KUALITAS DAYA SISTEM DISTRIBUSI

Dian Retno Sawitri

Masalah Kualitas Daya

- Voltage sags
- Momentary interruptions
- Sustained interruptions
- Overvoltages and Customer Equipment Failures
- Switching Surges
- Harmonic
- Flicker
- Voltage Unbalance

Persoalan Kualitas Daya

- Pelanggan yang berbeda memiliki gangguan yang berbeda.
- Pelanggan perumahan → sustained interruptions and momentary interruptions
- Komerial dan industri → sags and momentaries
- Setiap sirkuit/ jaringan adalah berbeda, dan respon setiap pelanggan berbeda untuk setiap gangguan kualitas daya.
- Persoalan kualitas daya disebabkan oleh gangguan pada utilitas sistem tenaga, dan terbesar pada sistem distribusi.
- Gangguan tidak sepenuhnya dapat dieliminasi, tetapi ada beberapa cara untuk meminimalkan tekanan pada pelanggan.

Mengenali Gangguan

- Apakah momentary interruptions disebabkan oleh gangguan pada feeder yang melayani pelanggan ?
- Apakah voltage sags disebabkan oleh gangguan pada tap atau feeder yang berdekatan.
- Apakah flicker tegangan periodik disebabkan oleh busur pengelas atau hal lain ?
- Ada fluktuasi beban pada sirkuit yang sama ?

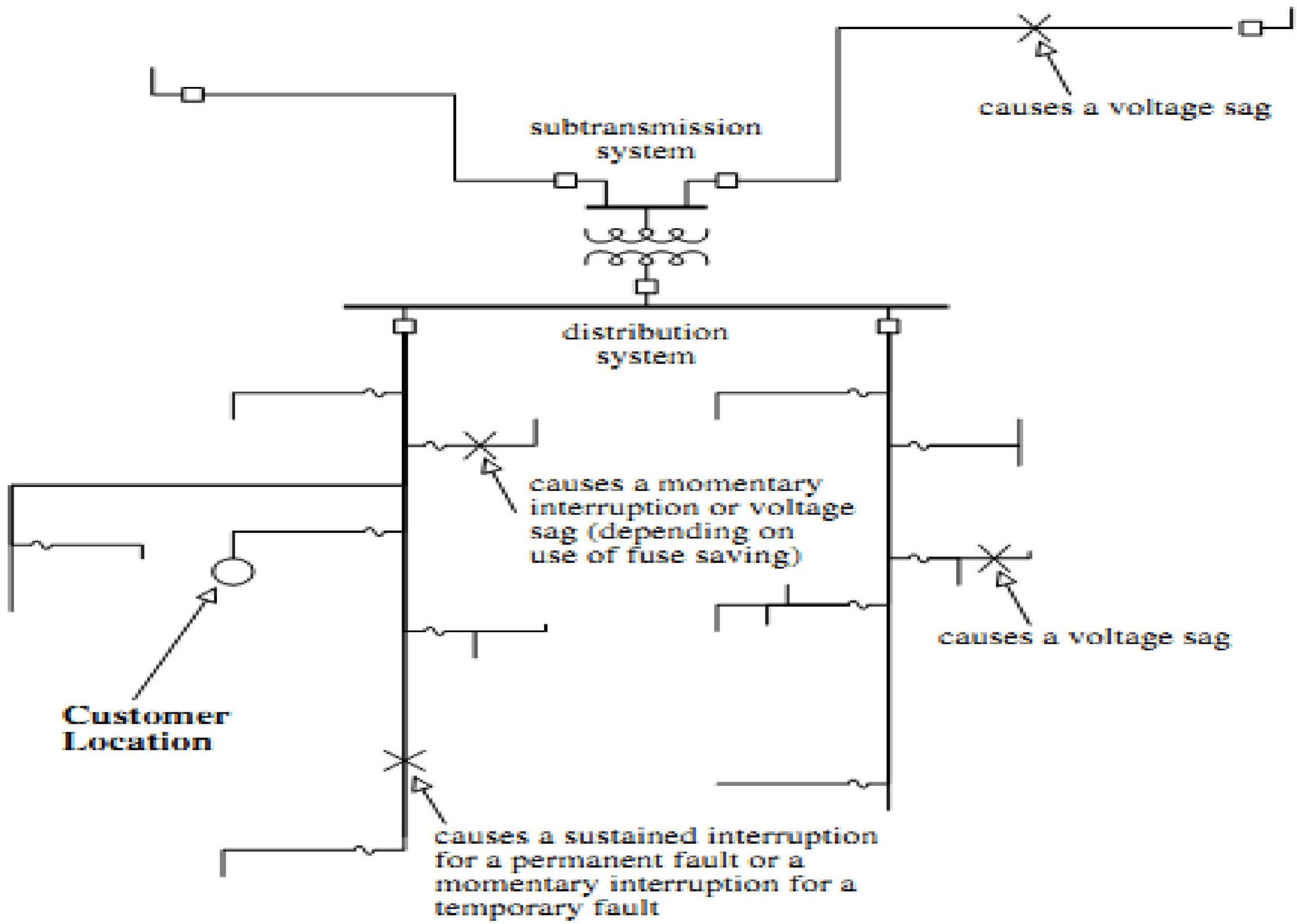
Strategi untuk identifikasi masalah

- Hilangnya daya pada semua atau beberapa komputer pada pelanggan komersial dan industri → permasalahan sag.
- Apakah flicker hanya terjadi pada lampu? Apakah beberapa komputer atau elektronik lain terjadi reset atau rebooting ? Jika masalah hanya pada lampu → terjadi flicker yang disebabkan fluktuasi beban.
- Membandingkan waktu kejadian gangguan di pelanggan dengan perangkat proteksi. Dicari korelasi antara keduanya. Jika perangkat proteksi adalah circuit breaker vs perangkat dekat pengendali proteksi → momentary interuption. Jika perangkat proteksi pada sirkuit yang berdekatan atau pada gardu induk → voltage sag

