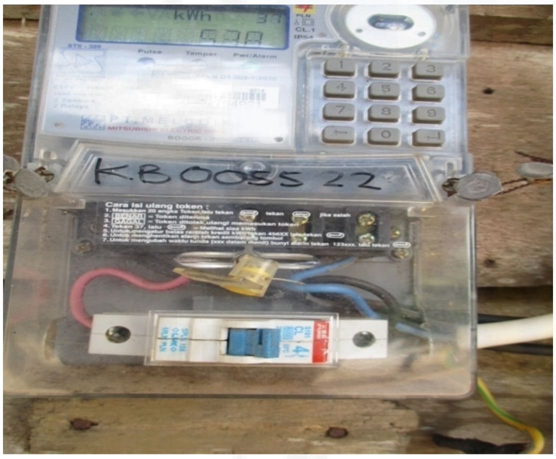
LAMPIRAN

A. Data KWh-Meter Pelanggan Rumah Tangga Di Desa Perlang

- **Rumah dengan daya 900 Watt**




KB005205


86 0255 4522 8
AWAS MERUSAK SEGEL DAN METER DIDENDA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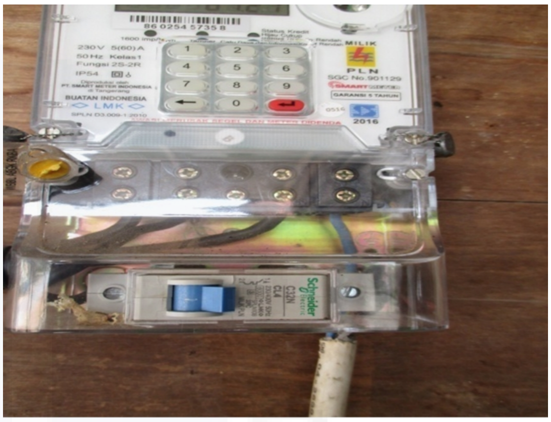
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AWAS MERUSAK SEGEL DAN METER DIDENDA


MILIK
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AWAS : MERUSAK SEGEL DAN METER DIDENDA


AWAS!!! MERUSAK SEGEL DAN METER DIDENDA


230 V 5(60) A
50 Hz Kelas 1
Fungsi 2S-2R
IP54
BUATAN INDONESIA
LMK
MILIK
PLN
SGC No.901129
2016
AWAS MERUSAK SEGEL DAN METER DIDENDA
Schneider


LMK
PLN
AWAS MERUSAK SEGEL DIDENDA


FASE TUNGGAL 2 KAWAT
230V 5(60)A
50 Hz Kelas 1
Fungsi 2S-2R
IP54
BUATAN INDONESIA
LMK
PLN
SGC No.901129
2016
Schneider


MILIK
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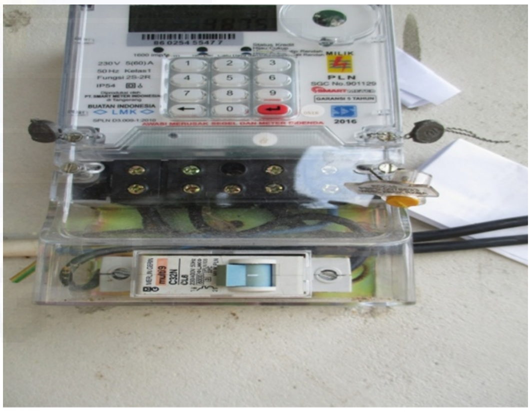
BUATAN INDONESIA
AWAS ! MERUSAK SEGEL DAN METER DIDENDA
Schneider


