accordance with both the amended CEA Regulations 2019.

A Draft Regulation to the Tamilnadu Electricity Supply Code in accordance with the amended CEA Regulations 2019 is proposed in part 5 for the Honourable Commission's kind consideration.

ANNEX B Minutes of discussion with TANGEDCO on 06.11.2020

1.0. PART I

At the outset, we (the Consultants) explained the following salient features (Points 1.1 to 1.5.) of the applicable standards to the TANGEDCO officials

1.1 CEA REGULATIONS - 2019 adopts IEEE 519-2014 standard, as amended, from time to time.

(**Note**: As and when IEEE 519-2014 is amended, the CEA regulations shall also be amended accordingly.)

1.2. IEEE 519-2014: The beginning part of IEEE 519-2014 is reproduced below:

"

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document including any amendments or corrigenda) applies.

- IEC Standard 61000-4-7, General Guide on Harmonics and Interharmonics Measurement and Instrumentation, for Power Supply Systems and Equipment Connected Thereto.
- IEC Standard 61000-4-30, Power Quality Measurement Methods.

"

It is to be noted that these two standards are undated references and hence the latest edition of the referenced document including any amendments or corrigenda, only applies.

1.3. The latest editions for the above two standards are:

IEC 61000-4-7 Edition 2.1, 2002: General Guide on Harmonics and Interharmonics Measurements and Instrumentation, for Power Supply Systems and Equipment Connected Thereto.

IEC 6100-4-30 Edition 3.0 2015-02: Electromagnetic compatibility (EMC) – Part 4-30: Testing and measurement techniques – Power quality measurement methods.

1.4. Measuring instruments shall comply with the above two standards with their respective editions and only these meters shall be used; otherwise the measurements are likely to be challenged by the consumer in a Court of Law. Hence it is the responsibility of the licensee to conduct the measurements with meters complying with the above standards with latest editions.

1.5. IEEE stipulates measurement period as below:

1 day for very short time harmonic measurement
7 days (one week) for short time harmonic measurement.

2.0 PART II

The TANGEDCO officials presented a power point presentation (PPT). The discussions held on the PPT are as below.

2.1. Clause (i) of PPT

Direction to the licensee vide the daily order by the Honourable Commission dt.06.10.2020.

"Measurements shall be made at the Point of Common Coupling (PCC) at the HV SIDE or the LV SIDE as the case may be as cited in the IEEE 519-2014".

Representation of the licensee:PCC as per IEEE 519 - 2014: Point on a public power supply system, electrically nearest to a particular load, at which other loads are, or could be, connected. The PCC is a point located upstream of the considered installation.

As PCC is always upstream of the installation, it is generally HV side, unless we have Metering System of HT industry in LV side.

Reply by the consultants:

IEEE 519-2014 states that:

" This recommended practice should be applied at interface points between system owners or operators and users in the power system. The limits in this recommended practice are intended for application at a point of common coupling (PCC) between the system owner or operator and a user, where the PCC is usually taken as the point in the power system closest to the user where the system owner or operator could offer service to another user. Frequently for service to industrial users (i.e., manufacturing plants) via a dedicated service transformer, the PCC is at the HV side of the transformer. For commercial users (office parks, shopping malls, etc.) supplied through a common service transformer, the PCC is commonly at the LV side of the service transformer".

2.2 Clause (ii) of PPT

Direction to the licensee :

"The short circuit current at PCC and the average maximum load current (as specified and arrived in the IEEE STANDARD) shall be furnished along with the detailed report".

Representation of the Licensee :

IEEE 519-2014 doesn't specify any method for calculating the short circuit at PCC.

However for the maximum demand load current it is specified as below:

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.

Reply by consultants

Without knowing the short circuit current, current distortion limits from the IEEE 519 tables (whether the old one IEEE 519-1992 or the revised one IEEE 519-2014) cannot be obtained.

Without knowing the short circuit current, how then the TANGEDCO arrived the limits in the past?

How then the fault MVA of a sub-station is arrived to decide the breaking capacity of breakers?