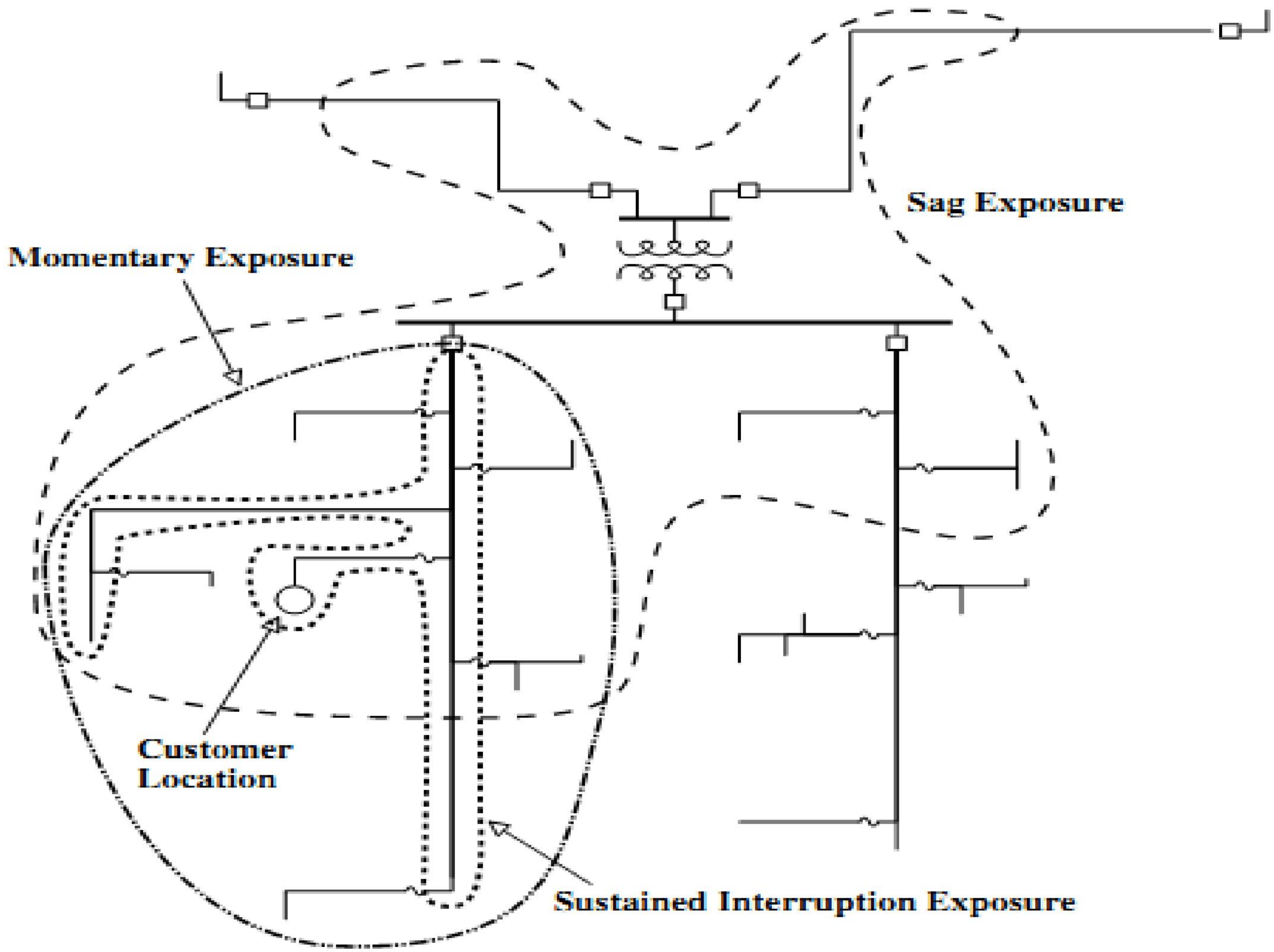
Strategi untuk identifikasi masalah

- A review of the number of operations of the protective devices on the circuit, if these records are kept, can reveal whether the customer is seeing an abnormal number of momentary interruptions or possibly sags from faults on adjacent feeders.
- Does the flickering occur because of changes in the customer load? For example in a house, does sump-pump starting cause the lights to dim in another room? If so, look for a local problem. A likely candidate — a loose neutral connection — causes a reference shift when load is turned on or off.
- Are other customers on the circuit having problems? If so, then the problem is probably due to momentary interruptions and not just a customer that is very sensitive to sags. Momentary interruptions affect most end users; voltage sags only impact the more sensitive end users.

Lokasi Gangguan



Penyebab Gangguan



MAIFI, SAIFI, SAIDI

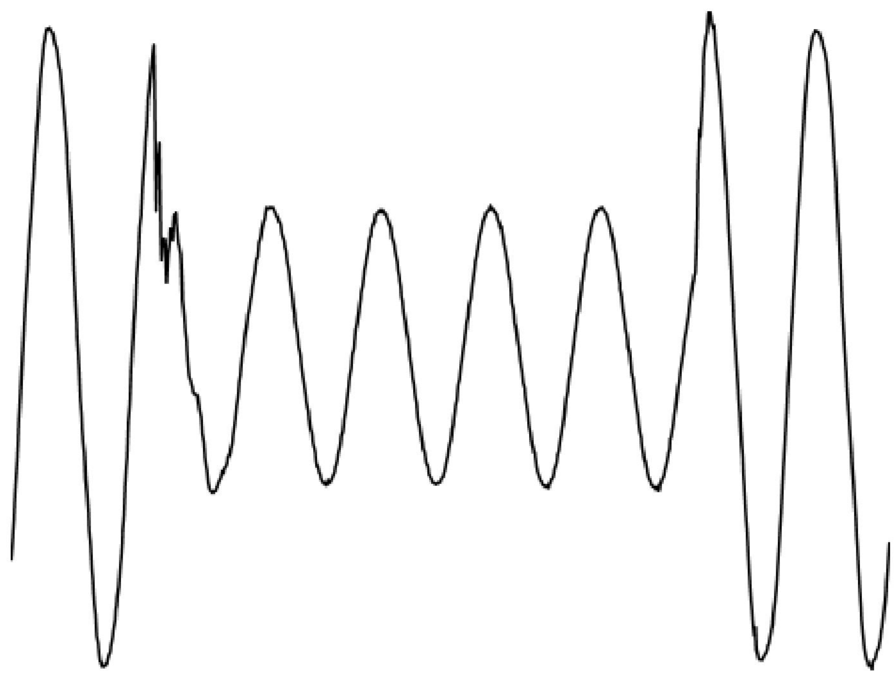
- **Momentary Average Interruption Frequency Index (MAIFI)**
  - MAIFI = (Total number of momentary interruptions in a year) / (Total number of consumers)
- **System Average Interruption Frequency Index (SAIFI)**
  - SAIFI = (Total number of sustained interruptions in a year) / (Total number of consumers)
- **System Average Interruption Duration Index (SAIDI)**
  - SAIDI = Total duration of sustained interruptions in a year / total number of consumers
- **Consumer Average Interruption Frequency Index (CAIFI)**
  - CAIFI = Total number of sustained interruptions in a year/Total number of consumers affected.
- **Consumer Average Interruption Duration Index (CAIDI)**
  - CAIDI = Total duration of sustained interruptions in a year/total number of interruptions.
  - It can also be seen that CAIDI = SAIDI/SAIFI

Voltage Sag

- A voltage sag is defined as an rms reduction in the ac voltage, at the power frequency, for durations from a half cycle to a few seconds (IEEE Std. 1159-1995).
- Sags are also called dips (the preferred European term).
- Faults in the utility transmission or distribution system cause most sags.
- Utility system protective devices clear most faults, so the duration of the voltage sag is the clearing time of the protective device.

