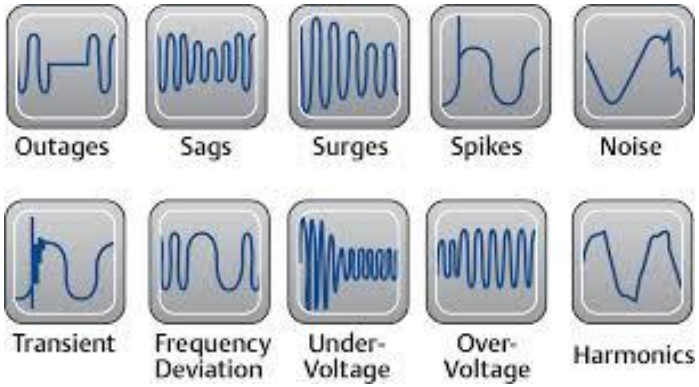


Introduction to Power Quality

Cawangan Kejuruteraan Elektrik

Program Kursus

HARI/MASA	8.30 Pagi – 10.30 Pagi	10.30-11.00 Pagi	11.00 Pagi - 1.00 T/hari	1.00 - 2.30 Ptg	2.30 Petang - 4.30 Petang	4.30 - 5.00 Ptg
15/2/2021 ISNIN	**PRE-TEST** **INTRODUCTION TO POWER QUALITY**	MINUM PAGI	**INTRODUCTION TO POWER QUALITY**	MAKAN TENGAHARI	**ELECTRICAL HARMONICS**	MINUM PETANG
	Penceramah: Ir. Hamzah Bin Ismail		**Penceramah:** Ir. Hamzah Bin Ismail		**Penceramah:** Ir. Hamzah Bin Ismail	
16/2/2021 SELASA	**WIRING & EARTHING FOR POWER QUALITY**		**POWER QUALITY MITIGATION & CONDITIONING DEVICES** **POWER QUALITY CASE STUDY AND TROUBLESHOOTING** **POST-TEST**			
	Penceramah: Ir. Hamzah Bin Ismail		**Penceramah:** Ir. Hamzah Bin Ismail			

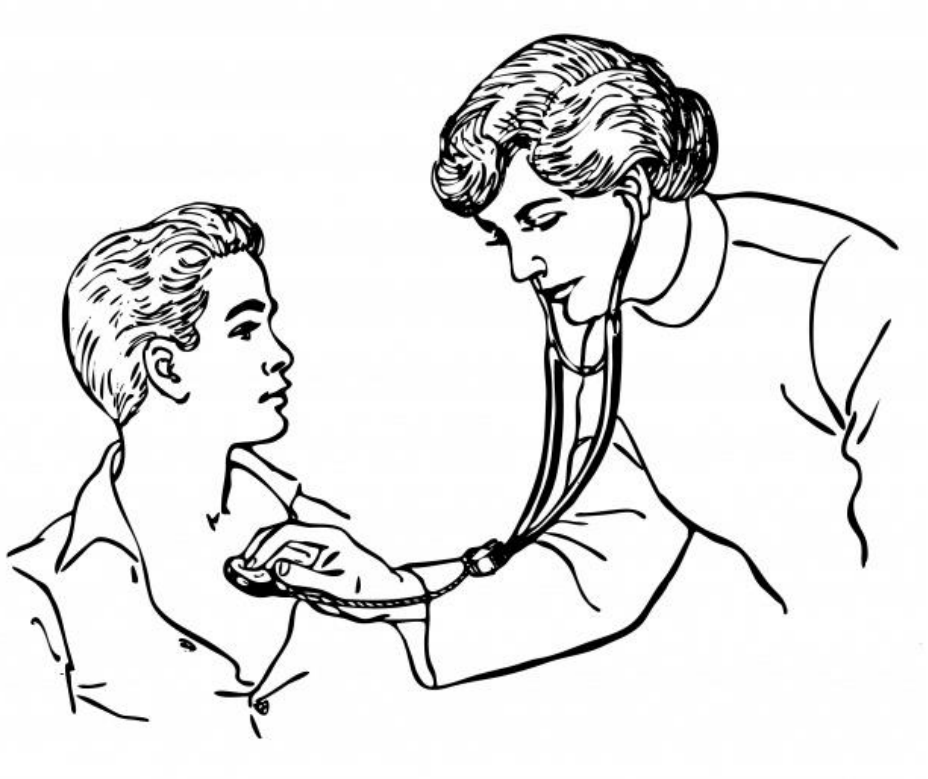
Pengenalan

- "*Electrical Power Quality*" di dalam premis perlu dipantau untuk mengelak berlakunya kerosakan dan pengurangan jangka hayat kepada peralatan elektrik, elektronik dan ICT.
- Parameter kualiti bekalan elektrik yang perlu dianalisa oleh pakar *Power Quality* adalah seperti voltan, arus, frekuensi, bentuk gelombang dan lain-lain.

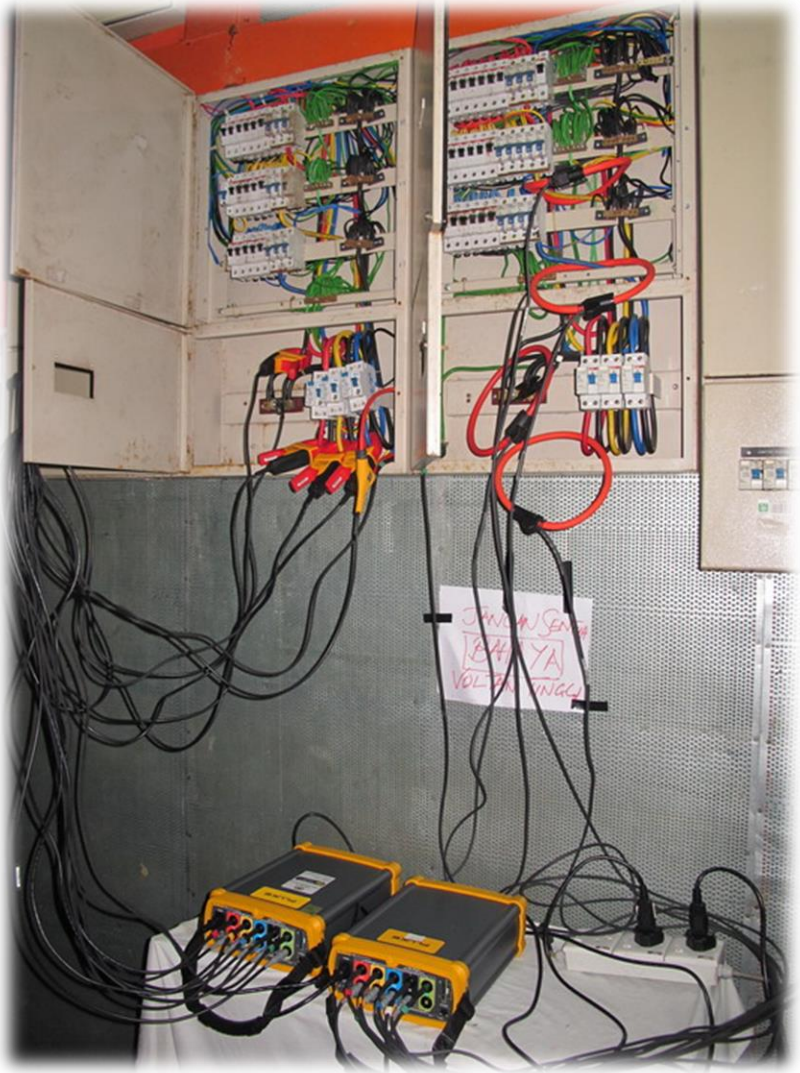
Pengenalan

- Seperti juga doktor pakar di mana mereka menggunakan x-ray, CT *Scan*, *fluoroscopy*, MRI, *mammography* dan *ultrasound* untuk menentukan jenis penyakit
- Manakala, pakar *Power Quality* menggunakan *power quality analyzer*, *voltage and current probes* untuk menentukan jenis masalah (penyakit) bekalan elektrik.

Pengenalan



stethoscope



voltage & current probe

Pengenalan

- Bagi menjadi pakar dalam bidang *Power Quality*, seorang Jurutera Elektrik memerlukan pengalaman secara meluas dan melalui proses dalam bidang pengujian khusus di tapak, diagnostik, mencari kerosakan, menganalisa data, penyiasatan di tapak, menentukan punca kerosakan dan latihan pengkhususan dalam bidang-bidang tertentu.

Pengenalan

- Semakin banyak kes yang dilaksanakan oleh seorang Jurutera Elektrik berkaitan *Power Quality*, maka tahap kepakaran jurutera tersebut dalam bidang *Power Quality* akan meningkat. Seorang Jurutera Elektrik biasa tidak dapat melaksanakan kerja-kerja *Power Quality* sekiranya tidak melalui proses seperti yang dinyatakan. Bagi menjadi pakar dalam bidang *Power Quality*, sekurang-kurangnya lima tahun pengalaman bekerja dalam bidang *Power Quality* diperlukan.

Definition Of Power Quality

Akta Bekalan Elektrik 1990 (Akta 447):

"Kualiti Kuasa" ertinya ciri-ciri elektrik pada titik yang diberikan pada suatu sistem elektrik, yang dinilaikan dengan membandingkannya dengan suatu set parameter rujukan teknikal, seperti magnitude voltan dan arus, frekuensi atau bentuk gelombang

Definition Of Power Quality

Akta Bekalan Elektrik 1990 (Akta 447):

***Seksyen* 4. Fungsi dan tugas Suruhanjaya.**

Suruhanjaya hendaklah menjalankan fungsi dan tugas seperti yang berikut:

(d) untuk menjalankan fungsi pengawalseliaan berkenaan dengan kepentingan pengguna dan penguatkuasaan berkenaan dengan –

(iv) kualiti bekalan elektrik yang termasuklah kebolehpercayaan dan kualiti kuasa;

Definition Of Power Quality

IEEE 1100

- The concept of powering and grounding electronic equipment in a manner that is suitable to the operation of that equipment and compatible with the premise wiring system and the other connected equipment. Powering means deviations in the voltage waveform from the ideal sine waves.