Hence the IEEE standard need not specify the method for calculating the short circuit current.

2.3 Clause (iii) in the PPT

Direction to the licensee :

"The report shall contain measurement methodology, duration of measurement, measurement of individual harmonic from 5th to 50th, for arriving the multiplier so as to give relief in respect of the individual harmonics limited within 25% of the values specified against the individual harmonics. All these shall be as per the CEA Regulation read with IEEE STANDARD 519-2014".

Representation from licensee:

Measurement of Individual Harmonic Current is not suggested in the methodology proposed by TANGEDCO, as the instruments (Though Class – A) are measuring the individual harmonic currents as a percentage of Fundamental current, arrived during measurement, and IEEE-519 Tables are giving limits for individual current harmonics as a percentage of max demand current.

The Instrument software only gets the measured THD and converts it to TDD with the input of Max Demand Current.

Reply by the consultants

The direction is to measure individual harmonics.

If the individual harmonics are not measured and known, multipliers as per the Table 5 of IEEE 519 -2014 cannot be read and used to give relief to the user for increasing the limit in case of filters provided partially.

The IEEE 519 – 2014 (which is duly adopted by CEA) has given the methodology to be followed to measure harmonics very elaborately.
Other than this methodology (as specified by CEA), the licensee is not entitled to frame its own methodology as it will not sustain before law.

In addition, whether the instrument, referred to by the Licensee in the PPT, complies with the latest editions of IEC STANDARDS?
The reply of TANGEDCO was: NO

2.4 Clause (iv) in PPT.

Direction to the licensee :

"The duration of measurement shall be strictly adhered to as per IEEE STANDARD, otherwise the current harmonic distortion value arrived by measurement may drift from the true value and lost the precision".

Representation by the licensee :

IEEE 519- 2014 recommends three durations

i) Daily 99th percentile very short time (3 s) - [Limit 2 × Given in Table]
ii) Weekly 99th percentile short time (10 m) - [Limit 1.5 × Given in Table]
iii) Weekly 95th percentile short time (10 m) - [Limit 1 × Given in Table]

Reply by consultants

The IEEE 519-2014 stipulates that the measurements shall be made for one day for very short time and 7 days for short time measurements.

Other durations lesser than the one specified as above, may not give a precise and accurate results

2.5 Clause (v) of the PPT

Direction to the licensee:

"The measurement shall be done with a class A meter which will be fully (not partially) compliant as per the specifications of both standards viz, IEC-6100-4-7 (edition 2.0)., IEC 6100-4-30 (Ed 3.0). The existing meters may be connected

in parallel and the recordings of both the meters shall be furnished. The difference between the measurement suggested by TANGEDCO and the CEA methodology is to be studied in detail".

Representation by the licensee:

In respect of Harmonic Measurement Synchronization of Aggregation Intervals in respect of Class-A meters as per Ed-2 & Ed-3 are exactly same. There is no difference except the introduction of UTC Clock in place of RTC. Please see the Algorithm given in the Standard.

Reply by the consultants

The question is whether the meter available and used so far by the Licensee is having capability to measure continuously for 1 week as per the revised IEEE 519-2014 standard?
The reply of TANGEDCO was NO.

In the figure shown in the PPT, the latest editions of IEC are shown in the top right corner. This is a basic measurement in the old as well as in the new version meters. But the point is, there are many other features in the NEW VERSION meters as stipulated in the IEEE 519 – 2014 std. For example, tables for different current distortion limits for different bus voltage levels, multipliers, statistical evaluation for finding 95^{th} and 99^{th} percentile values, are integrated in the latest version of meters. These aspects are to be considered.

2.6. Clause (vi) in the PPT

Direction to the licensee:

"Measurements shall be taken at least two or more industries likely with more harmonic generation in each voltage level of (HT) 11 kv, 22 kv, 33kv, and EHT and especially measurement at electric traction, induction and arc furnaces and welding, IT parks, variable drive frequencies load etc., shall be done".