Shenzhen Star Instrument CO.,LTD. DDSY23S
PLN

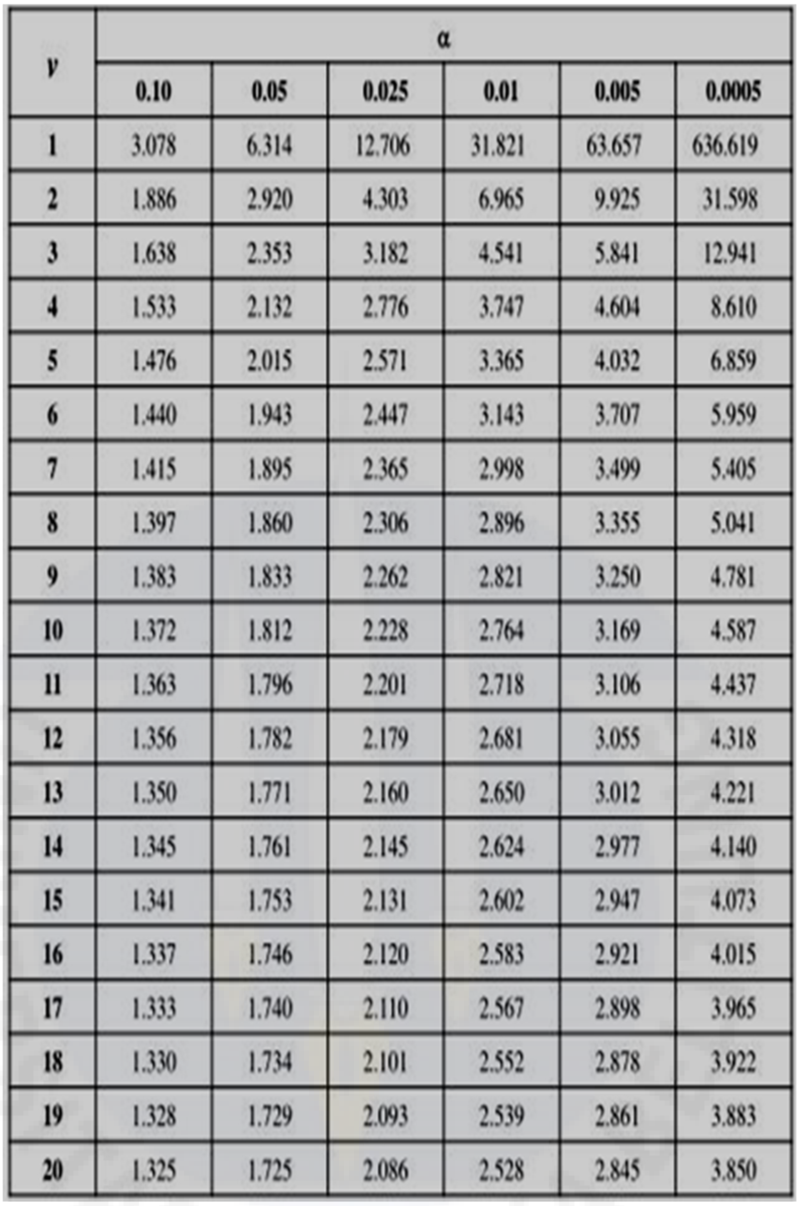
- **Rumah dengan daya 1300 Watt**



- **Rumah dengan daya 2200 Watt**

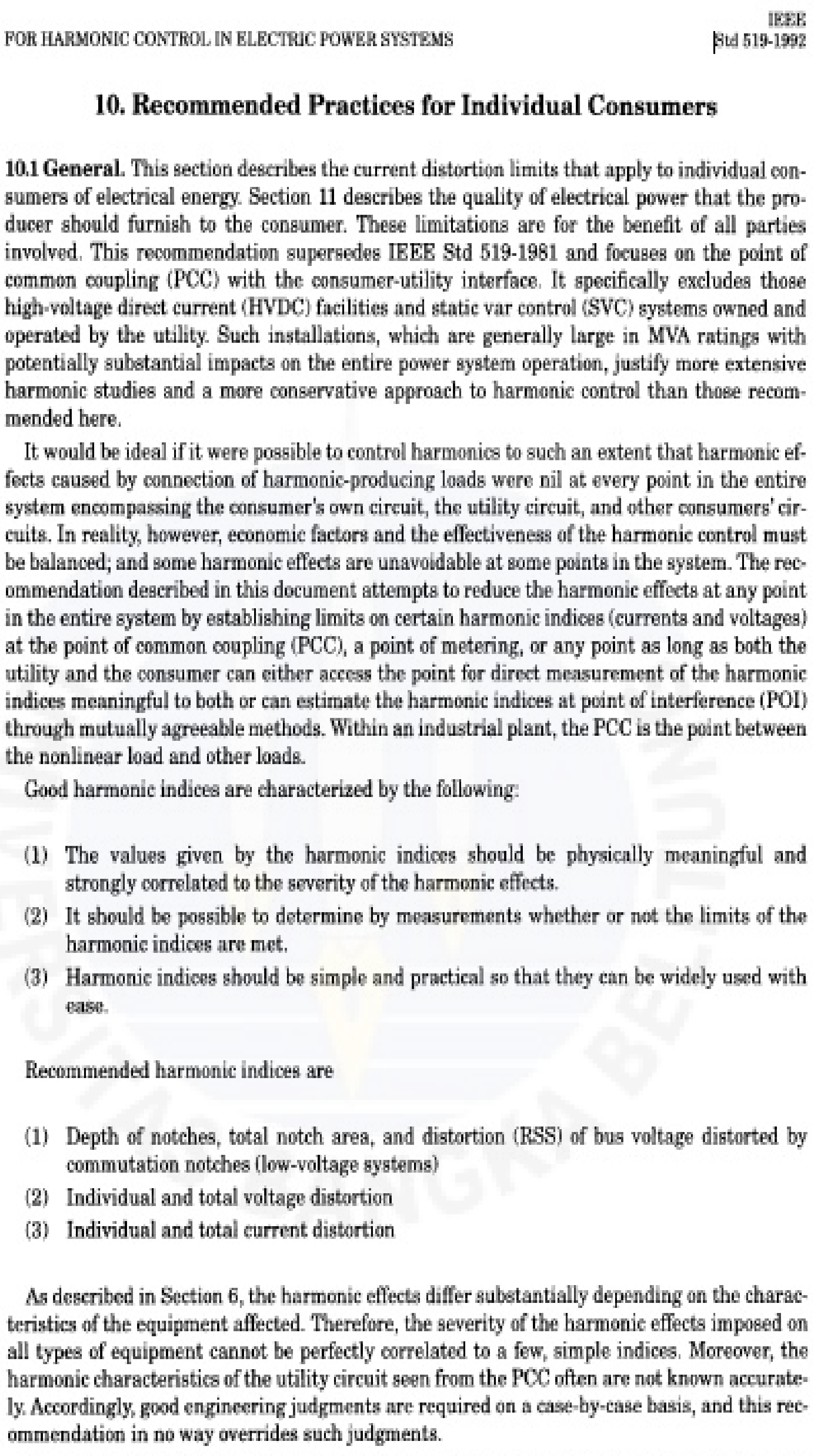
B. Nilai kritis sebaran t

Tabel 1.1 Nilai-Nilai Kritis Sebaran t-berekor satu



v	α					
	0.10	0.05	0.025	0.01	0.005	0.0005
1	3.078	6.314	12.706	31.821	63.657	636.619
2	1.886	2.920	4.303	6.965	9.925	31.598
3	1.638	2.353	3.182	4.541	5.841	12.941
4	1.533	2.132	2.776	3.747	4.604	8.610
5	1.476	2.015	2.571	3.365	4.032	6.859
6	1.440	1.943	2.447	3.143	3.707	5.959
7	1.415	1.895	2.365	2.998	3.499	5.405
8	1.397	1.860	2.306	2.896	3.355	5.041
9	1.383	1.833	2.262	2.821	3.250	4.781
10	1.372	1.812	2.228	2.764	3.169	4.587
11	1.363	1.796	2.201	2.718	3.106	4.437
12	1.356	1.782	2.179	2.681	3.055	4.318
13	1.350	1.771	2.160	2.650	3.012	4.221
14	1.345	1.761	2.145	2.624	2.977	4.140
15	1.341	1.753	2.131	2.602	2.947	4.073
16	1.337	1.746	2.120	2.583	2.921	4.015
17	1.333	1.740	2.110	2.567	2.898	3.965
18	1.330	1.734	2.101	2.552	2.878	3.922
19	1.328	1.729	2.093	2.539	2.861	3.883
20	1.325	1.725	2.086	2.528	2.845	3.850

C. Standar IEEE 519-1992



10. Recommended Practices for Individual Consumers

10.1 General. This section describes the current distortion limits that apply to individual consumers of electrical energy. Section 11 describes the quality of electrical power that the producer should furnish to the consumer. These limitations are for the benefit of all parties involved. This recommendation supersedes IEEE Std 519-1981 and focuses on the point of common coupling (PCC) with the consumer-utility interface. It specifically excludes those high-voltage direct current (HVDC) facilities and static var control (SVC) systems owned and operated by the utility. Such installations, which are generally large in MVA ratings with potentially substantial impacts on the entire power system operation, justify more extensive harmonic studies and a more conservative approach to harmonic control than those recommended here.

It would be ideal if it were possible to control harmonics to such an extent that harmonic effects caused by connection of harmonic-producing loads were nil at every point in the entire system encompassing the consumer's own circuit, the utility circuit, and other consumers' circuits. In reality, however, economic factors and the effectiveness of the harmonic control must be balanced; and some harmonic effects are unavoidable at some points in the system. The recommendation described in this document attempts to reduce the harmonic effects at any point in the entire system by establishing limits on certain harmonic indices (currents and voltages) at the point of common coupling (PCC), a point of metering, or any point as long as both the utility and the consumer can either access the point for direct measurement of the harmonic indices meaningful to both or can estimate the harmonic indices at point of interference (POI) through mutually agreeable methods. Within an industrial plant, the PCC is the point between the nonlinear load and other loads.