Definition Of Power Quality

IEEE 1100

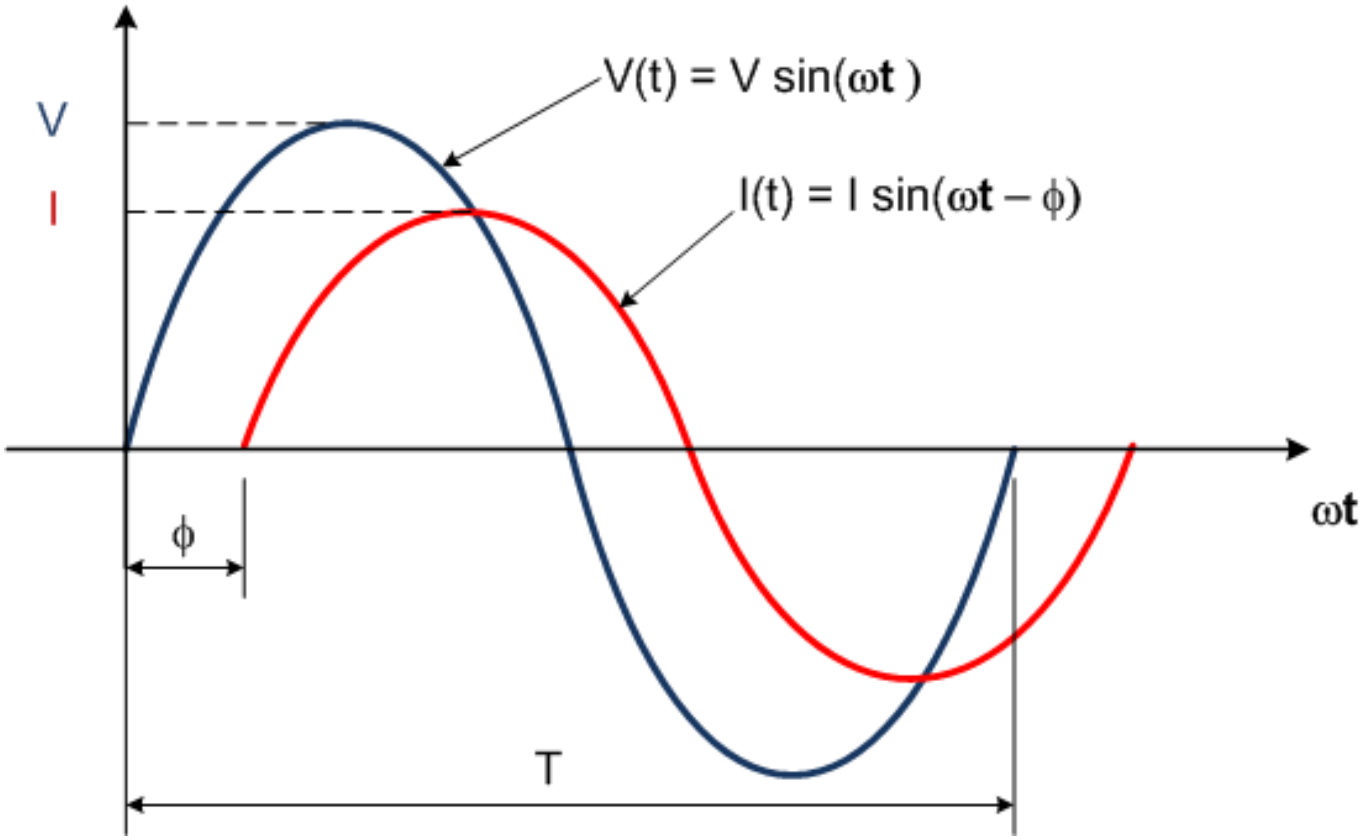
- Electronic equipment *(sensitive equipment)* means:
  - Every electronic load has a low voltage limit and a high voltage limit in which the load is designed to operate properly
  - Most devices are listed for a given voltage with a ± voltage variation limit

Definition Of Power Quality

IEEE 1100

- Powering electronic equipment

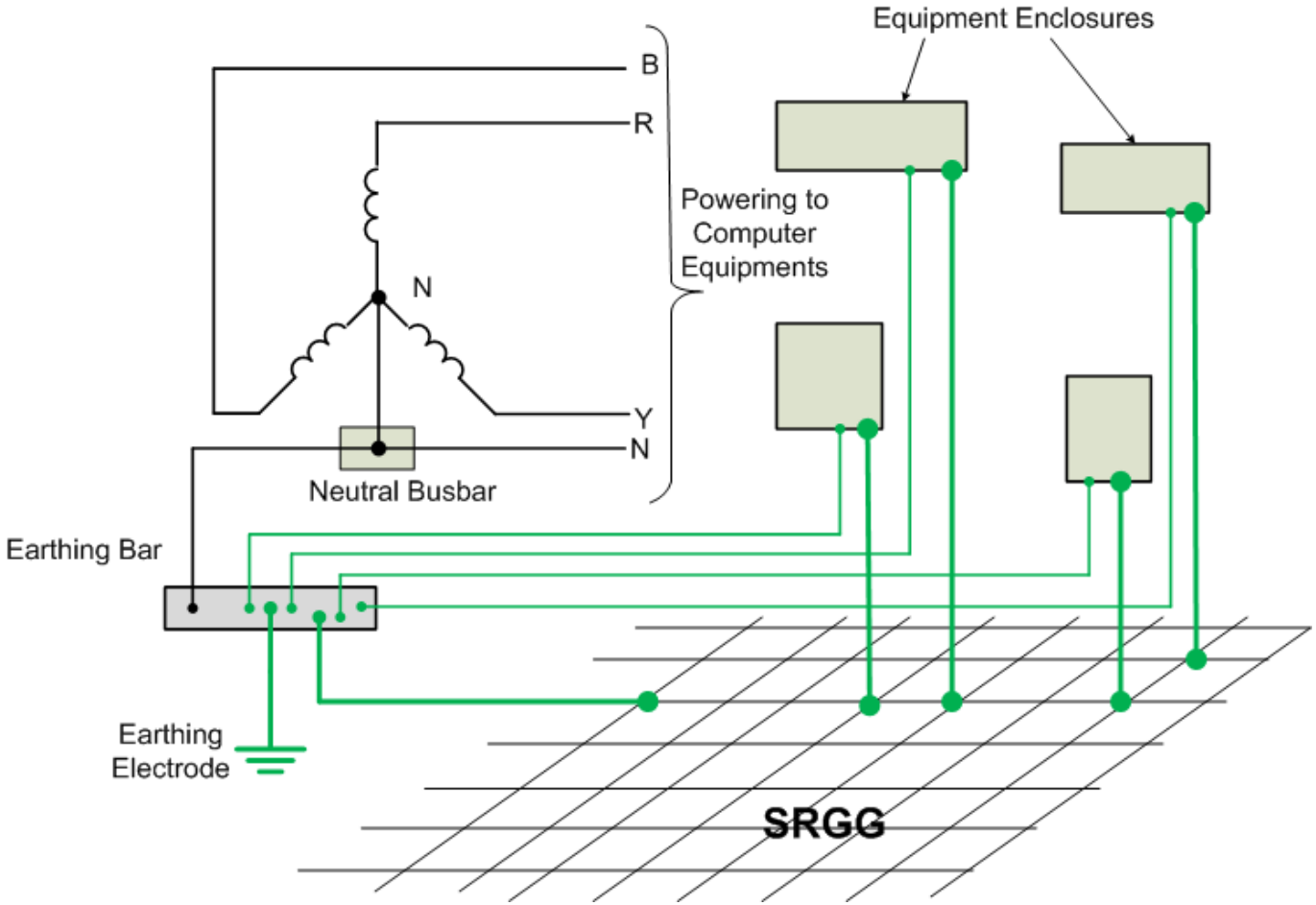
With acceptable voltage magnitude and shape



Definition Of Power Quality

IEEE 1100

- Grounding electronic equipment (Proper)



Definition Of Power Quality

IEC 61000-1-1:

Electromagnetic Compatibility (EMC) is the ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment

Definitions of PQ from TNB's website:

Power Quality or Voltage Quality refers to the changing of the perfect sinusoidal voltage waveform to non sinusoidal or distorted voltage waveform.

Definition Of Power Quality

- Power quality also means voltage quality because most of the power quality problems are referred to nominal voltage as reference.
- The official nominal voltage in Malaysia is 230/400 V with the tolerance of +10%, -6% for 3-phase 4 wire low voltage (LV) systems.

POWER QUALITY STANDARDS

IEC Standards, called Electromagnetic Compatibility Standards

a. General (IEC 61000-1-x)
b. Environment (IEC 61000-2-x)
c. Limits (IEC 61000-3-x)
d. Testing and Measurement Techniques (IEC 61000-4-x)
e. Installation and mitigation guidelines (IEC 61000-5-x)
f. Generic Standards (IEC 61000-6-x)

IEEE Standards

a. IEEE Standard 142-1991 – Grounding
b. IEEE Standard 519-1992 - Harmonic Control
c. IEEE Standard 1100 -1999 – Powering and Grounding
d. IEEE Standard 1159-1995 – Monitoring
e. IEEE standard 1346-1998 – Evaluating Electric Power System Compatibility

POWER QUALITY CONCERNS

- Economic impact on utilities, customers and equipment suppliers.
- The symptoms of poor PQ include equipment resets, corrupted data, premature equipment failure, over heating of components for no apparent cause, etc.

CAUSES OF PQ PROBLEMS

Two categories:

- Disturbances arising in the power system (utility).
- Disturbances induced by the operation of customer equipment (facility).

→ The electric utility company has long been viewed as the major source of power disturbances. This is not generally true.

→ Electrical problems within the building are responsible for most power disturbances.

POWER QUALITY PROBLEMS

- power interruption (outage)
- overvoltage
- undervoltage
- voltage and current unbalance
- high neutral to earth voltage
- neutral to earth voltage impulse
- surges (transients)
- voltage dips (sags)
- voltage swell
- voltage fluctuations
- harmonics
- direct current (DC) offset
- noise

13 Power Quality Disturbances

POWER QUALITY PROBLEMS

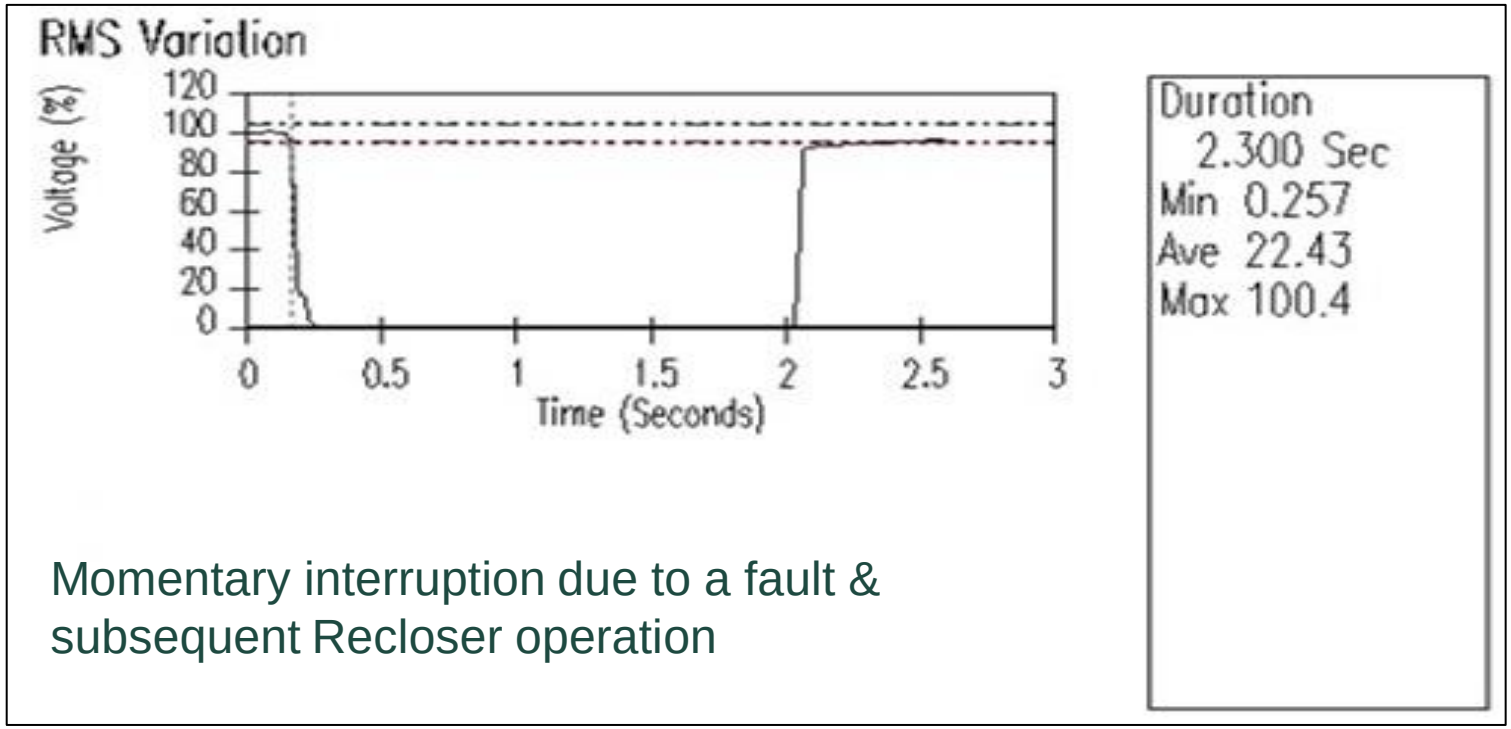
- Power Interruption (Outage)
  - Momentary interruption
  - Temporary interruption
  - Sustained interruption