Representation by the licensee:

TANGEDCO had already taken measurements in 10 different industries of various voltage levels, during 6/2019 for comparing the harmonic measured values between 10m and 3s, over a period of 24 hours.

The list of industries and the comparison of the 3s *vs* 10m reading is given in the next few slides.

Reply by consultants:

The Honourable Commission wants the measurements as per the Central Electricity Authority (Technical Standards for Connectivity to the Grid) (Amendment) Regulations, 2019 published in THE GAZETTE OF INDIA : EXTRAORDINARY [PART III—SEC. 4] dated 6th February 2019, which states that

" The limits of voltage harmonics by the distribution licensee in its electricity system, the limits of injection of current harmonics by bulk consumers, point of harmonic measurement, i.e., point of common coupling, method of harmonic measurement and other related matters, shall be in accordance with the IEEE 519-2014 standards, as amended from time to time; "

IEEE 519-2014 refers to the latest IEC standards aforementioned.

The old measurements, based on the previous IEEE standard, ie, IEEE 519-1992 and old CEA regulations with a meter complying with old editions of IEC standards presented in Licensee's PPT, in no way helps the Honourable Commission to take a proper decision.

Further, it is pointed out that the measurements were taken during 6 / 2019 based on the old standards after the issue of amended CEA Regulations in the gazette dated 6th February 2019.

2.7. Clause (vii) in PPT

Direction to the licensee:

"The measurement shall be done when industry is working with a load current nearer to maximum demand average current arrived as per the IEEE definition so as to get a real representative current harmonic distortion value be done".

Representation by the licensee:

The load in the industry can have seasonal variation. A load in the summer (May) cannot be expected in winter (December). Also, the value of TDD will be low, at lower loads. Hence, TANGEDCO has proposed in the methodology, to take measurements when the industry is in operation with at least 75% of the Maximum demand average current.

Reply by consultants:

The licensee's methodology as mentioned above cannot have an overriding effect on the Regulations of the Nation's apex body CEA and Standards of the international bodies IEEE and IEC.
The methodology as per the revised IEEE 519-2014 ONLY Is acceptable.

The intention is to fix the harmonic distortion levels when the industry is working with its maximum demand load current

2.8 Clause (viii) in the PPT

Direction to the licensee:

"The measurement shall be done in the presence of the consumer or his authorized representative".

Representation by the licensee:

Regular Harmonic Measurements are always taken in the presence of consumer. We get the signature in the report from the consumer also.

Reply by consultants:

OK.

2.9 Clause (x) in the PPT

Direction to the licensee:

"The report shall be in hard copy (in duplicate) and all measurements and loggings by the meter in soft form for analysis purpose"

Representation by the licensee:

The Power Quality Analyser's output file is having the extension *.fpqo. It cannot be opened in any platform other than the dedicated software given by the OEM. It cannot be edited.

From the software, the results can be analyzed and it can be exported in to excel for taking print out of the Power Quality Parameters.

TANGEDCO will provide the hard copies of the sample harmonic results, if advised.

Reply by consultants:

The TANGEDCO officials were requested to use a meter complying with the latest editions of IEC STANDARDS.

2.10 Clause (xi) in PPT

Direction to the licensee:

The licensee shall be in a position to clarify any queries raised on measurement and its report.

Representation by the licensee:
TANGEDCO can clarify the results of the measurement taken

Reply by consultants
OK.

2.11 CONCLUSION:

The direction from the Honourable Commission vide its daily order is to take sample measurements as per the amended CEA regulations, revised IEEE 519-2014 STANDARD, with a meter complying with LATEST EDITIONS OF IEC.

But the measurements taken before 18 months, based on old CEA regulation, old IEEE standard, old editions of IEC were only presented. This will in no way help to take a decision in accordance with the revised regulations and standards.

However, we hope that the presentation and the discussion thereon give a lot of understanding on the future method of measurement by the TANGEDCO oficials as per the revised standards.

3.0 PART III

Our Guidance for new measurement is,

3.1 Field measurements shall be done only with a meter complying with the latest editions of the IEC STANDARDS as per the IEEE 519-2014.