Voltage Sag

- Voltage Sag akibat gangguan



Memperbaiki Voltage Sag

- *Reduce faults* — Tree trimming, tree wire, animal guards, arresters, circuit patrols
- *Trip faster* — Smaller fuses, instantaneous trip, faster transmission relays
- *Support voltage during faults* — Raising the nominal voltage, current-limiting fuses, larger station transformers, line reactors

Karakteristik Voltage Sag

Average Annual Number of Voltage Sags below the Given Magnitude for Longer than the Given Duration from the NPL Data with a Five-Minute Filter

	Duration							
Magnitude	**1 Cycle**	**6 Cycles**	**10 Cycles**	**20 Cycles**	**0.5 sec**	**1 sec**	**2 sec**	**10 sec**
87%	126.4	56.8	36.4	27.0	23.0	18.1	14.5	5.2
80%	44.8	23.7	17.0	13.9	12.2	10.0	8.0	4.3
70%	23.1	17.3	14.5	12.8	11.5	9.7	7.9	4.3
50%	15.9	14.1	12.9	11.8	10.6	9.4	7.8	4.3
10%	12.2	12.0	11.7	11.0	10.2	9.0	7.5	4.2

Source: Dorr, D. S., Hughes, M. B., Gruzs, T. M., Juewicz, R. E., and McClaine, J. L., "Interpreting Recent Power Quality Surveys to Define the Electrical Environment," *IEEE Transactions on Industry Applications*, vol. 33, no. 6, pp. 1480–7, November 1997.

Karakteristik Voltage Sag

Average Annual Number of Voltage Sags Below the Given Magnitude for Longer than the Given Duration from the EPRI Feeder Data with a Five-Minute Filter

	Duration							
Magnitude	**1 Cycle**	**6 Cycles**	**10 Cycles**	**20 Cycles**	**0.5 sec**	**1 sec**	**2 sec**	**10 sec**
90%	77.7	31.2	19.7	13.5	10.7	7.4	5.4	1.8
80%	36.3	17.4	12.4	9.3	7.9	6.4	4.9	1.7
70%	23.9	13.1	10.3	8.3	7.2	6.2	4.8	1.7
50%	14.6	9.5	8.4	7.5	6.6	5.9	4.6	1.7
10%	8.1	6.5	6.4	6.2	5.6	5.1	4.0	1.7

Source: Dorr, D. S., Hughes, M. B., Gruzs, T. M., Juewicz, R. E., and McClaine, J. L., "Interpreting Recent Power Quality Surveys to Define the Electrical Environment," *IEEE Transactions on Industry Applications*, vol. 33, no. 6, pp. 1480–7, November 1997.

Karakteristik voltage Sag

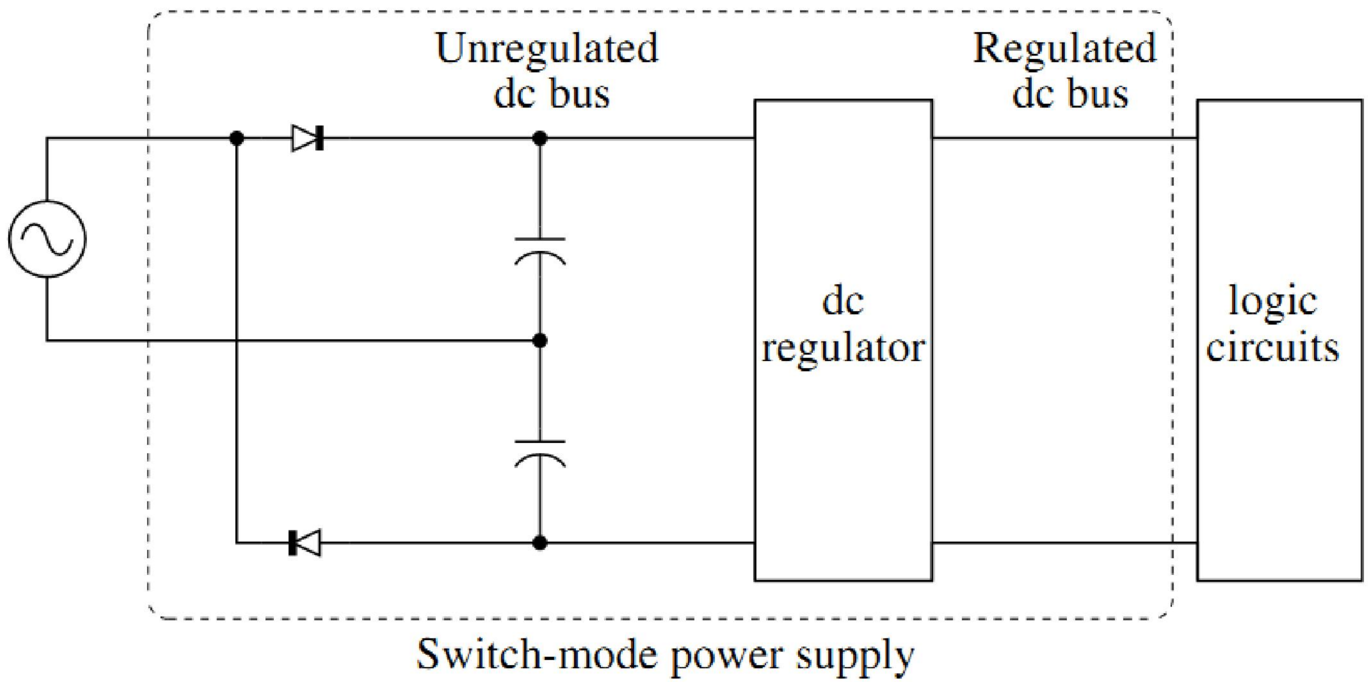
Annual Number of Power Quality Events (Upper Quartile, Median, and Lower Quartile) for the EPRI DPQ Feeder Sites with a One-Minute Filter