POWER QUALITY PROBLEMS

- Power Interruption (Outage)
  - Momentary interruption
    - Duration: 10 ms – 3 s
    - Voltage magnitude: < 10 % nominal voltage
    - Cause: switching operations trying to isolate an electrical problem when lightning strikes nearby (e.g. short on one phase) and maintain power to your area
    - Possible Effects: equipment trips off, programming is lost, or disc drive crashes

POWER QUALITY PROBLEMS

- Power Interruption (Outage)
  - Momentary interruption



Momentary interruption due to a fault & subsequent Recloser operation

POWER QUALITY PROBLEMS

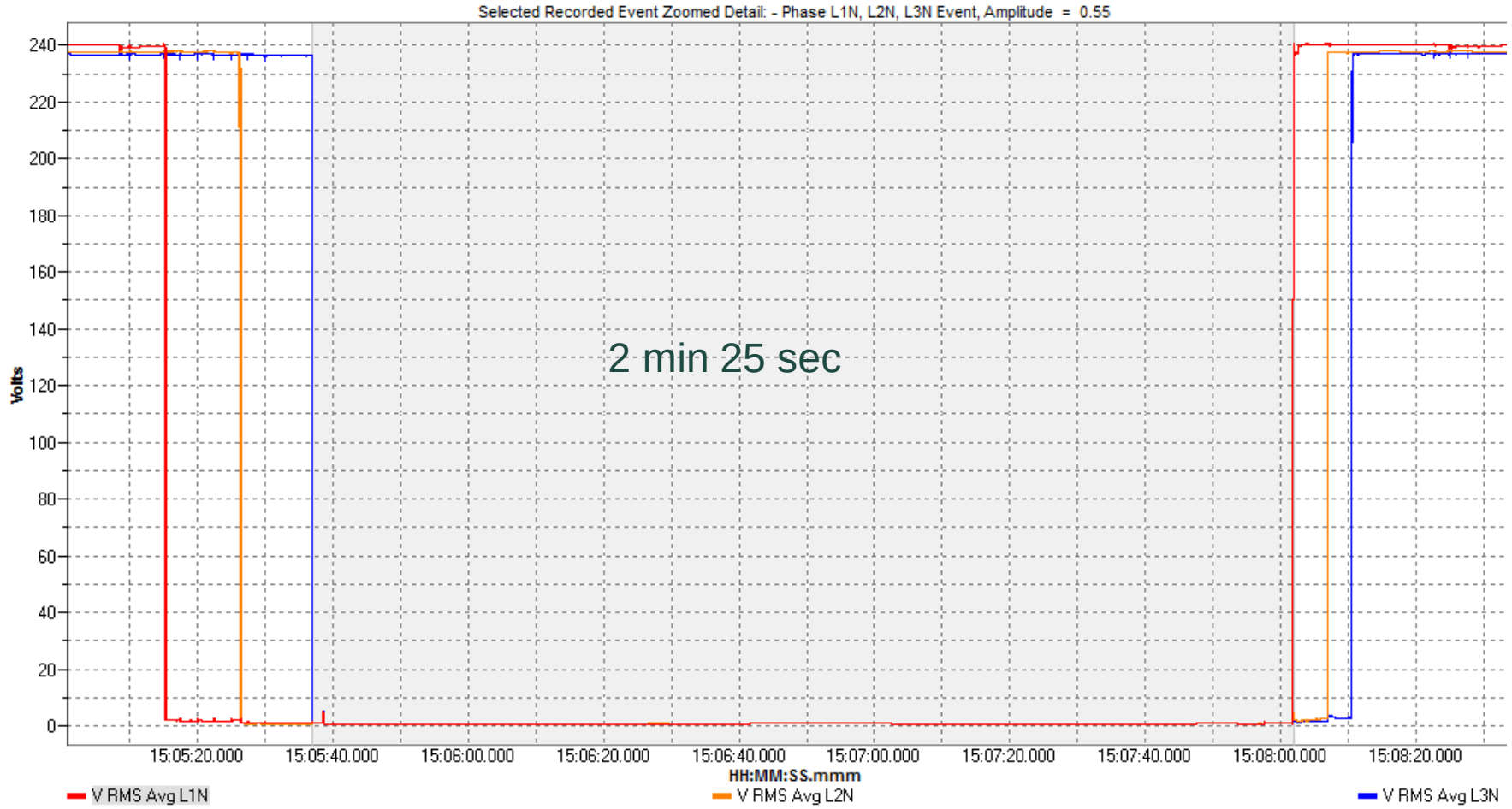
- Power Interruption (Outage)
  - Temporary interruption
    - Duration: > 3 s – 1 min
    - Voltage magnitude: < 10 % nominal voltage
    - Cause: utility power failure and a time gap between power interruption and when a genset takes over (15 s).
    - Possible Effects: systems shut down

POWER QUALITY PROBLEMS

- Power Interruption (Outage)
  - Sustained interruption
    - Duration: > 1 min
    - Voltage magnitude: < 10 % nominal voltage
    - Cause: utility or customer equipment failure
    - Possible Effects: systems shut down

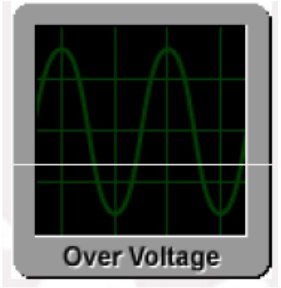
POWER QUALITY PROBLEMS

- Power Interruption (Outage)



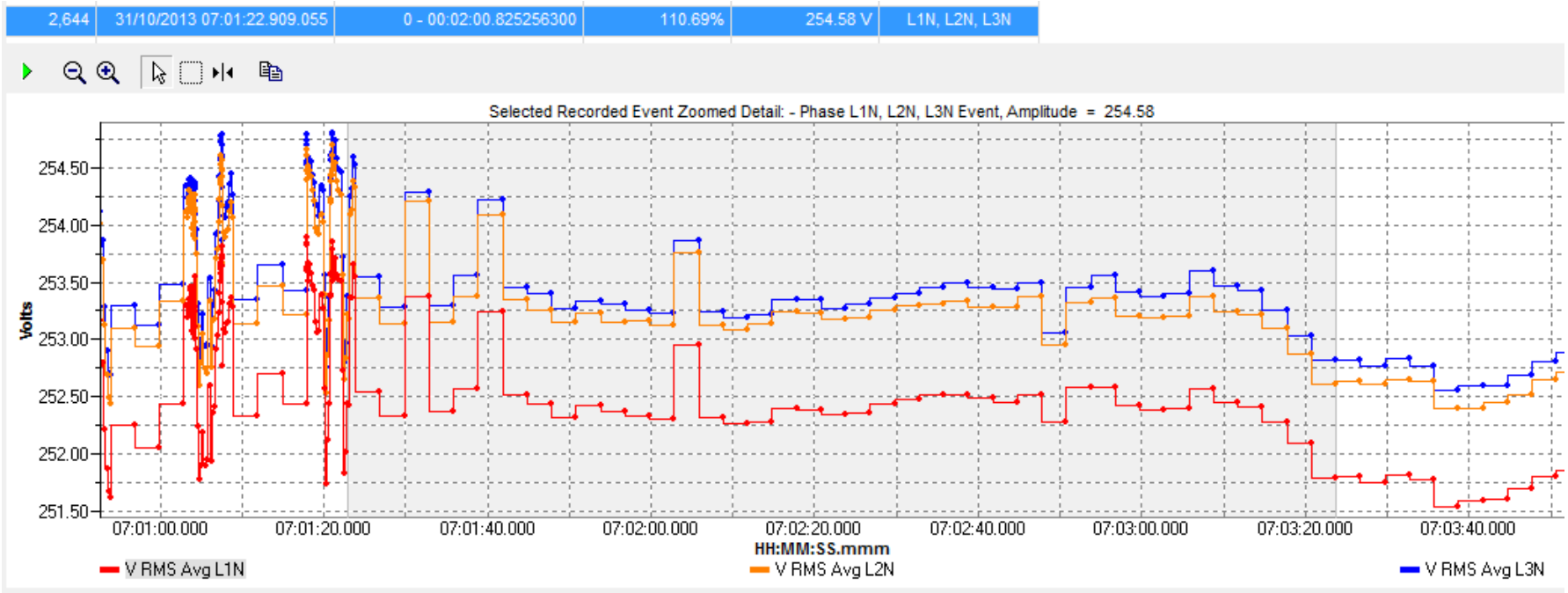
POWER QUALITY PROBLEMS

- Overvoltage
  - Duration: > 1 min
  - Voltage magnitude: ≥ 110 % nominal voltage
  - Cause: load switching (e.g. switching OFF a large load or energizing a capacitor bank), incorrect tap changer settings on transformers
  - Possible Effects: equipment failure and overheating (reduction in length of life of equipment)



POWER QUALITY PROBLEMS

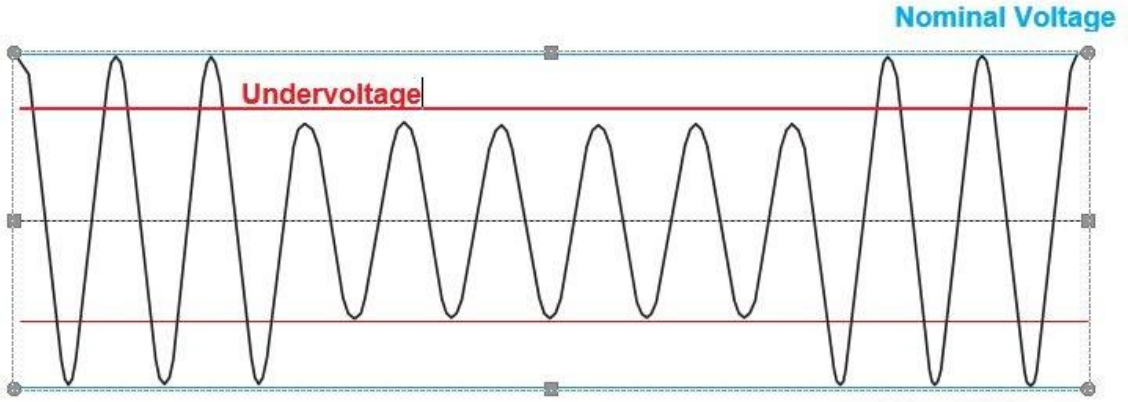
- Overvoltage

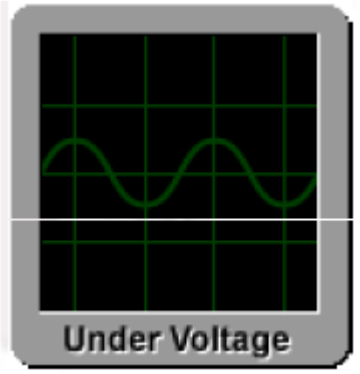


2 minute overvoltage

POWER QUALITY PROBLEMS

- Undervoltage
  - Duration: > 1 min
  - Voltage magnitude: ≤ 90 % nominal voltage
  - Cause: overloaded transformers, undersized cables, overloaded circuits
  - Possible Effects: memory loss or data errors, dim or bright lights, equipment shutdown/reset