Good harmonic indices are characterized by the following:

(1) The values given by the harmonic indices should be physically meaningful and strongly correlated to the severity of the harmonic effects.
(2) It should be possible to determine by measurements whether or not the limits of the harmonic indices are met.
(3) Harmonic indices should be simple and practical so that they can be widely used with ease.

Recommended harmonic indices are

(1) Depth of notches, total notch area, and distortion (RSS) of bus voltage distorted by commutation notches (low-voltage systems)
(2) Individual and total voltage distortion
(3) Individual and total current distortion

As described in Section 6, the harmonic effects differ substantially depending on the characteristics of the equipment affected. Therefore, the severity of the harmonic effects imposed on all types of equipment cannot be perfectly correlated to a few, simple indices. Moreover, the harmonic characteristics of the utility circuit seen from the PCC often are not known accurately. Accordingly, good engineering judgments are required on a case-by-case basis, and this recommendation in no way overrides such judgments.

Strict adherence to the recommended harmonic limits will not always prevent problems from arising, particularly when the limits are approached. It is reasonable to consider that system changes will often justify reexamination. Harmonic measurements should be performed from time to time to determine system behavior and equipment performance. The consumer should confirm:

(1) That power factor correction capacitors or harmonic filters are not being overstressed by excessive harmonics
(2) That a harmful series or parallel resonance is not occurring
(3) That the level of harmonics at PCC and utilization points is not excessive

10.2 Development of Current Distortion Limits. The philosophy of developing harmonic limits in this recommended practice is to

(1) Limit the harmonic injection from individual customers so that they will not cause unacceptable voltage distortion levels for normal system characteristics
(2) Limit the overall harmonic distortion of the system voltage supplied by the utility

In order to develop limits for the harmonic current injection by individual customers, it is first necessary to define what is meant by normal system characteristics.

For purposes of this document, it will be assumed that the system can be characterized by a short-circuit impedance. The effect of capacitors is neglected. This is a conservative assumption for higher frequencies at which capacitors can provide low-impedance paths for harmonic currents to flow. At lower frequencies, resonant conditions could cause the system impedance to be greater than the assumed short-circuit impedance. The effect of loads is also neglected. The most important effect of loads is to provide damping near resonant frequencies, thereby reducing the impedance seen by the harmonic current source.