	Duration, seconds						
Voltage	0	0.02	0.05	0.1	0.2	0.5	1
0.9	32.8 57.5 104.8	30.8 49.0 95.1	24.4 35.3 65.6	13.6 22.7 38.7	7.6 13.2 24.0	3.3 7.3 14.2	1.4 3.2 8.9
0.8	16.4 31.6 54.1	14.8 26.0 50.1	12.1 20.9 37.9	8.1 15.0 25.1	4.9 9.6 16.9	2.4 5.3 11.0	0.9 2.7 7.5
0.7	10.1 20.5 33.8	8.6 18.8 32.7	8.1 15.3 27.6	5.8 11.3 18.8	4.0 7.8 13.5	1.8 4.5 9.3	0.9 2.5 7.0
0.5	4.7 9.7 19.2	4.5 9.0 17.4	4.2 7.7 14.3	3.5 5.9 11.2	2.3 5.0 9.6	1.4 3.3 7.7	0.8 2.2 5.7
0.3	2.1 4.8 12.8	1.8 4.5 11.0	1.6 4.2 9.5	1.4 3.6 8.6	1.1 3.5 8.3	0.8 2.8 6.6	0.5 1.6 5.1
0.1	0.9 3.2 8.3	0.9 2.9 7.8	0.8 2.8 7.8	0.8 2.7 7.8	0.7 2.7 7.8	0.5 2.2 6.1	0.3 1.6 4.9

Note: A *B* C represent the lower quartile *A*, the median *B*, and the upper quartile *C* of the total number of events below the given magnitude and longer than the given duration (up to 1 min).

Peralatan Sensitif

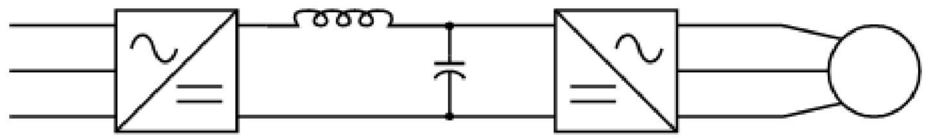
- Computers and Electronic Power Supplies
- Switch mode power supply

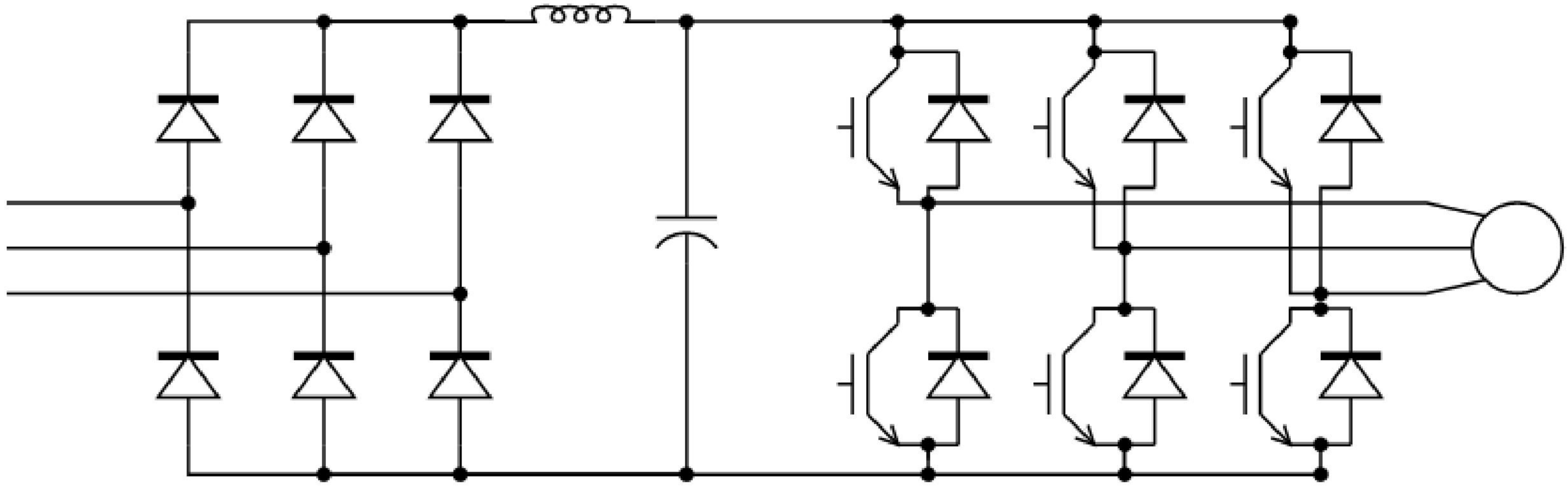


Peralatan Sensitif

- Industrial Processes and Equipment
  - Programmable logic controllers (PLCs)
  - Adjustable-speed drives (ASDs), also called variable-speed drives (VFDs)
  - Contactors
  - Relays
  - Control equipment

Adjustable-speed drives





Solusi untuk momentary interuption

- Immediate reclose
- Use of fuse blowing
- Single-phase reclosers
- Extra downstream devices (fuses or reclosers)
- Sequence coordination with downstream devices
- Reduce faults

Solusi Voltage Sag

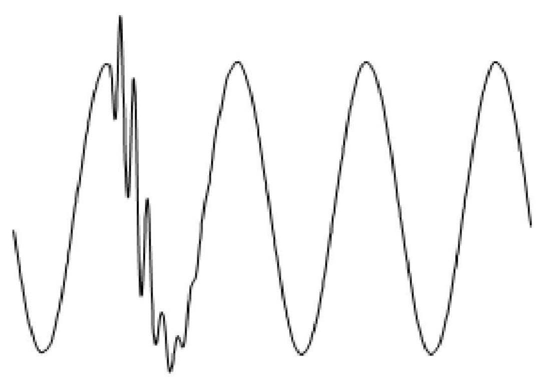
- Use of fuse saving
- Current limiting fuses
- Smaller lateral fuses
- Faster breakers or reclosers
- Raise the nominal voltage
- Reduce faults