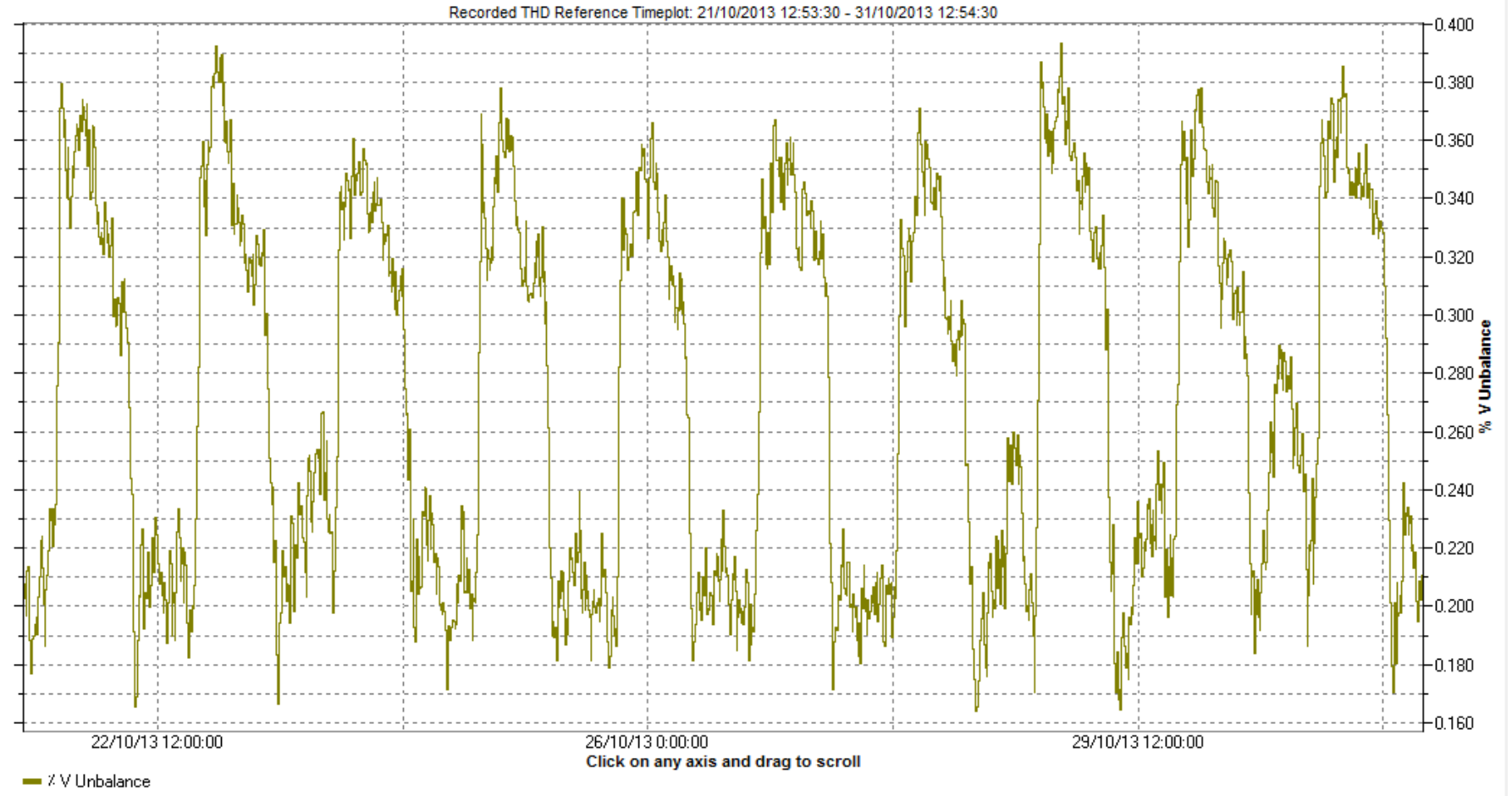


POWER QUALITY PROBLEMS

- Voltage Unbalance
  - Duration: ≥ 10 minute (steady state)
  - Voltage magnitude: ≥ 2 % between the phases
  - Cause: severe load unbalance, loose connections, blown fuse in one phase of capacitor bank, single-phasing (operation of a 3ph load on 2 phases).
  - Possible Effects: current unbalance, stator windings becomes blackened, higher than normal current in three-phase rectifiers.

POWER QUALITY PROBLEMS

- Voltage Unbalance

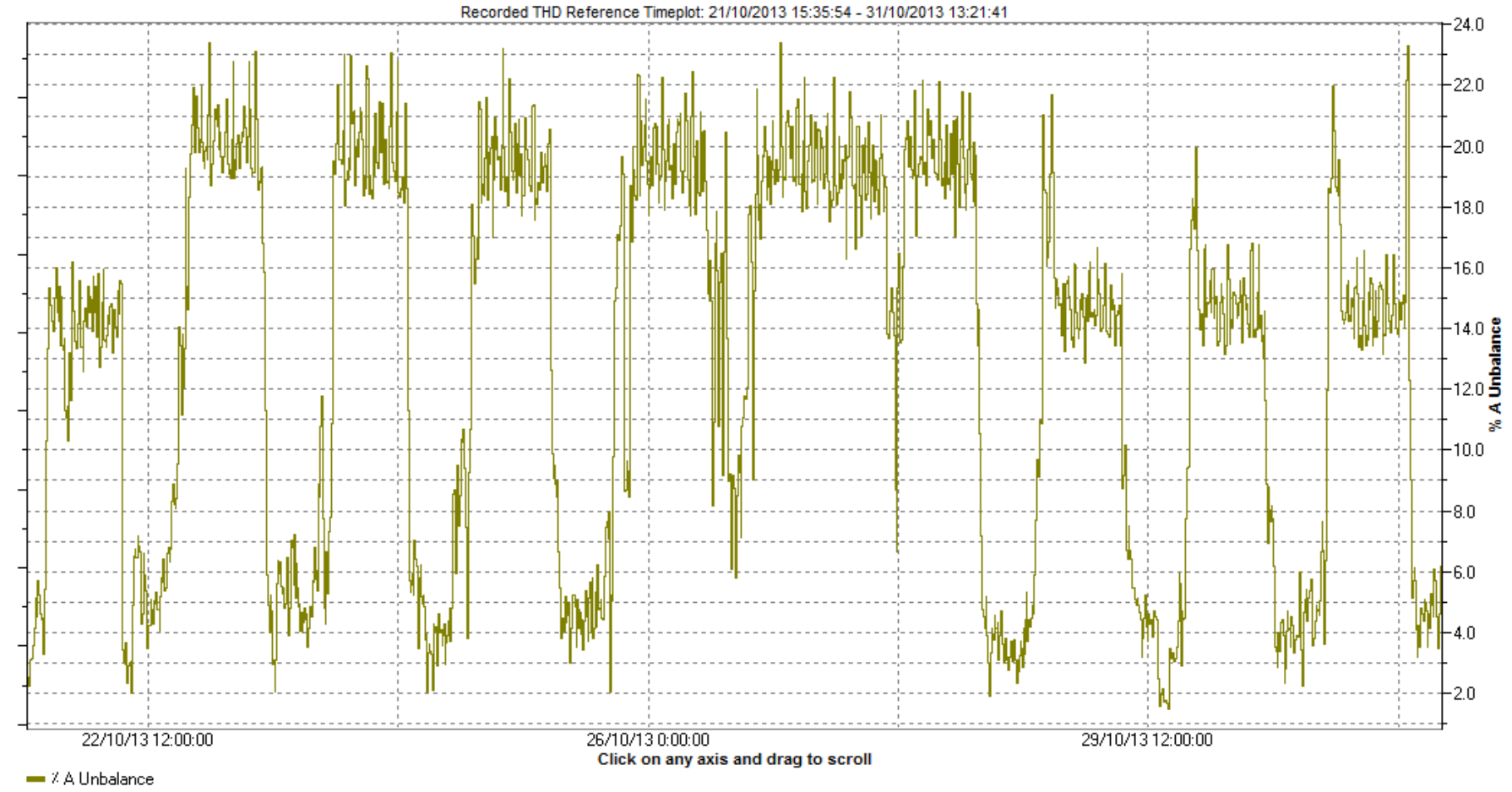


POWER QUALITY PROBLEMS

- Current Unbalance
  - Duration: ≥ 10 minute (steady state)
  - Current magnitude: ≥ 30 % between the phases
  - Cause: voltage unbalance, high current unbalance can be an indication of motor problems (damaged winding insulation), load unbalance.
  - Possible Effects: insulation breakdown (excessive heat), current flowing in the neutral conductor, nuisance tripping to the circuit breaker

POWER QUALITY PROBLEMS

- Current Unbalance

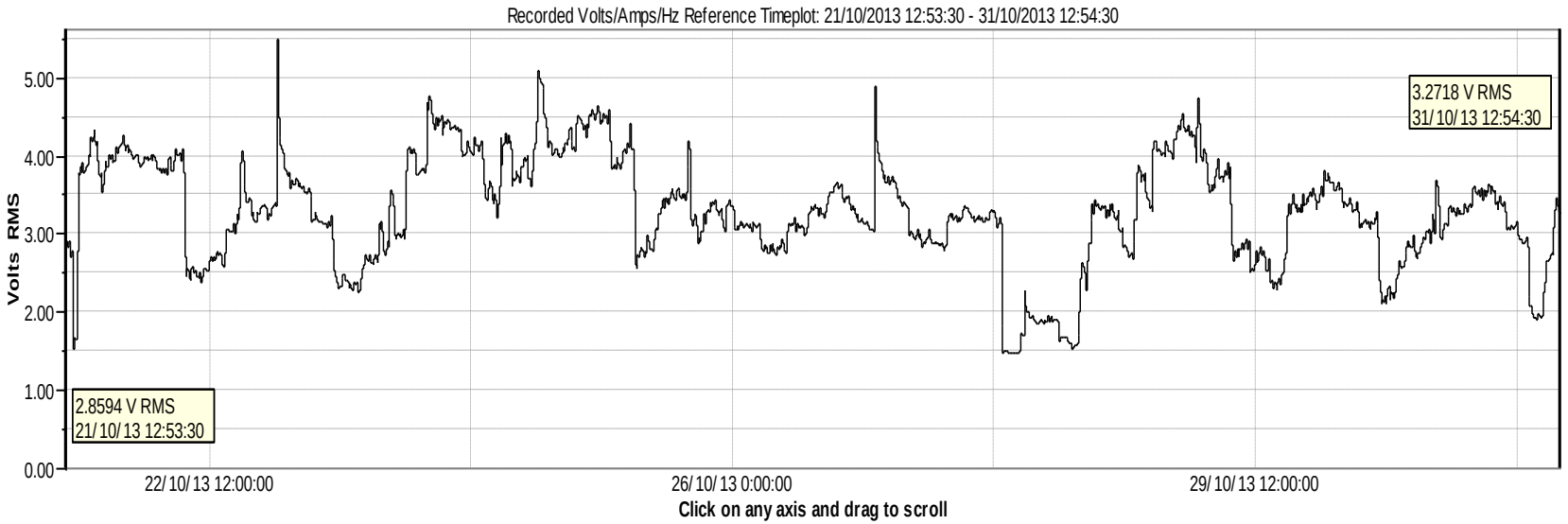


POWER QUALITY PROBLEMS

- High Neutral to Earth Voltage
  - Duration: ≥ 10 minute (steady state)
  - Voltage magnitude: ≥ 3 V
  - Cause: shared neutral, loose connection at the earth electrode, harmonics
  - Possible Effects: interference on data centres' devices