The harmonic voltage distortion on the system will be a function of the total injected harmonic current and the system impedance at each of the harmonic frequencies. The total injected harmonic current will depend on the number of individual customers injecting harmonic currents and the size of each customer. Therefore, a reasonable approach to limiting the harmonic currents for individual customers is to make the limits dependent upon the customer size. Larger customers will have more stringent limits because they represent a larger portion of the total system load. In Table 10.3, the customer size is expressed as the ratio of the short-circuit current capacity, at the customers point of common coupling with the utility, to the customer's maximum load current. The individual harmonic current limits are expressed in percent of this maximum load (demand) current.

The objectives of the current limits are to limit the maximum individual frequency voltage harmonic to 3% of the fundamental and the voltage THD to 5% for systems without a major parallel resonance at one of the injected harmonic frequencies. These voltage distortion limits are developed in Section 11.

The current distortion limits developed assume that there will be some diversity between the harmonic currents injected by different customers. This diversity can be in the form of different harmonic components being injected, differences in the phase angles of the individual harmonic currents, or differences in the harmonic injection vs. time profiles. In recognition of this diversity, the current limits are developed so that the maximum individual frequency harmonic voltage caused by a single customer will not exceed the limits in Table 10.1 for systems that can be characterized by a short-circuit impedance.

Table 10.1
Basis for Harmonic Current Limits

SCR at PCC	Maximum Individual Frequency Voltage Harmonic (%)	Related Assumption
10	2.5–3.0%	Dedicated system
20	2.0–2.5%	1–2 large customers
50	1.0–1.5%	A few relatively large customers
100	0.5–1.0%	5–20 medium size customers
1000	0.05–0.10%	Many small customers

If individual customers meet the current distortion limits, and there is not sufficient diversity between individual customer harmonic injections, then it may be necessary to implement some form of filtering on the utility system to limit voltage distortion levels. However, it is more likely that voltage distortion problems would be caused by system frequency response characteristics that result in magnification of harmonic current at a particular harmonic frequency. This changing of the system impedances vs. frequency characteristic is a result of the system's physical configuration. This situation has to be solved on the utility system by either changing capacitor locations or sizes, or by designing a harmonic filter.

10.3 Limits on Commutation Notches. The notch depth, the total harmonic distortion factor (THD), and the notch area of the line-to-line voltage at PCC should be limited as shown in Table 10.2.

Table 10.2
Low-Voltage System Classification and Distortion Limits

	Special Applications*	General System	Dedicated System†
Notch Depth	10%	20%	50%
THD (Voltage)	3%	5%	10%
Notch Area (A_N)‡	16 400	22 800	36 500

NOTE: The value A_N for other than 480 V systems should be multiplied by V/480

*Special applications include hospitals and airports.
†A dedicated system is exclusively dedicated to the converter load.
‡In volt-microseconds at rated voltage and current.

These limits are recommended for low-voltage systems in which the notch area is easily measured on an oscilloscope. It should be noted that the total voltage distortion factor is related to the total notch area, A_N, by the equality given in Eq 8.20.

Fig 10.1 defines notch depth and area.

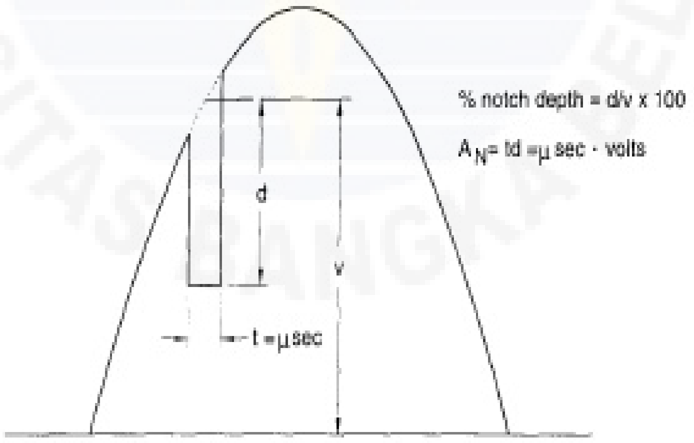


Fig 10.1
Definition of Notch Depth and Notch Area

10.4 Current Distortion Limits. Ideally, the harmonic distortion caused by a single consumer should be limited to an acceptable level at *any* point in the system; and the entire system should be operated without substantial harmonic distortion anywhere in the system. The harmonic distortion limits recommended here establish the maximum allowable current distortion for a consumer. The recommended current distortion limits are concerned with the following indice:

TDD: Total demand distortion (RSS), harmonic current distortion in % of maximum demand load current (15 or 30 min demand)

The limits listed in Tables 10.3, 10.4, and 10.5 should be used as system design values for the "worst case" for normal operation (conditions lasting longer than one hour). For shorter periods, during start-ups or unusual conditions, the limits may be exceeded by 50%.

These tables are applicable to six-pulse rectifiers and general distortion situations. However, when phase shift transformers or converters with pulse numbers (q) higher than six are used, the limits for the characteristic harmonic orders are increased by a factor equal to

$$\sqrt{\frac{q}{6}}$$

provided that the amplitudes of the noncharacteristic harmonic orders are less than 25% of the limits specified in the tables. See 13.1 for an example.