Jenis Kualitas Daya Lain

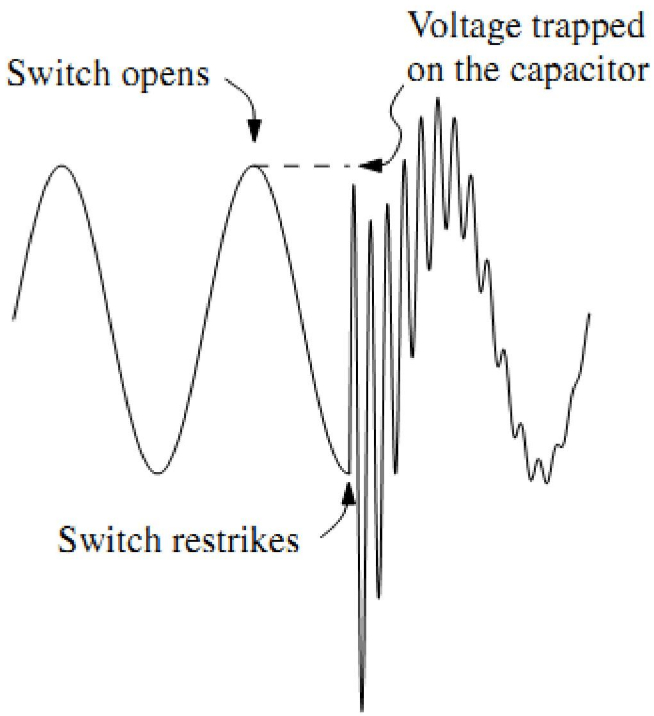
- Overvoltages and Customer Equipment Failures
  - Voltage swells — Peaks at about 1.3 per unit on most distribution circuits.
  - Switching surges — Normally peaks at less than 2 per unit and decays quickly.
  - Ferroresonance — Normally peaks at less than 2 per unit.

Jenis Kualitas Daya Lain

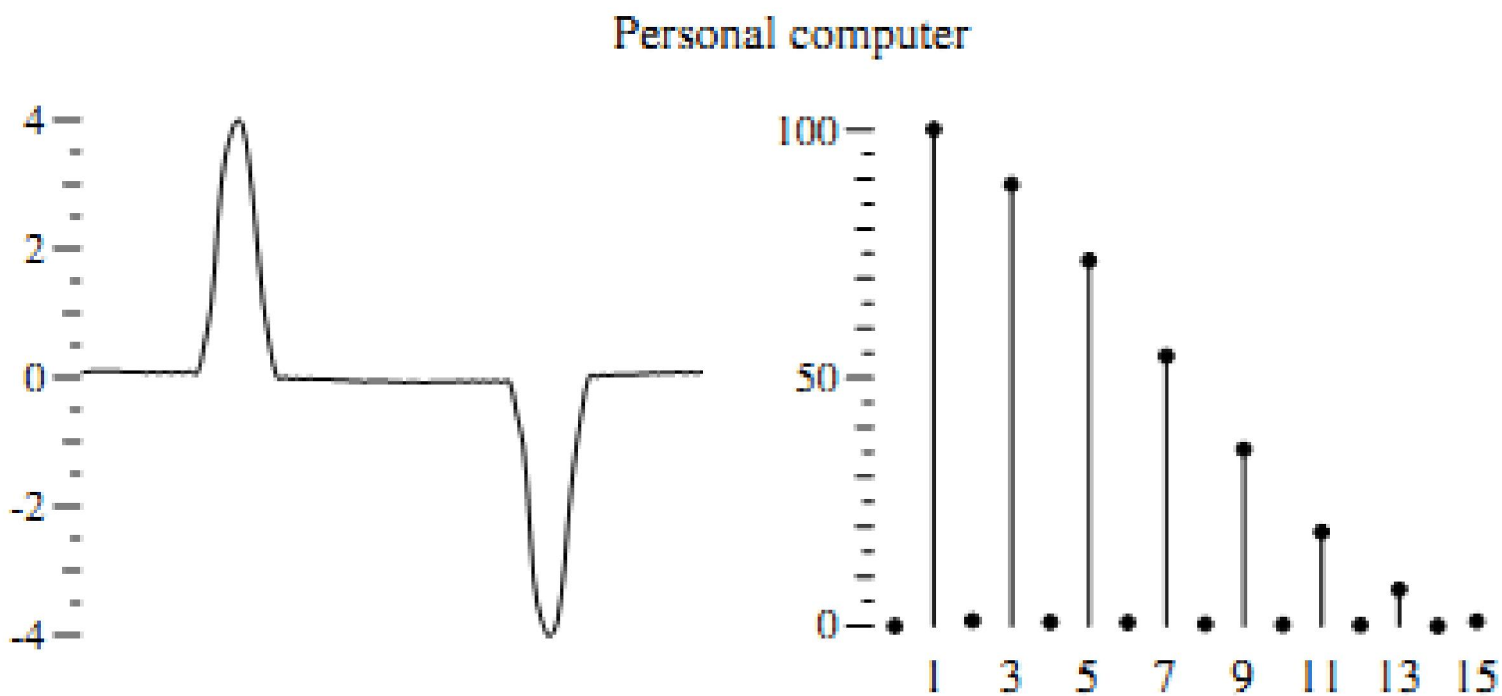
- Switching Surges
  - Capacitor switching transients normally cause the highest peak magnitudes. If a capacitor is switched just when the system voltage is near its peak, the capacitor pulls the system voltage down (as current rushes into the capacitor to charge it up).