POWER QUALITY PROBLEMS

- High Neutral to Earth Voltage

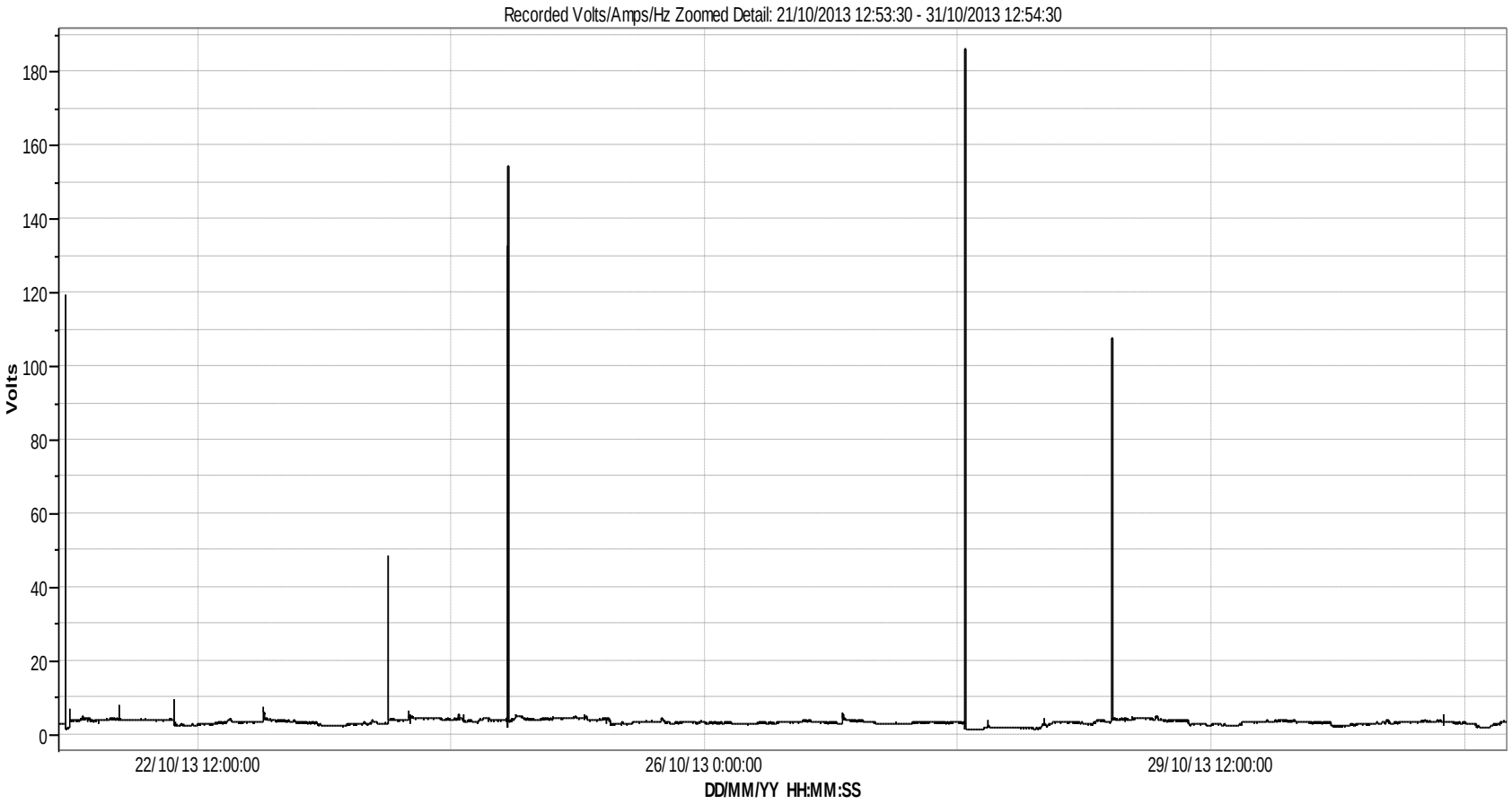


POWER QUALITY PROBLEMS

- Neutral to Earth Voltage Impulse
  - Duration: ≤ 70 ms
  - Voltage magnitude: ≥ 20 V
  - Cause: intermittent single line-to-earth fault
  - Possible Effects: equipment damage over time, nuisance tripping of RCCB, erratic data transfer (*pemindahan data yang tidak menentu)*

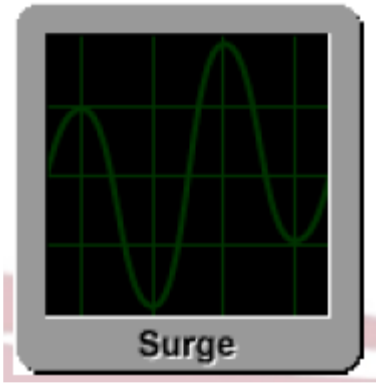
POWER QUALITY PROBLEMS

- Neutral to Earth Voltage Impulse



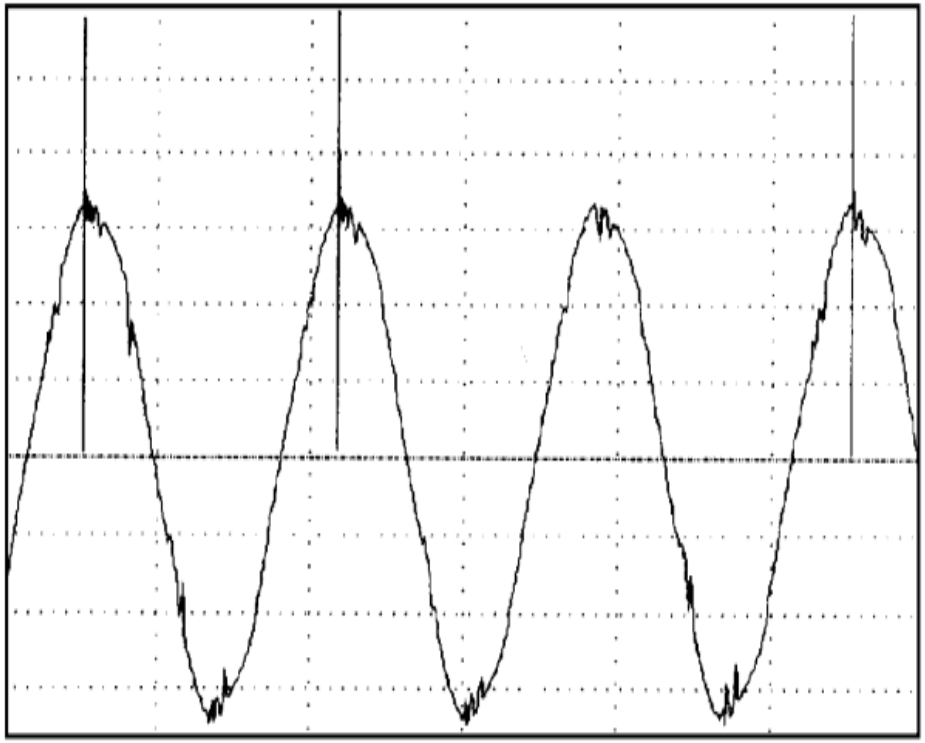
POWER QUALITY PROBLEMS

- Surges (transients)
  - Duration: < 10 ms
  - Voltage magnitude: ≤ 20 kV
  - Cause: lightning strikes, switching ON and OFF.
  - Possible Effects: processing errors, data loss, burned circuit boards

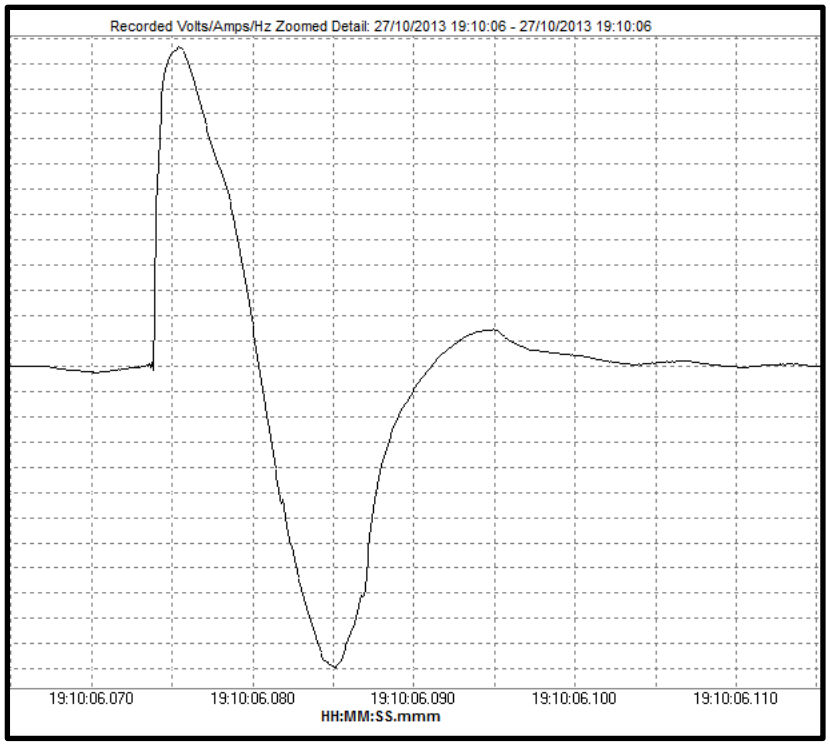


POWER QUALITY PROBLEMS

- Surges (transients)



IMPULSIVE TRANSIENT



OSCILLATORY TRANSIENT

POWER QUALITY PROBLEMS

- Voltage Dips (Sags)
  - Duration: 10 ms - 1 minute
  - Voltage magnitude: 10 % (not to 0 V) - 90 % nominal voltage
  - Cause:
    - system faults (short circuits),
    - lightning strikes which will create a single line-to-earth fault (auto reclosers operate),
    - energization of heavy loads which require high inrush currents for starting,
    - starting of large motors can cause voltage dips on undersized systems
    - intermittent loose connections of terminals

POWER QUALITY PROBLEMS

- Voltage Dips (Sags)
  - Possible Effects:
    - equipment shutdown by tripping the undervoltage protection,
    - data corruption in microprocessor-based equipment
    - high-intensity discharge (HID) lamp to turn OFF for several minutes