Table 10.3 lists the harmonic current limits based on the size of the load with respect to the size of the power system to which the load is connected. The ratio I_{sc}/I_L is the ratio of the short-circuit current available at the point of common coupling (PCC), to the maximum fundamental load current. It is recommended that the load current, I_L, be calculated as the average current of the maximum demand for the preceding 12 months. Thus, as the size of the user load decreases with respect to the size of the system, the percentage of harmonic current that the user is allowed to inject into the utility system increases. This protects other users on the same feeder as well as the utility, which is required to furnish a certain quality of voltage to its customers.

All generation, whether connected to the distribution, subtransmission, or transmission system, is treated like utility distribution and is therefore held to these recommended practices.

Table 10.3
Current Distortion Limits for General Distribution Systems
(120 V Through 69 000 V)

Maximum Harmonic Current Distortion in Percent of I_L						
Individual Harmonic Order (Odd Harmonics)						
I_{sc}/I_L	<11	$11\le h<17$	$17\le h<23$	$23\le h<35$	$35\le h$	TDD
<20*	4.0	2.0	1.5	0.6	0.3	5.0
20<50	7.0	3.5	2.5	1.0	0.5	8.0
50<100	10.0	4.5	4.0	1.5	0.7	12.0
100<1000	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20.0

Even harmonics are limited to 25% of the odd harmonic limits above.

Current distortions that result in a dc offset, e.g., half-wave converters, are not allowed.

*All power generation equipment is limited to these values of current distortion, regardless of actual I_{sc}/I_L.

where

I_{sc} = maximum short-circuit current at PCC.
I_L = maximum demand load current (fundamental frequency component) at PCC.

Table 10.4
Current Distortion Limits for General Subtransmission Systems (69 001 V Through 161 000 V)

Maximum Harmonic Current Distortion in Percent of I_L						
	Individual Harmonic Order (Odd Harmonics)					
I_{sc}/I_L	<11	$11 \le h < 17$	$17 \le h < 23$	$23 \le h < 35$	$35 \le h$	TDD
<20*	2.0	1.0	0.75	0.3	0.15	2.5
20<50	3.5	1.75	1.25	0.5	0.25	4.0
50<100	5.0	2.25	2.0	0.75	0.35	6.0
100<1000	6.0	2.75	2.5	1.0	0.5	7.5
>1000	7.5	3.5	3.0	1.25	0.7	10.0

Even harmonics are limited to 25% of the odd harmonic limits above.

Current distortions that result in a dc offset, e.g., half-wave converters, are not allowed.

*All power generation equipment is limited to these values of current distortion, regardless of actual I_{sc}/I_L.

where

I_{sc} = maximum short-circuit current at PCC.
I_L = maximum demand load current (fundamental frequency component) at PCC.

Table 10.5
Current Distortion Limits for General Transmission Systems (>161 kV), Dispersed Generation and Cogeneration

	Individual Harmonic Order (Odd Harmonics)					
I_{sc}/I_L	<11	$11 \le h < 17$	$17 \le h < 23$	$23 \le h < 35$	$35 \le h$	THD
<50	2.0	1.0	0.75	0.3	0.15	2.5
≥50	3.0	1.5	1.15	0.45	0.22	3.75

Even harmonics are limited to 25% of the odd harmonic limits above.

Current distortions that result in a dc offset, e.g., half-wave converters, are not allowed.

*All power generation equipment is limited to these values of current distortion, regardless of actual I_{sc}/I_L.

where

I_{sc} = maximum short-circuit current at PCC.
I_L = maximum demand load current (fundamental frequency component) at PCC.

10.4.1 Transformer Heating Considerations. The harmonic current distortion limits, as outlined in Tables 10.3 and 10.4, are only permissible provided that the transformer connecting the user to the utility system will not be subjected to harmonic currents in excess of 5% of the transformers rated current as stated in IEEE C57.12.00-1987 [2]. If the transformer connecting the user will be subjected to harmonic levels in excess of 5%, the installation of a larger unit, capable of withstanding the higher levels of harmonics, should be considered. When the harmonic current flowing through the transformer is more than the design level of 5% of the rated current, the heating effect in the transformer should be evaluated by applying the methodology contained in IEEE C57.110-1986 [3]. This evaluation will ensure that the transformer insulation is not being stressed beyond design limits.

10.4.2 Probabilistic Application of Harmonic Distortion Limits. Although the effects of harmonics on electric equipment, appliances, etc., are not fully understood at this time, it is recognized that the stated current distortion limits can be exceeded for periods of time without causing harm to equipment. When evaluating user compliance with the stated limits, it is recommended that probability distribution plots be developed from the recorded data and analyzed. If the limits are only exceeded for a short period of time, the condition could be considered acceptable. Fig 10.2 depicts a typical probability plot for harmonic current on a distribution feeder.