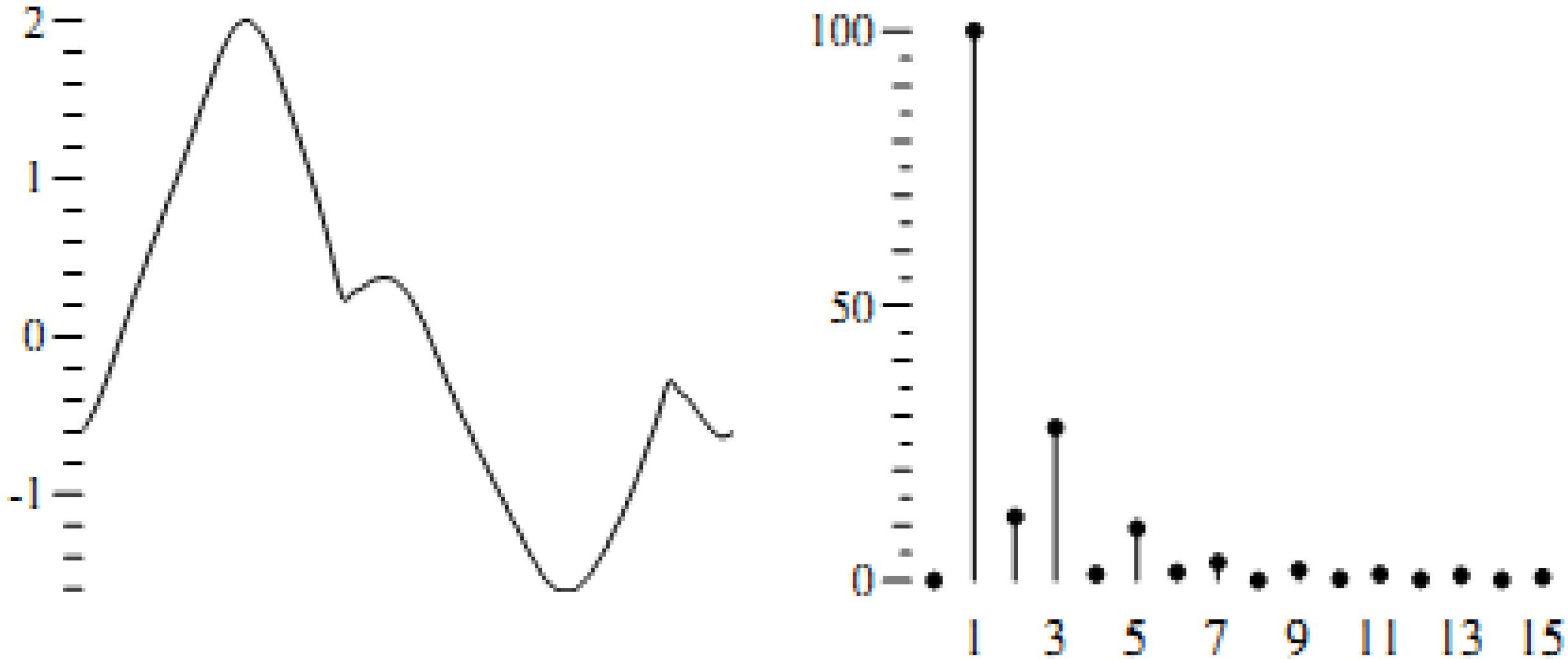
Restike Capasitor Bank



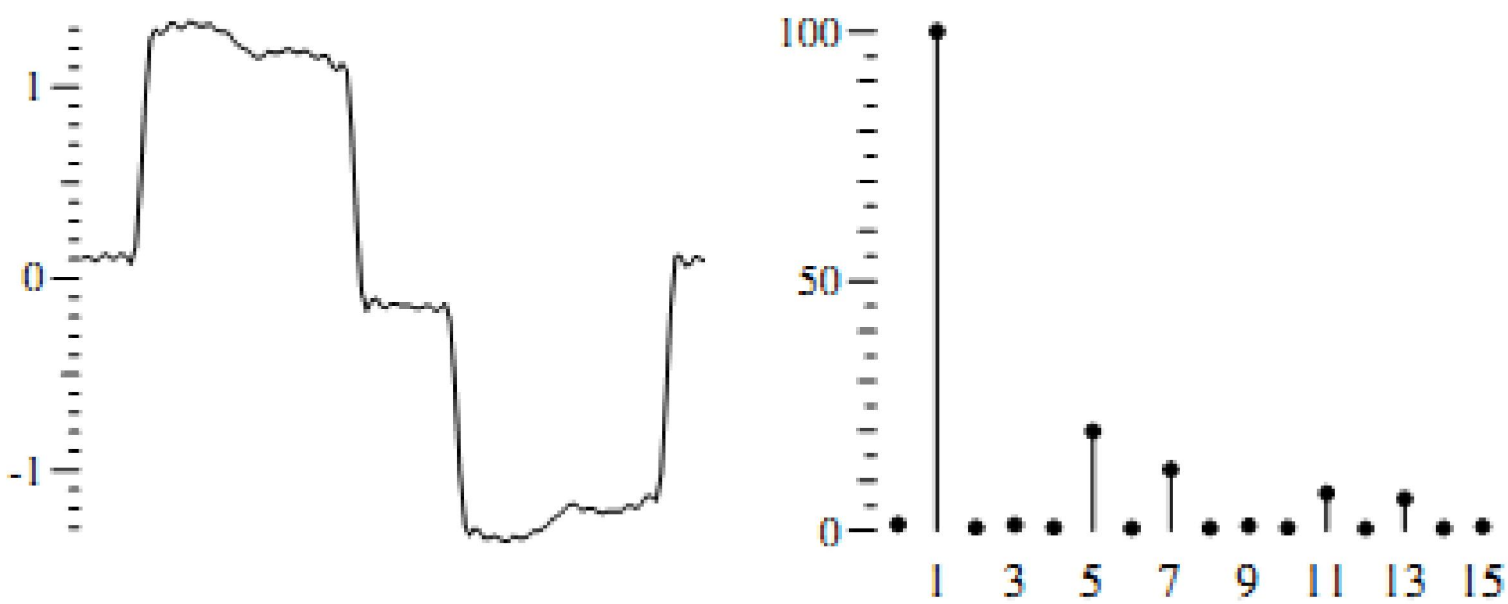
- Harmonic



Microwave oven



3-phase adjustable-speed drive



Waveforms
in per unit

Frequency spectrums
with amplitudes in percent

Total Harmonic Distorsion (THD)

- V_1 is the rms magnitude of the fundamental component, and *Vh* is therms magnitude of component *h*.

$$V_{THD} = \frac{\sqrt{\sum_{h=2}^{\infty} V_h^2}}{V_1}$$

THD

Voltage Distortion Limits

	Voltage Distortion Limit
Individual harmonics	3%
Total harmonic distortion (THD)	5%

Note: For a bus limit at the point of common coupling at and below 69 kV. For conditions lasting less than 1 h, the limits may be exceeded by 50%.