POWER QUALITY PROBLEMS

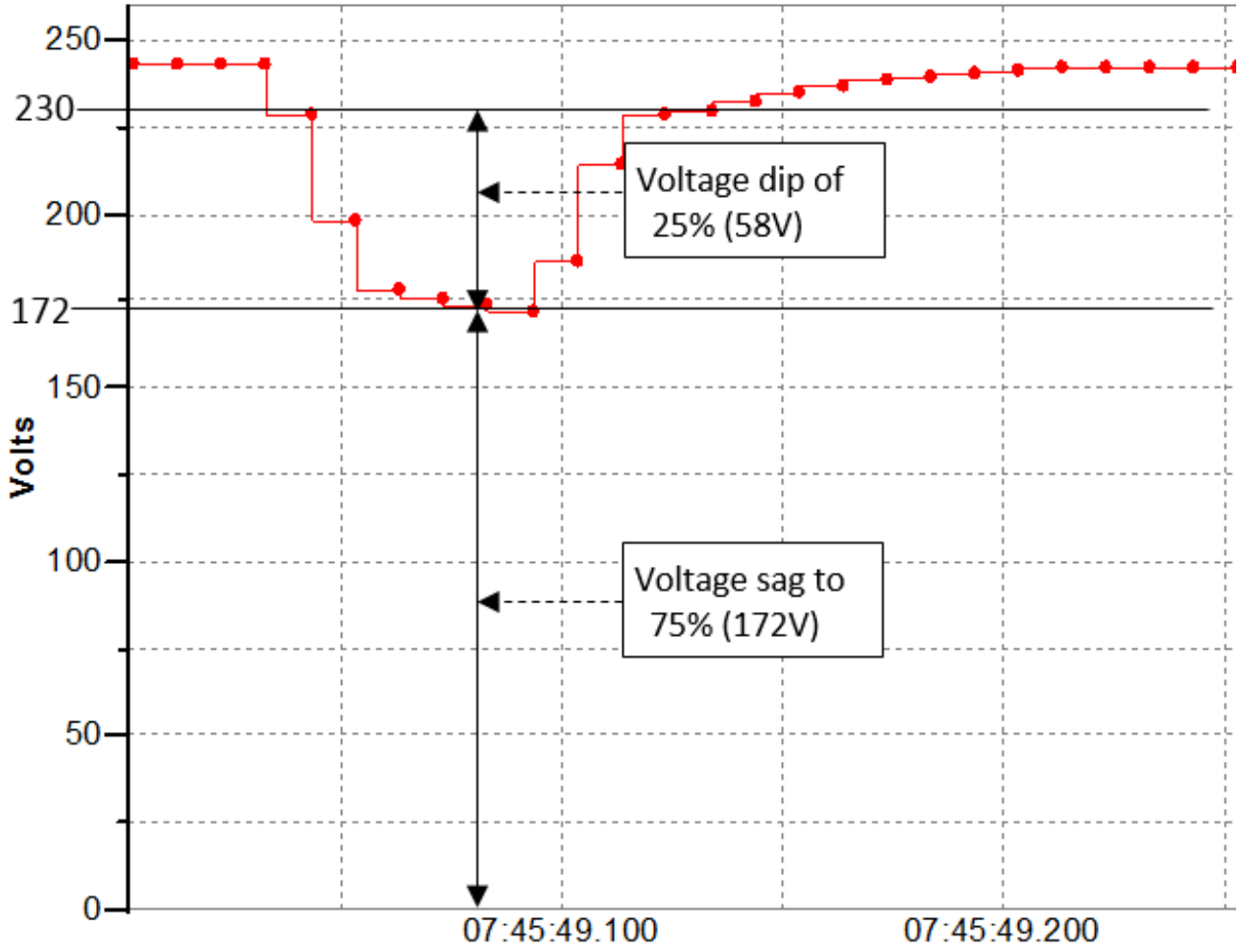
- Voltage Dips (Sags)
  - This voltage sag is also known as voltage dip.
  - It is important to understand the difference definition between voltage dip and voltage sag.
  - The IEC standard describes voltage dip as the difference between the voltage, during the voltage dip and the nominal voltage.
  - The magnitude of voltage dip is expressed as a percentage of the nominal voltage. A “dip of 25 %” can refer to the depth of the voltage dip

POWER QUALITY PROBLEMS

- Voltage Dips (Sags)
  - According to IEEE 1159, the preferred terminology is “a sag to 75 %”, which means that the voltage sag magnitude is defined as the remaining voltage during the event.

POWER QUALITY PROBLEMS

- Voltage Dips (Sags)

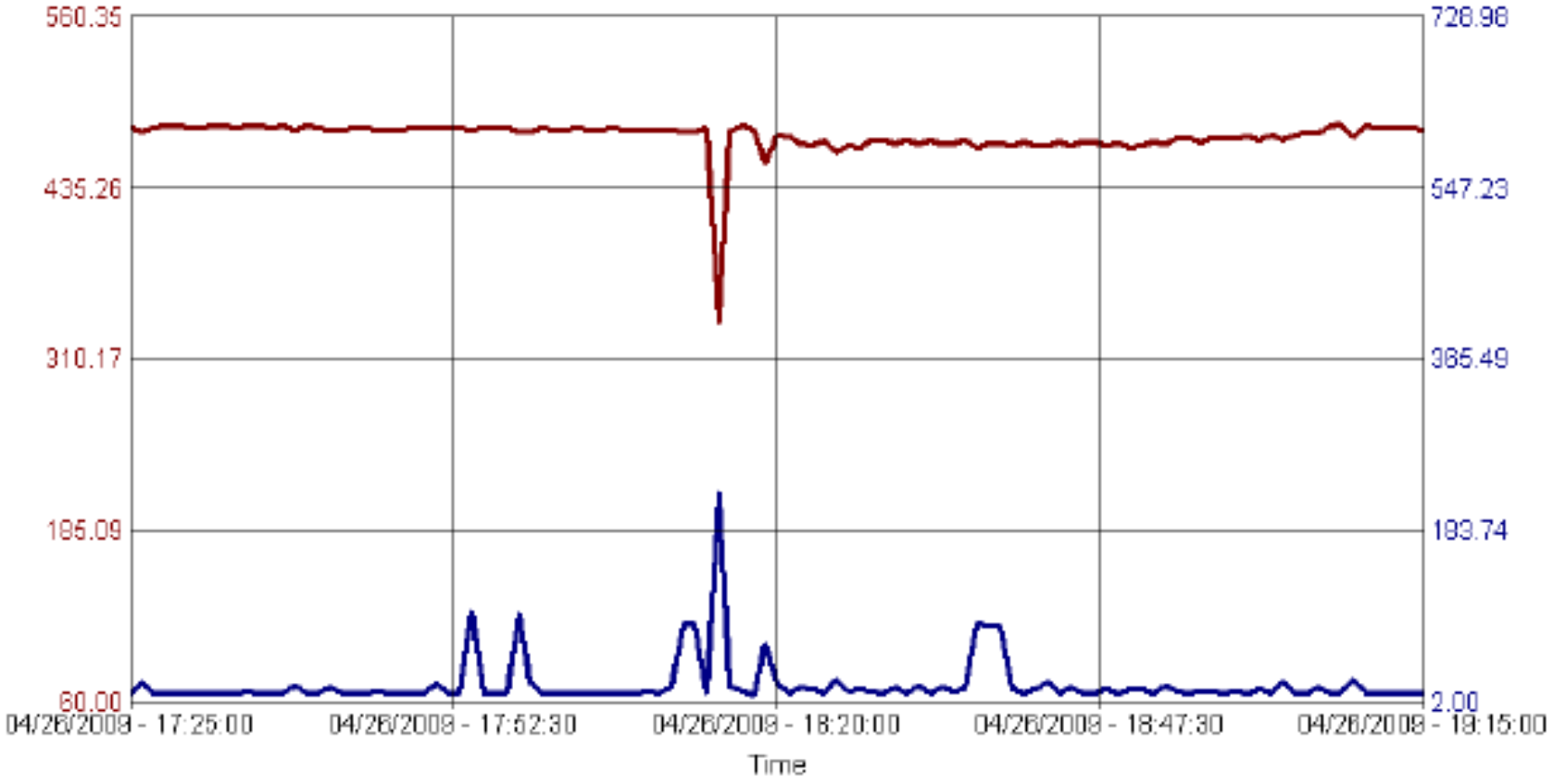


POWER QUALITY PROBLEMS

- Voltage Dips (Sags)
  - In order to locate the source of voltage sag, it can be determined by comparing voltage and current magnitudes recorded on the measurement point.
  - If voltage decreases and current increases slightly, decreases or drops to zero, the voltage sag is coming from upstream of the measurement point.
  - When the voltage decreases while the large current increases, the origin of voltage sag is located downstream.

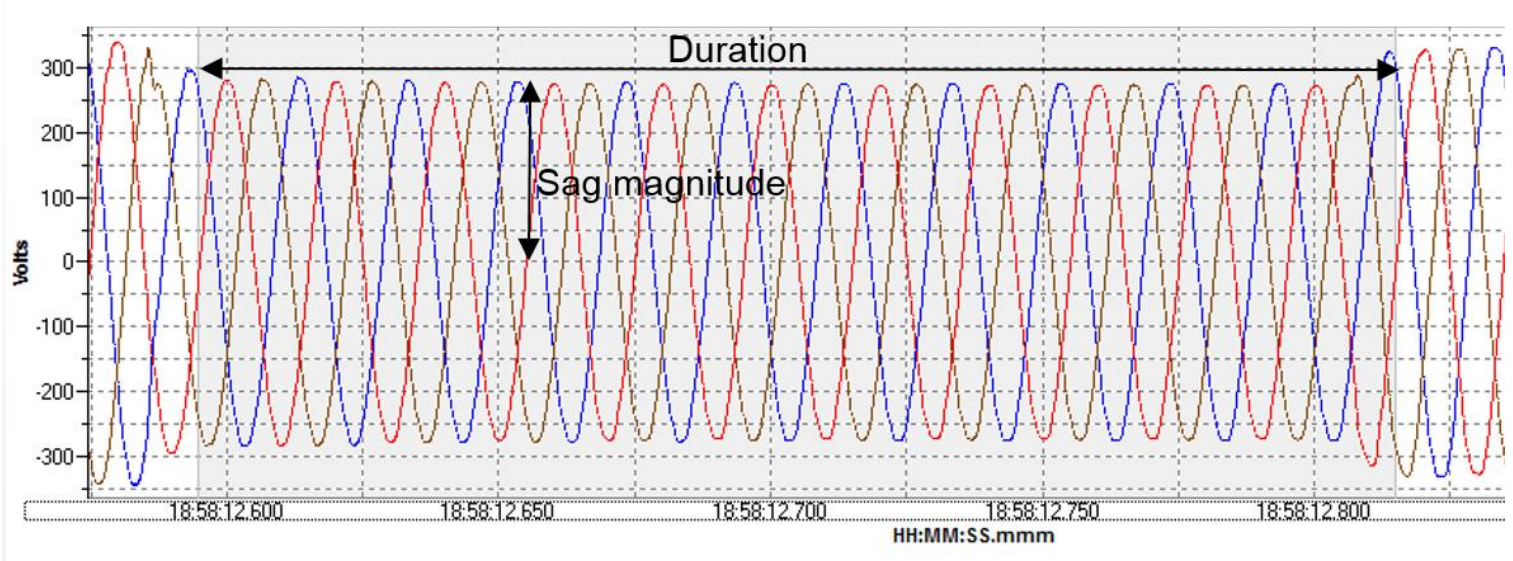
POWER QUALITY PROBLEMS

- Voltage Dips (Sags)