3.2 The company, whose meter is used for measurements, shall produce a Certificate of Calibration with expiry date and ensure that the meter complies with the latest editions i.e.,IEC 6100-4-7 edition no. 2.1, and IEC 6100-4-30 edition no. 3.0 2015-02.

3.3 Since the measurements are going to be representative, and be a basis for proper decision on harmonic distortion, measurements shall be carried on various categories of industries and various voltage levels.

3.4 The duration of measurement shall be as per the IEEE STD 519- 2014.

3.5 The load current shall be at maximum demand load current as defined in IEEE 519-2014 .

3.6 The voltage and current harmonic distortions shall be measured only at the PCC as defined in IEEE 519-2014.

3.7 Details of Input to the meter at the time of measuring, like voltage, power frequency, short circuit current and maximum demand load current at PCC etc., shall also be entered in the report.

3.8 Whether the meter is able to display the non-compliance at the end of the measurement period and the limit arrived as per IEEE Table?

3.9 Whether any harmonic filters are already provided in the consumer's installation where sample measurements are taken? If so, the details may be obtained from the consumer and incorporated in the report.

3.10 As directed by the Honourable Commission, the meter already used for measuring harmonics based on the old IEEE 519- 1992, may be connected in conjunction with NEW meter conforming to the latest editions of IEC standards. The readings of both the meters may be furnished in the report.

3.11 Measurements are to be made at 230kV, 110kV, 33kV, 22kV and 11kV levels and on the different categories of services.

We therefore request the TANGEDCO to conduct measurements as per the above guidance and submit the report to the TNERC.

(Sd) Dr.K.R.Valluvan Dr.A.S.Kandasamy

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ANNEX C

Consultants' comments to some of the replies of TANGEDCO to SIMA, PQ WELFARE CONSORTIUM.

1.SIMA

i. TANGEDCO reply to SIMA comments vide page 4 of 17, that when the voltage harmonic limits are fixed by IEEE 519 compliance, TANGEDCO has to adopt it as per the CEA regulation. When the voltage harmonics is observed to be beyond the limits at PCC, expecting not to levy the compensation charges is not correct".

Consultants' comments:

First IEEE has not stipulated compensation charges for exceeding either current distortion and voltage distortion limits specified in the IEEE STD.

Secondly CEA has also not specified any compensation charges.

For example, if a consumer is having linear loads which do not generate current distortion (current harmonics), but the measured voltage distortion at this consumer PCC exceeds the limit , can we penalize the consumer?. The consumer cannot be penalized, as the excess voltage distortion at his installation PCC is due to injection of current harmonics by other consumers and due to the impedance characteristics of licensee power system. IEEE and CEA categorically stated that limiting voltage distortion is rest with licensee.

Hence the TANGEDCO assumption as above is not in accordance with IEEE STD and CEA and need not be given due consideration.

ii. In reply to SIMA, (page3 of 17) TANGEDCO quoted partially from IEEE that, "Users produce harmonic currents that flow through the system owner's or operator's system, which lead to voltage harmonics in the voltages supplied to other users".

Consultants' comments

The partial quoting the clause gives an impression that the licensee role in limiting voltage harmonics is nil.

Full text of clause 1.2 is given below for the honourable commission's kind perusal.it is stated that users (consumers) limit their harmonic current emissions and system owner (licensee*) takes action to decrease voltage distortion levels by modifying the supply system impedance characteristics as necessary".*

It is therefore evident that limiting current harmonics rest with the consumers and limiting voltage harmonics by the licensee.

iii .TANGEDCO reply to SIMA COMMENTS (page 9 of 17) that," shouldering the responsibility of voltage harmonics by TANGEDCO is not reasonable"

consultants' comment:

in this connection, the following is invited to the Honourable Commission for kind perusal

IEEE Std 519- 2014 (revision of IEEE Std 519-1992

In the introduction and clause 1.2 , it is clearly stated that,

"The limits in this recommended practice represent a shared responsibility for harmonic control between system owners or operators and users. Users produce harmonic currents that flow through the system owner's or operator's system, which lead to voltage harmonics in the voltages supplied to other users. The amount of harmonic voltage distortion supplied to other users is a function of the aggregate effects of the harmonic current producing loads of all users and the impedance characteristics of the supply system.