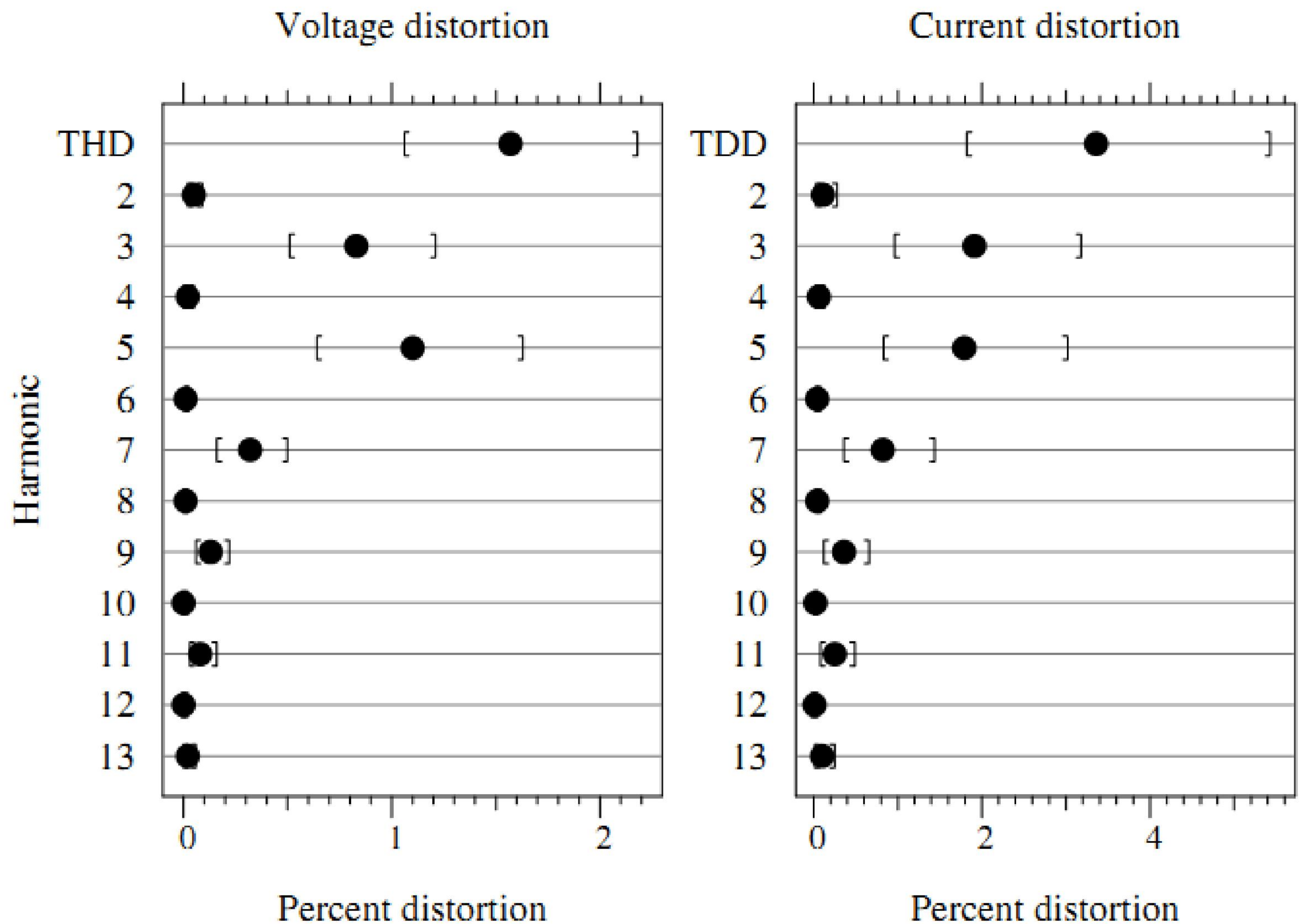
Source: IEEE Std. 519-1992.

Current Distortion Limits for Distribution Systems (120 V through 69 kV)

I_{sc}/I_L	$h < 11$	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$34 \leq h$	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

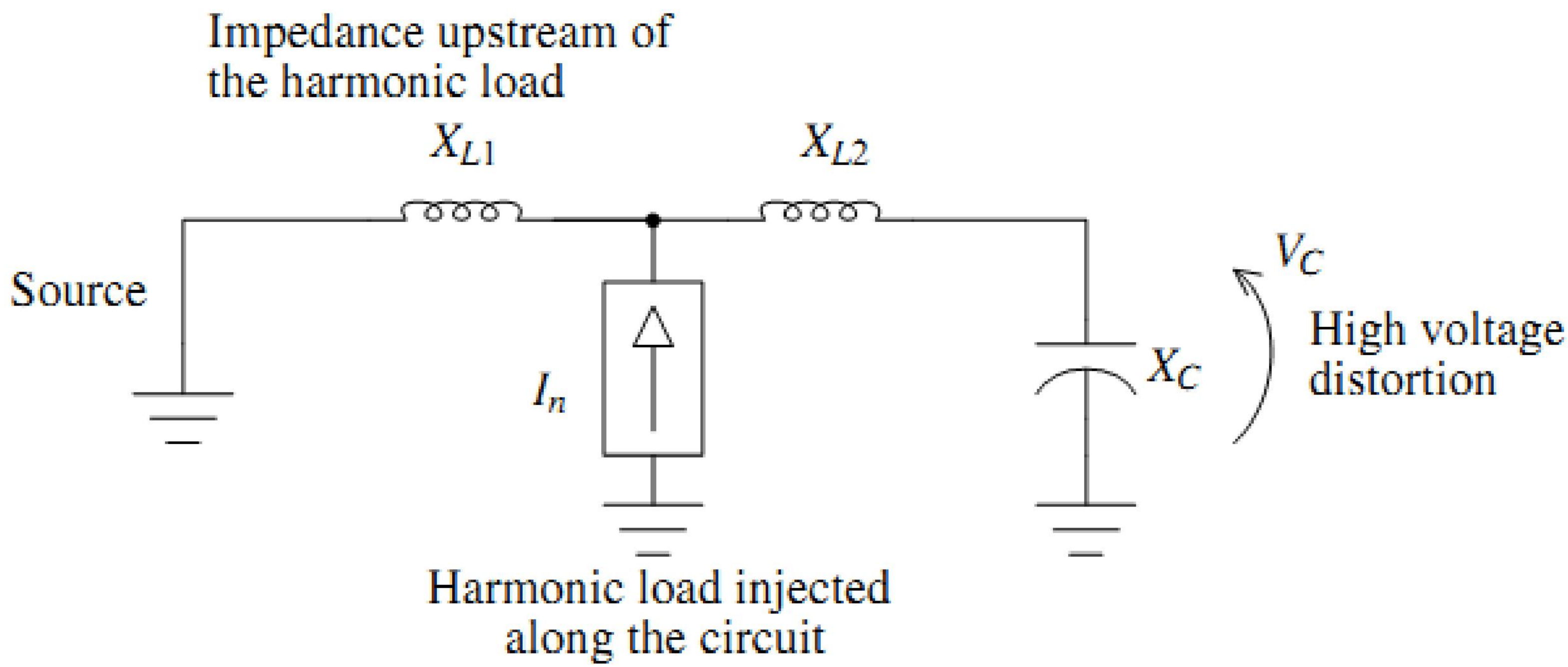
Note: Even harmonics are limited to 25% of the odd harmonic limits above. Current distortions that result in a dc offset are not allowed. For conditions lasting less than 1 h, the limits may be exceeded by 50%.

Source: IEEE Std. 519-1992.