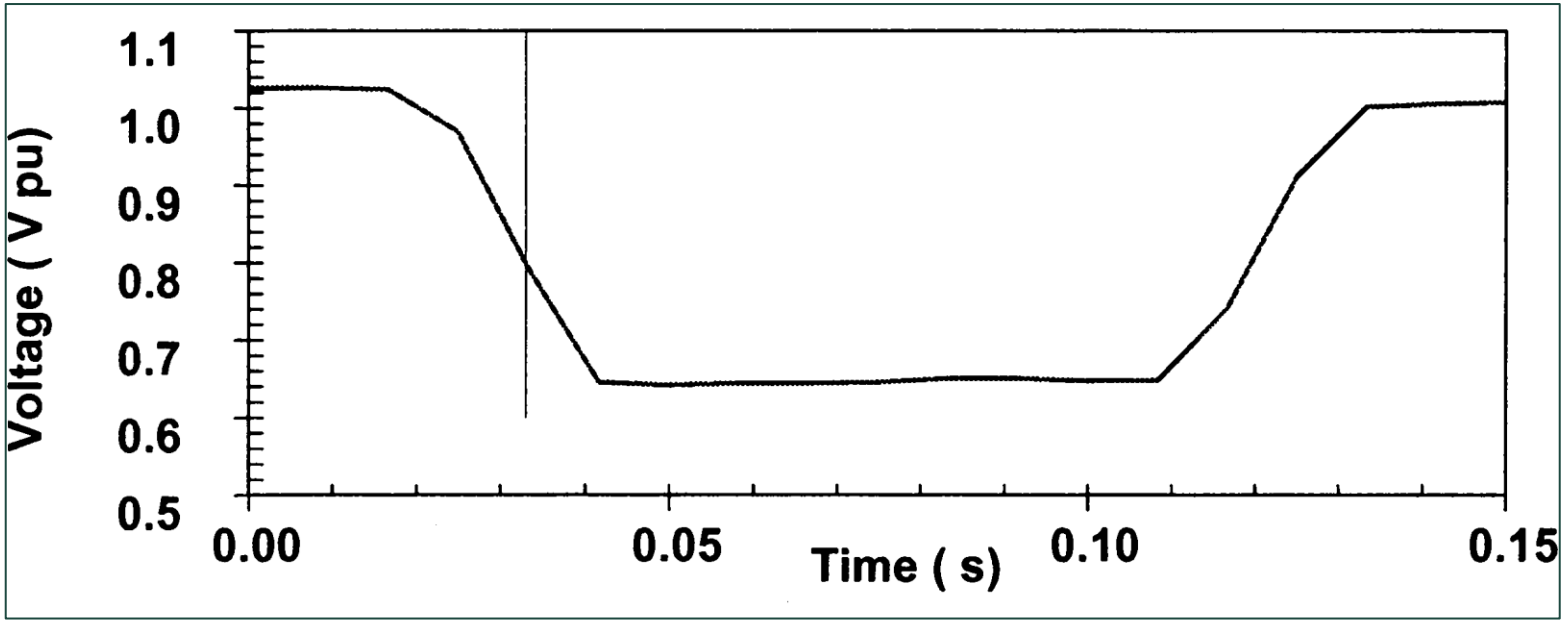
POWER QUALITY PROBLEMS

- Voltage Dips (Sags)
  - The magnitude of voltage sag are related to the distance from fault location.
  - The duration of voltage sag is determined by the automatic recloser to open and reclosing when fault.



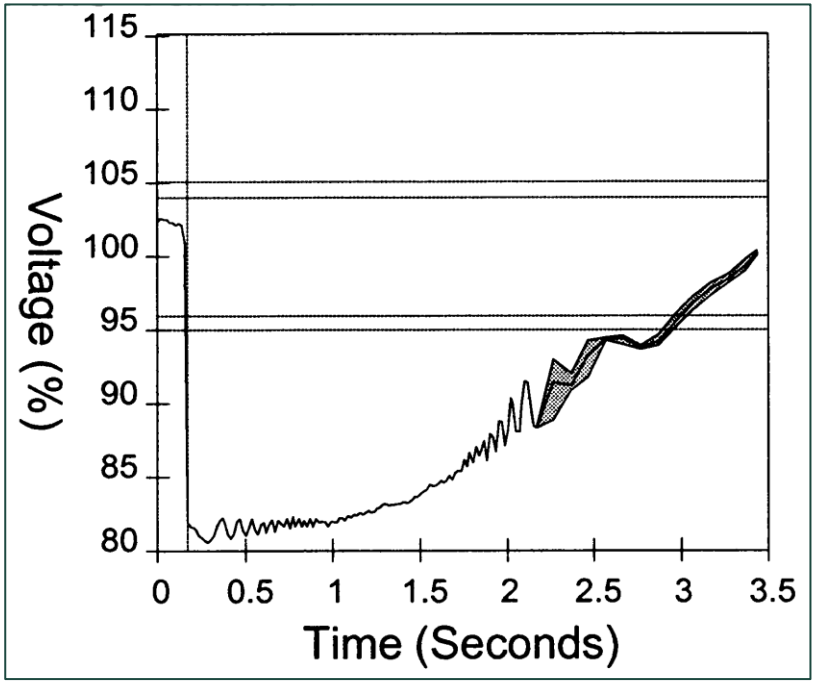
POWER QUALITY PROBLEMS

- Voltage Dips (Sags)
  - A voltage sag wave shape due to a fault is rectangular, the voltage is constant during the fault and then recovers fast after fault clearing.



POWER QUALITY PROBLEMS

- Voltage Dips (Sags)
  - A non-rectangular wave shape of voltage sag is caused by motor starting. In this case, the voltage drop fast at beginning and gradually recovered



POWER QUALITY PROBLEMS

- Voltage Dips (Sags)
  - TNB's ESAH

    1.3.2.3 It is the responsibility of the consumer to ensure that his/her voltage sensitive equipment is able to function continuously through unanticipated voltage sags, caused when the system is subject to external interference such as lightning, 3rd party cable damage, other consumer's equipment fault, TNB equipment fault etc.

POWER QUALITY PROBLEMS

- Voltage Dips (Sags)
  - TNB's ESAH

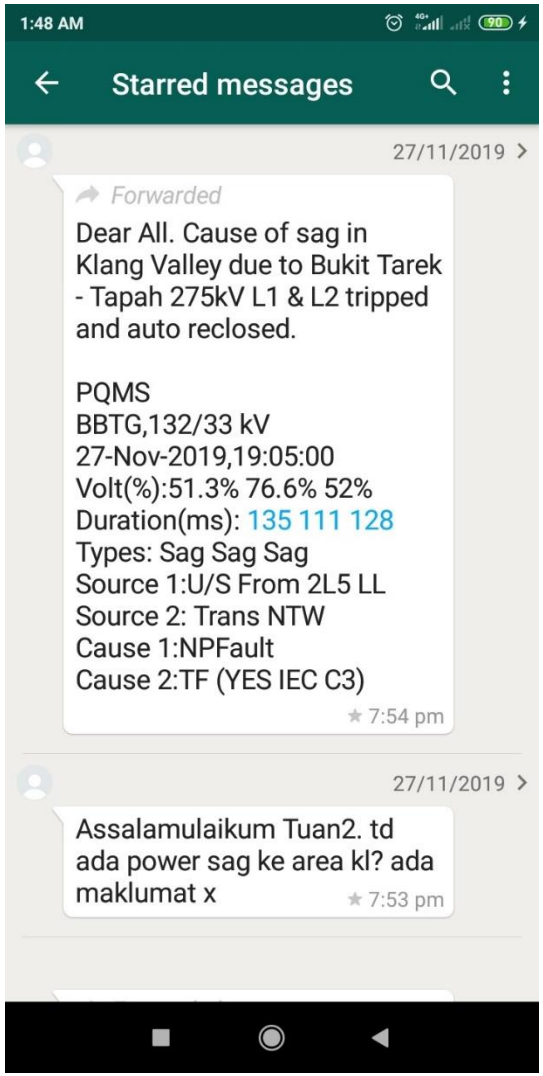
1.3.2.4 The consumer must select modern equipment that is able to ride through many of these voltage sags. Consumers should ask their equipment manufacturers whether their equipment can function properly during the voltage sag conditions illustrated in the European Standard EN 50160, IEC Standard 61000-2-2 and IEC Standard IEC 61000-2-4. If the equipment does not have any immunity to voltage sags, then the consumer should request from the manufacturers on measures to immune the equipment against voltage sags.

POWER QUALITY PROBLEMS

- Voltage Dips (Sags)
  - Ride through
    - Ride through capability is the ability of a power supply to deliver usable power for a limited time during a power loss.

POWER QUALITY PROBLEMS

- Voltage Dips (Sags)



POWER QUALITY PROBLEMS

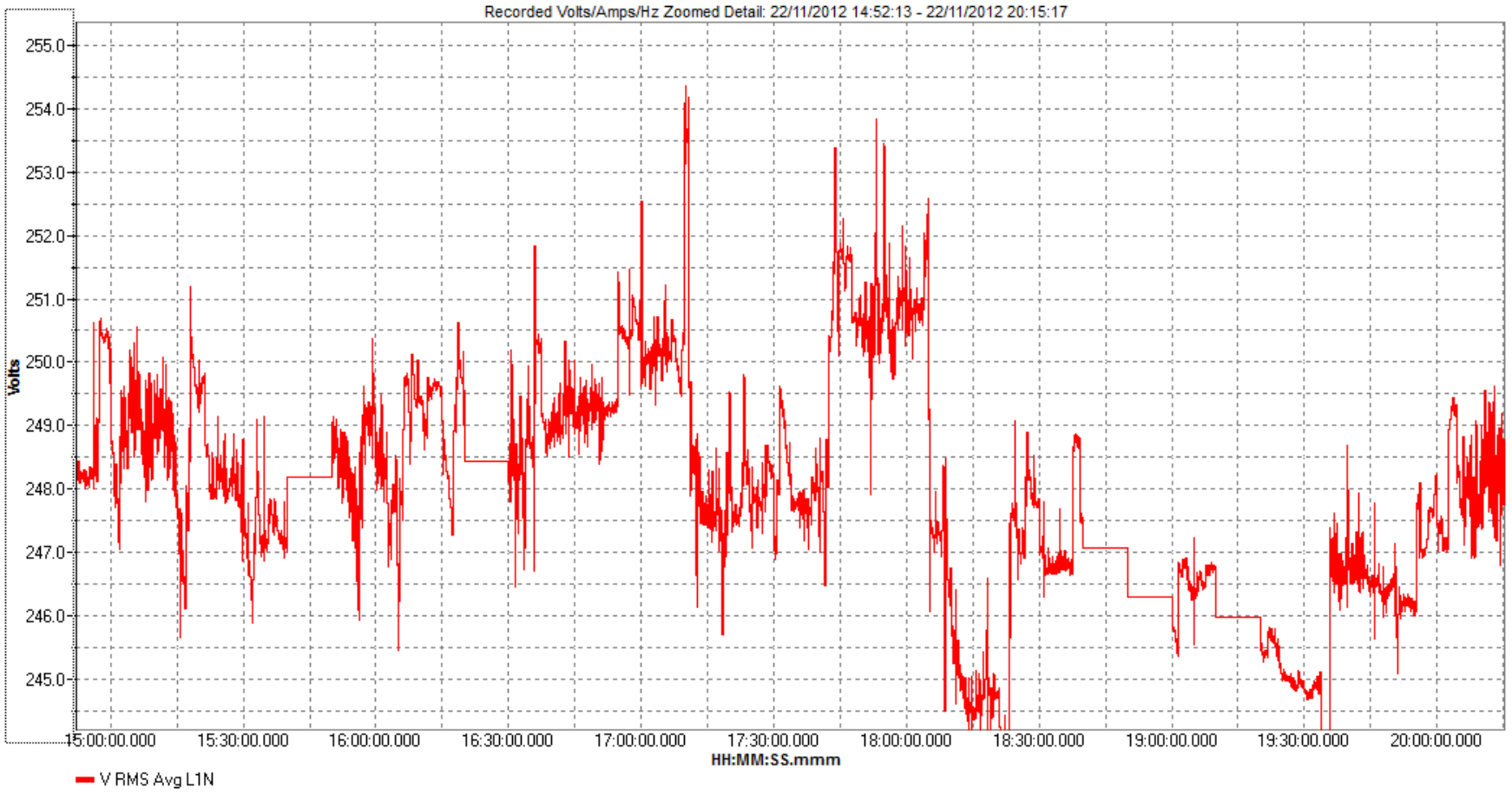
- Voltage Swell
  - Duration: 10 ms - 1 minute
  - Voltage magnitude: ≥ 110 % nominal voltage
  - Cause: switching OFF large load, single line-to-earth fault on the system resulting voltage swell on the two unfaulted phases
  - Possible Effects:
    - data corruption,
    - flickering of lighting and computer screens,
    - premature failure of equipment, such as electronic components and components on the power supplies of the equipment.