Harmonic voltage distortion limits are provided to reduce the potential negative effects on user and system equipment. Maintaining harmonic voltages below these levels necessitates that

– All users limit their harmonic current emissions to reasonable values determined in an equitable manner based on the inherent ownership stake each user has in the supply system and

– Each system owner or operator takes action to decrease voltage distortion levels by modifying the supply system impedance characteristics as necessary".

Further CEA AMENDMENT REGULATION 2019 part IV stipulates that,

"(3) Voltage and Current Harmonics. - (i) The limits of voltage harmonics by the distribution licensee in its electricity system, the limits of injection of current harmonics by bulk consumers" ….

Thus, the licensee cannot disown the responsibility of maintaining the voltage distortion level. The TANGEDCO'S above reply is not in accordance with the above technical fact laid down in the international standard of IEEE consequently not as per the CEA amendment regulations 2019

2.PQ WELFARE CONSORTIUM.

i. The licensee's reply to PQ WELFARE CONSORTIUM comments vide page 13,

"TANGEDCO suggests that , a class A Power Quality Analyzer will be sufficient, if it is validated for harmonic measurement as per edition 2.

The same is also suggested by GMC Instrument /Germany.."

ii.The licensee's comments on the trial measurement by PQ WELFARE CONSORTIUM, "the insistence of ED-3 complied meter in every paragraph of the report of PQ WELFARE CONSORTIUM, that too with the statements not relevant to the applicable standard, indicate that they may be interested to promote a specific brand of ed-3 among the consumers" appearing on page 387 of the licensee's report.

Consultants' comment

In this connection, the following is invited to the Honourable Commission's kind perusal.

Extract from IEC:

"IEC 61000-4-30:2015 © IEC 2015 – 7 –

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMAGNETIC COMPATIBILITY (EMC) – Part 4-30: Testing and measurement techniques – Power quality measurement methods

FOREWORD

6) All users should ensure that they have the latest edition of this publication.

This standard forms part 4-30 of IEC 61000. It has the status of a basic EMC publication in accordance with IEC Guide 107.

This third edition cancels and replaces the second edition published in 2008. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) the measurement method for current, previously informative, is now normative with some changes;

b) the measurement method for RVC (rapid voltage change) has been added;

c) the measurement method for conducted emissions in the 2 kHz to 150 kHz range has been added in informative Annex C;

d) under deviation and over deviation parameters are moved to informative Annex D;

e) Class A and Class S measurement methods are defined and clarified, while Class B is moved to informative Annex E and considered for future removal;

f) measurement methods continue in this standard, but responsibility for influence quantities, performance, and test procedures are transferred to IEC 62586-2".

CEA AMENDMENT REGULATION 2019 STIPULATES

"(3) Voltage and Current Harmonics. - (i) The limits of voltage harmonics by the distribution licensee in its electricity system, the limits of injection of current harmonics by bulk consumers, point of harmonic measurement, i.e., point of common coupling, method of harmonic measurement and other related matters, shall be in accordance with the IEEE 519-2014 standards, as amended from time to time.

(ii) Measuring and metering of harmonics shall be a continuous process with meters complying with provisions of IEC 61000-4-30 Class A".

Consultants' submission

We have to point out that , can we adopt the cancelled and replaced edition or can we choose any edition of our choice leaving the latest?

What is the rule to be followed in respect any standards viz.. Indian standards, IEEE, IEC, and any regulations of CEA and TNERC?

if any standard / regulation is revised, from the date of revision, only the revised or the latest one is legally acceptable and universally followed

61000-4-30 edition 3 was issued 6 years back i.e., during 2015

Will meter manufacturers now manufacture meter for the specifications of cancelled and replaced edition and able to get it certified from the standard lab based on the replaced edition?