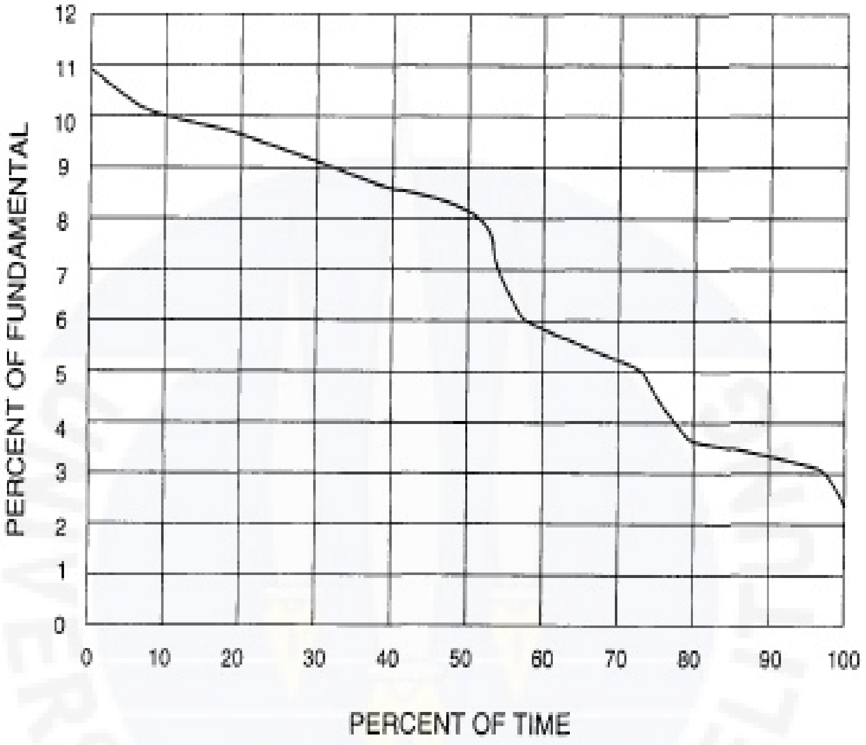


Fig 10.2
Probability Distribution of Current THD

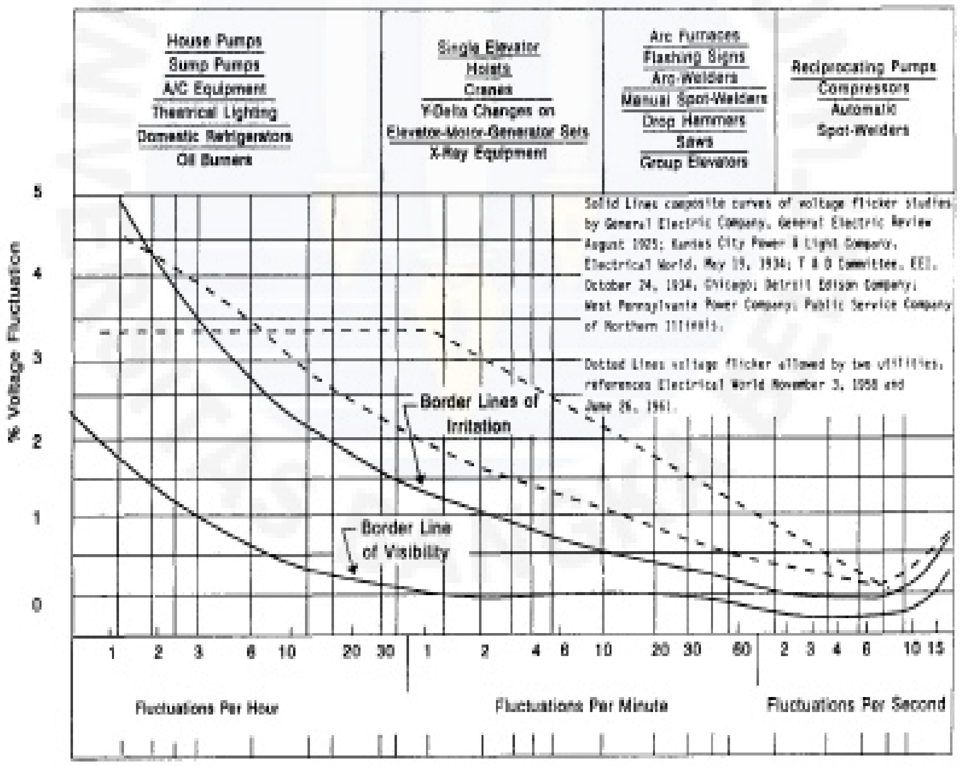
10.5 Flicker. This phenomenon is a result of applying a load on the converter, releasing it, then reapplying it some time later, etc. The converter does not in itself cause flicker. If this process is carried out at a frequency to which the human eye is susceptible, and if the resulting system voltage drop is great enough, a modulation of the light level of incandescent or fluorescent lamps will be detected. This is the effect that gives the phenomenon its name, and one that may be a matter of concern. In modern power systems, however, there may be other apparatus, such as computers, instrumentation, and communication equipment, that suffer deleterious effects. For some cases, these effects may exist even though the flicker of incandescent lamps is not discernible.

The measure of flicker is comprised of the amount of system voltage variation involved and the frequency at which the variation recurs. The frequency may be a pure single frequency; but it is more often a frequency band. Sources of flicker in industrial power distribution systems can be, for instance, the somewhat random variations of load typified by an arc furnace melting scrap steel or an elevator motor's starts and stops. A flicker source may be nearly periodic, as in the case of jogging or manual spot-welding. A source may also be periodic, as in the case of an automatic spot-welder.