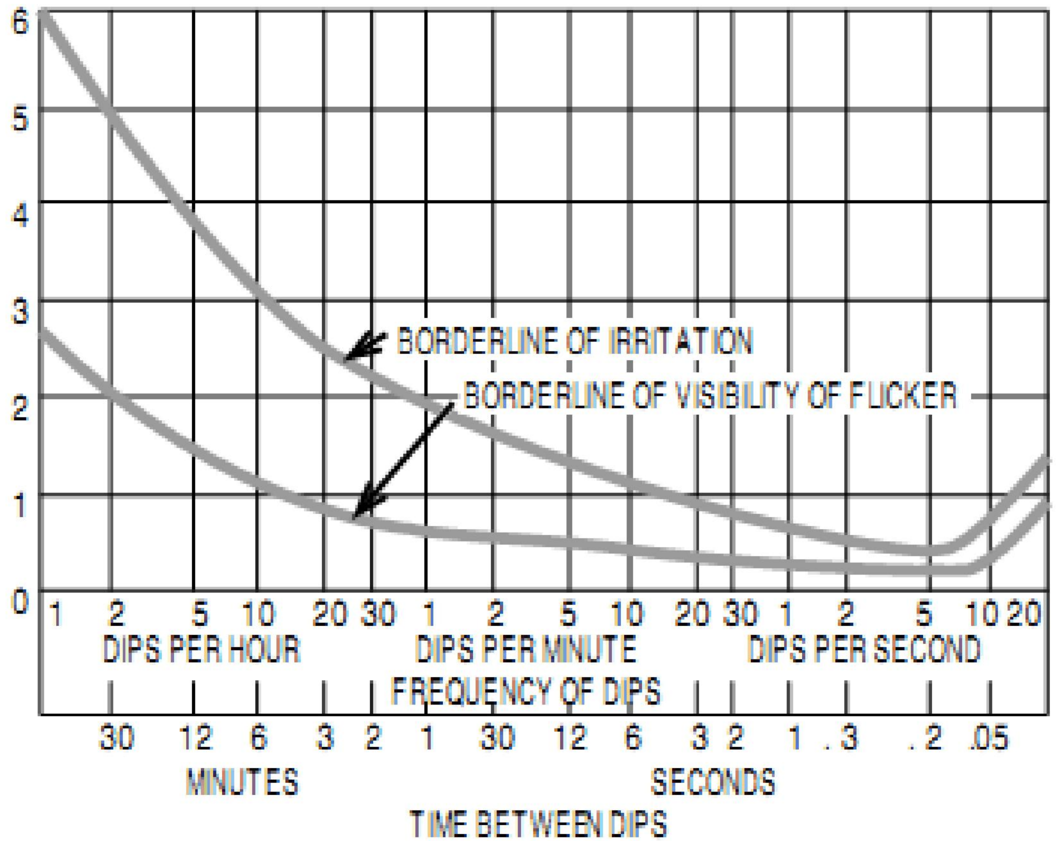


Voltage distortion
Current distortion
THD
TDD
2
3
4
5
6
7
8
9
10
11
12
13
Harmonic
0
1
2
0
2
4
Percent distortion
Percent distortion

Resonansi Harmonic

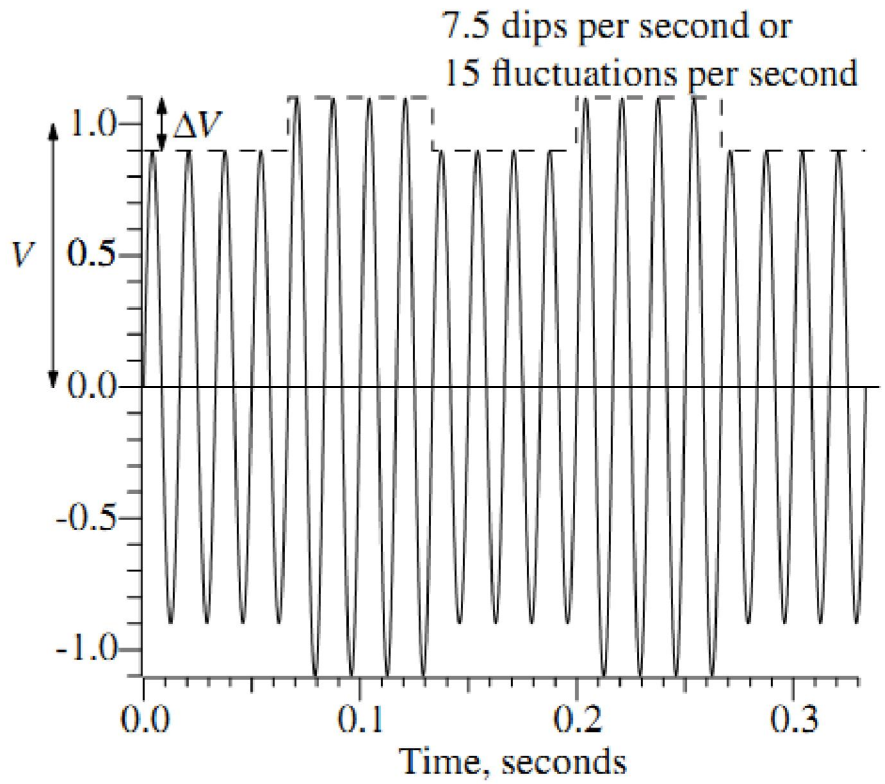


Flicker



6
5
4
3
2
1
0
BORDERLINE OF IRRITATION
BORDERLINE OF VISIBILITY OF FLICKER
1 2 5 10 20 30 1 2 5 10 20 30 1 2 5 10 20
DIPS PER HOUR
DIPS PER MINUTE
DIPS PER SECOND
FREQUENCY OF DIPS
30 12 6 3 2 1 30 12 6 3 2 1 .3 .2 .05
MINUTES
SECONDS
TIME BETWEEN DIPS

Perubahan frekuensi dan tegangan



Flicker

Thresholds Where Fluctuating Loads Will Not Cause Flicker Problems per (IEC 61000-3-7, 1995; UIEPQ-9715, 1999)

Number of Voltage changes per minute, r	$\Delta I \,/\, I_{SCr}$ %
$r > 200$	0.1
$10 \leq r \leq 200$	0.2
$r < 10$	0.4

Voltage Flicker Limits at Several Utilities during Motor Starting

Utility	Voltage Criteria
Dense urban area	3%
Urban/suburban	3%
Suburban and rural	3%
Urban and rural	3%
Rural, mountainous	4 V (on a 120-V base)
Rural, mountainous	none

Source: Willis, H. L., *Power Distribution Planning Reference Book*, Marcel Dekker, New York, 1997.

One Utility's Allowable Motor Starting Currents

System	Maximum Allowable Starting Current, A
Single Phase	
120 V	100
208 V	160
240 V	200
Three Phase	
208 V	1554
240 V	1346
480 V	673
2400 V	135

Note: Automatically controlled motors are limited to half of the allowable starting currents in the table.