That is why CEA amendment regulations 2019 stipulates that, "…shall be in accordance with the IEEE 519-2014 standards, as amended from time to time."

Further, section 2 of IEEE 519-2014 itself stipulates ,

"2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEC Standard 61000-4-7, General Guide on Harmonics and Inter-harmonics Measurement and Instrumentation, for Power Supply Systems and Equipment Connected Thereto.

IEC Standard 61000-4-30, Power Quality Measurement Methods.

As these IEC standards are undated references, the latest edition only applies".

Consultants' submission

Hence in our consultative report, we use only the latest edition 3 of IEC 61000-4-30 class A for power quality meter as specifically stipulated in the IEEE 519-2014.Such a detailed authoritative explanation is required in view of the licensee's comment as below on the trail measurement by PQ WELFARE CONSORTIUM,

"the insistence of ED-3 complied meter in every paragraph of the report of PQ WELFARE CONSORTIUM, that too with the statements not relevant to the applicable standard, indicate that they may be interested to promote a specific brand of ed-3 among the consumers" appearing on page387 of the licensee's report.

The contention of PQ WELFARE CONSORTIUM to adopt only edition 3 is in accordance with IEEE, IEC and CEA.

Such a reply on PQ WELFARE CONSORTIUM comment by the licensee is unnecessary and does not augur well for such an Organisation which is supplying electricity to its millions of consumers.

Further the licensee statement vide page 8 of its report," though, IEC 61000-4-30 has been revised and Ed-3 is issued, considering the technical explanations given above , it would not be wrong to use the class A analyzers certified for Ed-2 of IEC 61000-4-30 , for taking measurements in the field".

Such a recommendation of TANGEDCO to use the replaced edition 2 is against the provisions of CEA, IEEE AND IEC.

To support the licensee statement to use the replaced edition 2, the licensee has called for reports from meter manufactures as seen in the TANGEDCO report and is giving more emphasis by discussing and referring elaborately on the replaced EDITION -2. All these will not sustain before law in case of dispute.

The proposed state regulation shall be in accordance with the CEA amendment regulation2019, revised IEEE 519-2014 and the latest edition (EDITION3) of IEC 61000-4-30 CLASS A.

NOTE:

The rest of the stake holders' comments and the TANGEDCO replies are clarified in detail in our consultancy report itself.

ANNEX D – CONSULTANTS' PROFILE

Dr A.S.KANDASAMY

- Emeritus Professor
- Member, State Advisory Committee TNERC, Chennai
- Former Chief Engineer Transmission and Commercial, TNEB
- 36 years' field experience in the erstwhile TAMILNADU ELECTRICITY BOARD.
- 20 years teaching experience in Engineering Institutions.
- Represented INDIA in the energy summit held at Washington (DC) USA-2000
- Served as an expert committee member for preparation of various manuals including manual for energy accounting and audit in power system, Ministry of Power Govt. of India, New Delhi-2000-2001
- Served as a Member in the steering committee of accelerated power development programme, Ministry of Power Govt. of India, New Delhi
- Author of the book, ELECTRICITY -Theory and Practice, published by AMITY University, New Delhi-2021.

Dr K.R. VALLUVAN

- Obtained PhD from Anna university for the thesis titled "*Implementation Of ADALINE On DSP And FPGA For Measurement Of Harmonics*"
- Worked in industries like ABB for 11 years and teaching for past 27 years.
- Has written six books on fundamental concepts on Electrical and Electronics Engineering .

Paper Published by the Consultants on harmonics:

K.R.Valluvan, A.S.Kandasamy, A.M.Natarajan "A Survey of Voltage and Current Harmonics in Various Industries Connected to a State Electrical Grid" International. Journal of Applied Engg. Research Vol. 3 No.6, June 2008, pp. 801-816.

Consultancy Works on harmonics done by the Consultants:

1. Harmonic measurements in various HT / EHT industries at the request of TNEB conducted in 2005.
2. Presentation on harmonics and their ill-effects to the Honourable TNERC MEMBERS in 2005.