Flicker intensity (that is, the magnitude of the voltage variation) is determined by the power system source impedance and load peak power requirements. When planning to install pulsed converters, the effects of the pulse load on other parts of the distribution system should be calculated. This requires knowledge of

(1) The voltampere requirements of the pulsed load, magnitude, and frequency
(2) The impedance of the source(s) within the distribution system back to a supply of such stiffness that variations can be considered truly inconsequential
(3) Whether or not apparatus that are susceptible to flicker are within the exposed distribution sector and their degree of susceptibility

10.5.1 Limits of Flicker. Frequently, the degree of susceptibility is not readily determinable. Fig 10.3 is offered as a guide for planning for such applications. This curve is derived from empirical studies made by several sources. There are several such curves existing that have approximately the same vertical scale.



Solid Lines composite curves of voltage flicker studies by General Electric Company, General Electric Review August 1925; Kansas City Power & Light Company, Electrical World, May 19, 1934; T & D Committee, EEI, October 24, 1934, Chicago; Detroit Edison Company; West Pennsylvania Power Company; Public Service Company of Northern Illinois.

Dotted Lines voltage flicker allowed by two utilities, references Electrical World November 3, 1958 and June 26, 1961.

Fig 10.3
Maximum Permissible Voltage Fluctuations

11. Recommended Practices for Utilities

11.1 General. The factors that define the quality of electrical service include harmonic distortion in addition to more familiar factors such as safety of service (e.g., surge protection and step-and-touch voltage), service continuity, voltage regulation, and flicker. The distortion limits recommended in this section establish the maximum voltage distortion at the point of common coupling (PCC) with each consumer.

If the limits are exceeded, the following steps may be taken:

(1) Perform harmonic measurements at selected points within the utility circuit, including the PCC, and look for consumers with converters operating with current distortion beyond the limits. If identified, such consumers should be asked to keep the harmonic distortion within the recommended limits by installing filters, by reducing harmonic generation, or through other means.
(2) Install filters to control the harmonics.
(3) Install a new feeder. This is effective in stiffening the source and isolating the harmonic problems. However, it is not always economically feasible.

It should be noted that it is possible to add new converter loads to a circuit already polluted with harmonics to the recommended limits as long as properly designed filters are also provided.

11.2 Addition of Harmonics. The waveshape of the converter ac current is determined by the delay angle at which commutation starts and by the commutating overlap angle. Consequently, the harmonic current components generated by one converter may not be in phase with the respective harmonic current components generated by another converter connected to the same feeder circuit. The same can be said for the respective harmonic impedance voltage drop components. The addition of the harmonic voltage and current contributions from multiple converters is conceptually simple. Kirchoff's voltage and current laws are applied to the phasers of each harmonic frequency. In practice, the rigorous addition of the harmonic components is likely to be impossible. A prohibitive amount of phasing data would have to be collected and then analyzed statistically for time-of-day variations.

A simple, approximate, and conservative method of addition is recommended; namely, solving the circuit for each harmonic source separately to determine the branch currents and node voltages caused by the harmonic source, and then arithmetically adding them up. Coincidence factors of the converter loads can be used to refine the addition if such data are readily available.

Harmonic measurements should be performed from time to time at selected points at which a high level of harmonic distortion is suspected to determine the system behavior and confirm

(1) That utility capacitors, filters, cables, and transformers are not being overstressed by excessive harmonics
(2) That a harmful degree of series or parallel resonance is not occurring
(3) That the level of harmonics are within the limits

The harmonic analysis based on the coincidence factors of converter loads should be made to evaluate the measurement results and to extrapolate the results for the assessment of the effects of new converters to be installed. Sole reliance on an extensive analytical addition of harmonics is not recommended.

11.3 Short-Duration Harmonics. Devices such as a thyristor-controlled drive applied to a rolling mill generate short-duration bursts of harmonic currents as the material passes through the mill. Generation of intermittent harmonics and the resulting voltage stress on the capacitors, the transformers, and other power apparatus is sometimes more tolerable than the stress caused by the constant generation of harmonics. Intermittent harmonics and constant harmonics will cause similar effects as far as harmonic interference to the control circuits, the communication circuits, and the electronic equipment is concerned. It is likely, however, that flicker is the major problem in this case and that harmonic problems are secondary. A solution to the flicker problem may well eliminate the harmonic problems.

11.4 Abnormal Conditions for Harmonic Problems. Some of the less common conditions known to cause harmonic problems are described here. They are the natural resonance of a transmission line, overexcitation of transformers, and harmonic resonance in the zero-sequence circuit.

Each transmission line has many natural resonant frequencies determined by its length, its geometry, and its termination. The input impedance of a transmission line can become close to zero and resistive (series resonance) or infinitely large (parallel resonance) at the natural resonant frequencies. If a series resonance frequency is close to one of the dominant harmonics generated by converters, there is a risk of severe telephone interference. The problem can be corrected by changing the natural frequency of the transmission line (by changing the termination or the line length) or by preventing the harmonic current flow into the line with a series blocking filter, a shunt filter, or both. Unfortunately, these solutions are often expensive.

Because of transformer core characteristics, overexcited transformers generate odd order harmonics. There is a tendency to operate high-voltage circuits with voltage that is substantially higher than nominal by switching in capacitor banks well ahead of daily load increase. This assures a desired load flow and voltage stability, but can cause harmonic problems. Excess reactive power during light load conditions can cause similar problems.

A harmonic resonance can occur in the zero-sequence circuit under the following conditions:

(1) Wye-connected generator neutrals are grounded through reactors.