3. Training course on harmonics and their ill-effects to Engineers of TNEB-2005.
4. Harmonic study and its effects on 500 MVA alternator at Neyveli Lignite Corporation in 2006.
5. Presentation on harmonics and their ill-effects to the Engineers of Neyveli Lignite Corporation in 2006.
6. Presentation on harmonics and their ill-effects to various Engineering Institutions in Tamilnadu in 2006 - 2009.
7. Measurement of harmonics while carrying out Energy Audit in various industries in 2004-2009.

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Explanatory statement

The Electricity Act 2003 has enshrined the basic need of consumers to be provided with continuous, reliable and quality supply by the Distribution Utilities. Clause (i) of sub-section (1) of section 86 of the Electricity Act, 2003 confers powers to the SERC " *Specify or enforce standards with respect to quality, continuity and reliability of service by licensees".*

2. The tariff policy of Ministry of Power notified on 28th January 2016 provides as

"8.0 DISTRIBUTION

Supply of reliable and quality power of specified standards in an efficient manner and at reasonable rates is one of the main objectives of the National Electricity Policy. The State Commission should determine and notify the standards of performance of licensees with respect to quality, continuity and reliability of service for all consumers. It is desirable that the Forum of Regulators determines the basic framework on service standards. A suitable framework could be provided for the licensees to reach the desired levels of services as quickly as possible. Penalties may be imposed on licensees in accordance with section 57 of the Act for failure to meet the Standards".

3. Therefore, in order to ensure quality of power, the Commission is required to specify and enforce the standards of harmonics to be maintained by stakeholders in pursuit of quality, continuity and reliability of service as mandated by the Act and Tariff Policy.

4. Also the Central Electricity Authority has amended the (Technical Standards for Connectivity of the Distributed Generation Resources) Regulations, 2013 to include the consumers of below 33KV also to maintain the harmonics within limits prescribed and renamed the said Regulation as Technical Standards for connectivity below 33 kilovolts (Amendment) Regulations, 2019.

In compliance with the above set of Act, policy and Regulation , there is a need to incorporate changes in Regulation in the Supply code stipulating harmonic limits, Methodology of measurements, meter standards, penalties etc., to ensure quality of supply to consumers.

5. The amendment seeks revision of regulations accordingly.

(By order of the Tamil Nadu Electricity Regulatory Commission)

(S.Chinnarajalu)
Secretary
Tamil Nadu Electricity Regulatory Commission

Annexure

Tamil Nadu Electricity Supply Code

Sl. No.	Existing regulation	Regulation as amended
1.	**4. Charges recoverable by the Licensee-** 1(i) (ii) (iii) (iv) Additional charges for harmonics dumping Where any equipment installed by a consumer generates harmonics, the consumer shall provide adequate harmonic suppression units to avoid dumping of harmonics into Licensee's distribution system and the Licensee is at liberty to provide suitable metering equipment to measure the harmonic level pursuant to such harmonic. Where the consumer fails to provide such units, he shall be liable to pay compensation at such rates as the Commission may declare from time to time. (v) (vi)	**4. Charges recoverable by the Licensee-** 1(i) (ii) (iii) *(iv)" Current Harmonic control a) Nonlinear loads change the sinusoidal nature of the ac power current (and consequently the ac voltage drops), thereby resulting in the flow of harmonic currents in the ac power system that can cause many ill-effects to the power system and to the consumer's installations. Hence the harmonic currents generated by the loads of bulk consumers/ consumers/ prosumers/ charging stations have to be brought within limits.*

		b) Both the CEA (Amendment) Regulations 2019 stipulate the same provision in respect of Current harmonics that "the limits of injection of current harmonics at the point of common coupling by the user, method of harmonic measurement and other such matters, shall be in accordance with the IEEE Std. 519-2014, as amended, from time to time". *c) Measurement of current distortion / harmonic currents shall be made at the point of common coupling (PCC) of the Installation of bulk consumers at 33kV and above and consumers, prosumers, charging stations below 33kV.* *d) Power quality meter complying with the IEC Standard*

		61000-4-30 edition 3.0 class A- shall be used. *e) The licensee shall use his portable power quality meter for one week for each consumer installation to measure the harmonic currents.* *f) All three total demand distortion (TDD) values at 99th percentile very short time (3s) value, 99th percentile short time (10 min) value, 95th percentile short time (10 min) value shall be measured and compared with the values specified in IEEE Std. The highest value among the above three shall be considered for levying penalty* *g) If the measured values exceed the limits, a notice shall be issued to*

		the bulk consumer/ consumer/prosumer/ charging station by the licensee to install adequate harmonic filters within 6 months. The notice shall also convey that in case of non-compliance, penalty at the rate mentioned in the following sub-regulation h) will be levied for the subsequent 12 months and there after supply to the service shall be disconnected in case of noncompliance even after the said 12 months. *h) A penalty of a maximum of 10% in steps of 1% increase will be levied on the monthly current consumption charges as shown below:* ***TDD excess % over*** | ***Penalty charge % or***

		and above the limit	***the monthly current consumption charges***
		Up to 3%	*1%*
		Above 3% up to 6%	*2%*
		Above 6% up to 9%	*3%*
		Above 9% up to 12%	*4%*
		Above 12% up to 15%	*5%*
		Above 15% up to 18%	*6%*
		Above 18% up to 21%	*7%*
		Above 21% up to 24%	*8%*
		Above 24% up to 27%	*9%*
		Above 27% up to 30%	*10%*
		Above 31 %	*10%*

		If the excess TDD over and above the limit involves decimals and if the decimal is from 0.1 to 0.4, the whole number may only be reckoned. If it is from 0.5 and 0.9, the next whole number will be reckoned. *i) The levying of penalty shall be stopped upon installation of filters by the consumer and testing by the licensee. If it is confirmed by testing that the harmonic currents are brought within the limits specified in the IEEE Standards, the penalty will be stopped from the date of intimation of the consumer to the effect that the installation of filters are fully completed and ready for testing by the Licensee. If the measured values exceed the limits, the penalty would continue. The*

		Licensee shall issue a notice to the consumer forthwith to this effect. It is open to the consumer to rectify/re install the filters again and intimate the Licensee forthwith for re-testing before expiry of said 12 months. *j) Even after 12 months penalty period, if the consumer is not forth coming to install the required harmonic filters or unable to bring the values within prescribed limits, the Licensee shall issue a 30 days disconnection of supply notice to the consumer for non- compliance. If the consumer installs the filters and makes them ready for testing by the Licensee during the notice period, the Licensee shall test before disconnection. If the measured values are within limits, the supply shall not be disconnected. However*

		the penalty shall be levied till the date of intimation by the consumer to the effect that filters are installed and ready for testing. If the measured values exceed limits, supply to the service shall be disconnected by the Licensee after expiry of the original 30 days' disconnection notice period under report to the Commission. *k) During subsequent measurement by the licensee, if the current distortion limit as specified in IEEE standards is not maintained, the Licensee is at liberty to disconnect the supply to the consumer service by issuing 30 days' disconnection of supply notice under report to the Commission.* *l) In case of new supply*

		connectivity, a self-declaration by the applicant that adequate harmonic filters will be installed, shall be enclosed with the application requesting supply. The supply may be initially given and after 12 months the current distortion shall be measured and if it is found to be exceeding the limit, the supply to the consumer installation shall be straight away disconnected after issuing a 30 days' notice under report to the Commission. The penalty applicable as stipulated in sub regulation h) shall be levied from the date of completion of said 12 months. *m) The licensee is at liberty to conduct current harmonic distortion measurement at any time at the consumer's installation to check as*

		to whether the consumer is maintaining the current harmonic distortion within the limit. *n) This Regulation shall apply to all bulk consumers at 33kV and above and consumers, prosumers, charging stations of below 33kV voltage level except HT tariff IV (Lift Irrigation)"* .

(By Order of the Tamil Nadu Electricity Regulatory Commission)

(S.Chinnarajalu)
Secretary
Tamil Nadu Electricity Regulatory Commission