(2) Generators are connected to the feeders directly or through transformers with wye-connected windings, on the generator side, that are grounded solidly or through neutral reactors.

(3) Power factor correction capacitors connected in a grounded-wye arrangement are applied along a feeder.

These conditions may be satisfied in small isolated systems. The generator voltage always contains zero-sequence harmonic voltages. These harmonic voltages act like voltage sources because of the small internal impedances involved. The harmonic voltage sources are connected to a series combination of an inductive reactance (generator reactance, transformer reactance, feeder reactance, and neutral grounding reactance) and a capacitive reactance. If the two are similar in magnitude at one of the harmonic frequencies, a large amount of harmonic current will flow in the loop and can cause unusual problems such as high step-and-touch voltages, erroneous operation of kWh meters for single-phase consumers, and false operation of ground overcurrent relays. One solution is to break the ground loop by changing grounding schemes for generators and capacitors. Proper use of delta-connected windings of step-up transformers also breaks the ground loop.

11.5 Voltage Distortion Limits. The recommended voltage distortion limits (see Table 11.1) are concerned with the following indice:

THD: Total (RSS) harmonic voltage distortion in percent of nominal fundamental frequency voltage.

The limits listed in Table 11.1 should be used as system design values for the "worst case" for normal operation (conditions lasting longer than one hour). For shorter periods, during start-ups or unusual conditions, the limits may be exceeded by 50%.

Table 11.1
Voltage Distortion Limits

Bus Voltage at PCC	Individual Voltage Distortion (%)	Total Voltage Distortion THD (%)
69 kV and below	3.0	5.0
69.001 kV through 161 kV	1.5	2.5
161.001 kV and above	1.0	1.5

NOTE: High-voltage systems can have up to 2.0% THD where the cause is an HVDC terminal that will attenuate by the time it is tapped for a user.

11.6 Limits of Interference With Communication Circuits. It is difficult to place specific limits on the telephone influence that the harmonic components of current and voltage in converter systems can inflict. The actual interference to voice communication systems in proximity to the power system supplying the converter is dependent upon a number of factors not under the control of the designer of the converter system. These factors will vary from location to location and from time to time as the state-of-the art of inductive coordination progresses.

There are some data available that relate to the *I·T* (see 6.9.1) performance of large converters used in telephone offices to charge batteries (see Table 11.2). It should be noted that the values shown in Table 11.2 are given for illustrative purposes and are not to be considered as requirements. Furthermore, the values shown are applicable to the secondary distribution within the telephone building. The *I·T* on the primary system would be reduced by the turns ratio in the distribution transformer, which is typically in the range of 40:1 to 60:1. For example, an *I·T* of 100 000 for a 240 V, 1600 A converter would become 2000 on a 12 kV primary. This, of course, is important because the exposure to the primary feed will be greater in length. Fig 11.3 gives typical *I·T* values for 48 V dc ferroresonant converters.

Table 11.2
Typical *I·T* Values for 48 V DC Converters

Three-Phase Line-to-Line Voltage	Rectifier Full Load Output Current Rating	*I·T* on Secondary Distribution
208/240 V	400	25 000
	800	50 000
	1600	100 000
480 V	400	12 000
	800	25 000
	1600	50 000

NOTE: For the case of ferroresonant units that do not utilize phase shifting, the *I·T* is typically much lower, as indicated in Table 11.3.

These converters were of the six-pulse type with phase-shifting taps to permit two converters to be operated in parallel on a 12-pulse basis or four converters to be operated on a 24-pulse basis. Recently, consideration has been given to lower the specified maximum values to one-half or less of the above figures, particularly where the battery plant is to be associated with an electronic switching office.

The *I·T* on primary transmission is of most interest to a telephone company inductive coordination engineer. Although there are no specific requirements, experience with interference problems over the years had provided some guidelines that may be useful. These are summarized in Table 11.4.

Noise sensitive installations fall into Category I. Commercial buildings and industrial plants fall into Category II. Unrestricted areas fall into Category III.

Table 11.3
Typical *I·T* Values for 48 V DC Ferroresonant Converters

Three-Phase Line-to-Line Voltage (Secondary)	Converter Full Load Output Current Rating	*I·T* on Secondary Distribution
208/240 V	100*	750
	400	1500
480 V	100*	350
	400	750

*Single-phase rectifiers

It should be pointed out that the above guidelines are applicable to balanced rather than residual components on power systems. Table 11.4 provides representative *I·T* guidelines for electric lines that tie industrial and commercial converter installations to primary distribution and transmission line networks, see [8]. Similar *I·T* guidelines for HV and EHV transmission lines are published in IEEE Std 368-1977 [8].

Table 11.4
Balanced *I·T* Guidelines for Converter Installations, Tie (Supply) Lines

Category	Description	*I·T*
I	Levels most unlikely to cause interference	Up to 10 000*
II	Levels that might cause interference	10 000 to 25 000
III	Levels that probably will cause interference	greater than 25 000

NOTE: These values of *I·T* product are for circuits with an exposure between overhead systems, both power and telephone. Within an industrial plant or commercial building, the exposure between power distribution in cables and telephone lines in cable with twisted pairs is extremely low and no interference is normally encountered. *I·T* products similar to those of Table 11.2 should be used within plants and buildings.

* For some areas that use a ground return for either telephone or power circuits, this value may be as low as 1500.