POWER QUALITY PROBLEMS

- Voltage Swell
  - Voltage swell is the reverse of voltage sag.
  - Voltage swells can often be more severe and destructive than voltage sags.
  - The failure may take place gradually, because voltage swells can occur frequently.

POWER QUALITY PROBLEMS

- Voltage Swell



POWER QUALITY PROBLEMS

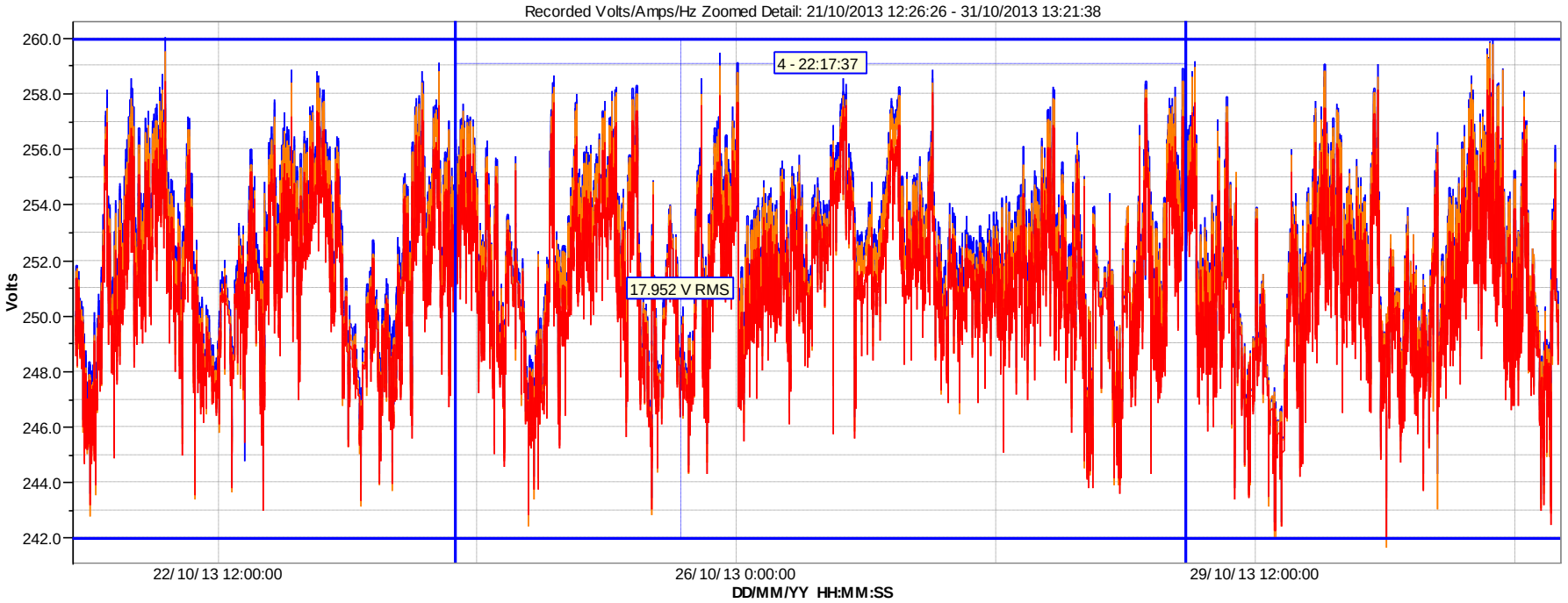
- Voltage Fluctuations
  - Duration: intermittent
  - Voltage magnitude: ≥ 6 % nominal voltage
  - Cause:
    - overloaded transformers (undersized)
    - unbalanced transformer loading
    - undersized cables
    - poor electrical connections
    - loose connections on the system
    - branch circuit runs are too long
    - large loads are turned ON

POWER QUALITY PROBLEMS

- Voltage Fluctuations
  - Possible Effects:
    - flickering of lighting
    - insulation breakdown (excessive heat),

POWER QUALITY PROBLEMS

- Voltage Fluctuations



The voltage fluctuation is 18 V (7.8 %). This voltage fluctuation is high (above 6 % of nominal voltage, i.e. >13.8 V).

POWER QUALITY PROBLEMS

- Voltage Fluctuations
  - The voltage fluctuation is due to the high system impedance.
  - To reduce the voltage fluctuation, the system impedance should be reduced
  - > 6% - Weak supply (high system impedance)
  - ≤ 6% - Strong supply (low system impedance)

POWER QUALITY PROBLEMS

- Voltage Fluctuations
  - Parliament of Australia

VOLTAGE FLUCTUATIONS: EFFECT ON COMPUTERS

Senator ROCHER:
WESTERN AUSTRALIA

-Is the Leader of the Government in the Senate aware of reports that voltage fluctuations in electricity supplies, especially surges and spikes, allegedly cause unpredictable difficulties in the functioning of computers? Can he say whether there have been any reports of permanent loss of memory bank data or other computer malfunctions due to inconsistent power supplies? Are power supplies at Commonwealth Government computer installations adequately protected? Is protection desirable and technically possible?

Senator CHANEY:
LP

– This matter comes within my area of responsibility as I represent the Minister for Administrative Services. I have some information on the matters raised by **Senator Rocher.** With respect to the first part of his question, voltage fluctuations in electrical supplies may cause difficulties in the functioning of computer equipment. As to whether there have been any reports of permanent loss of memory bank data or other computer malfunctions, I am advised there have been no known reports to date of irretrievable loss of data from computer memory. However, there have been some cases of computer malfunction due to inconsistent power supplies.

As to the adequacy of the protection which is given, I suppose that the previous part of my answer indicates that there is a reasonable level of protection available since there has been no irretrievable loss of data. I am advised that it is technically possible to protect computer installations against inconsistent power supplies. That can be provided at various levels according to the importance of the functioning of the computer and the sensitivity of the data contained on it. The responsibility for determining the appropriate level of protection is left to the individual departments operating the computers. I do not have detailed information as to what level of protection is provided in any particular case.

POWER QUALITY PROBLEMS

- Harmonics
  - Duration: ≥ 10 minute (steady state)
  - Voltage magnitude: VTHD ≤ 5 %
  - Current magnitude: ITHD ≤ 20%
  - Cause: nonlinear loads, adjustable/variable speed drives, arc furnaces, arc welders, fluorescent lights (magnetic and electronic ballasts), battery chargers, etc.

POWER QUALITY PROBLEMS

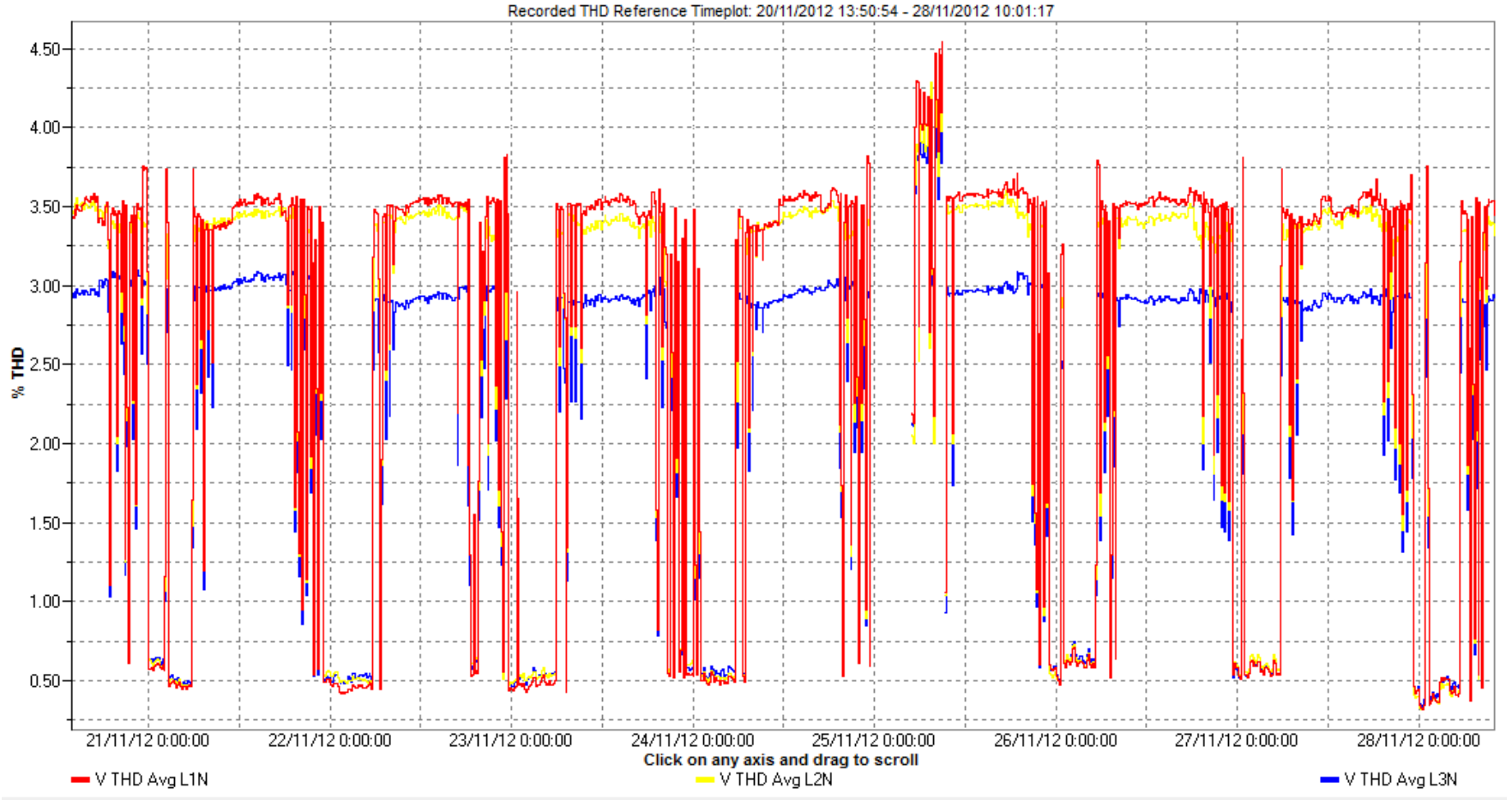
- Harmonics
  - Possible Effects:
    - Motors to burn out
    - False circuit breaker tripping/ nuisance tripping
    - Premature insulation failure from excessive heat (kerosakan pramatang penebat disebabkan daripada suhu yang tinggi).
    - 3rd harmonic currents from 1Ø loads add in the neutral
    - Telephone interference
    - Transformer heating
    - Audible noise from motors and transformers

POWER QUALITY PROBLEMS

- Harmonics
  - Possible Effects:
    - False tripping of RCDs
    - capacitor protection fuses to blow, circuit breakers to trip and capacitors to fail
    - Computer may reset

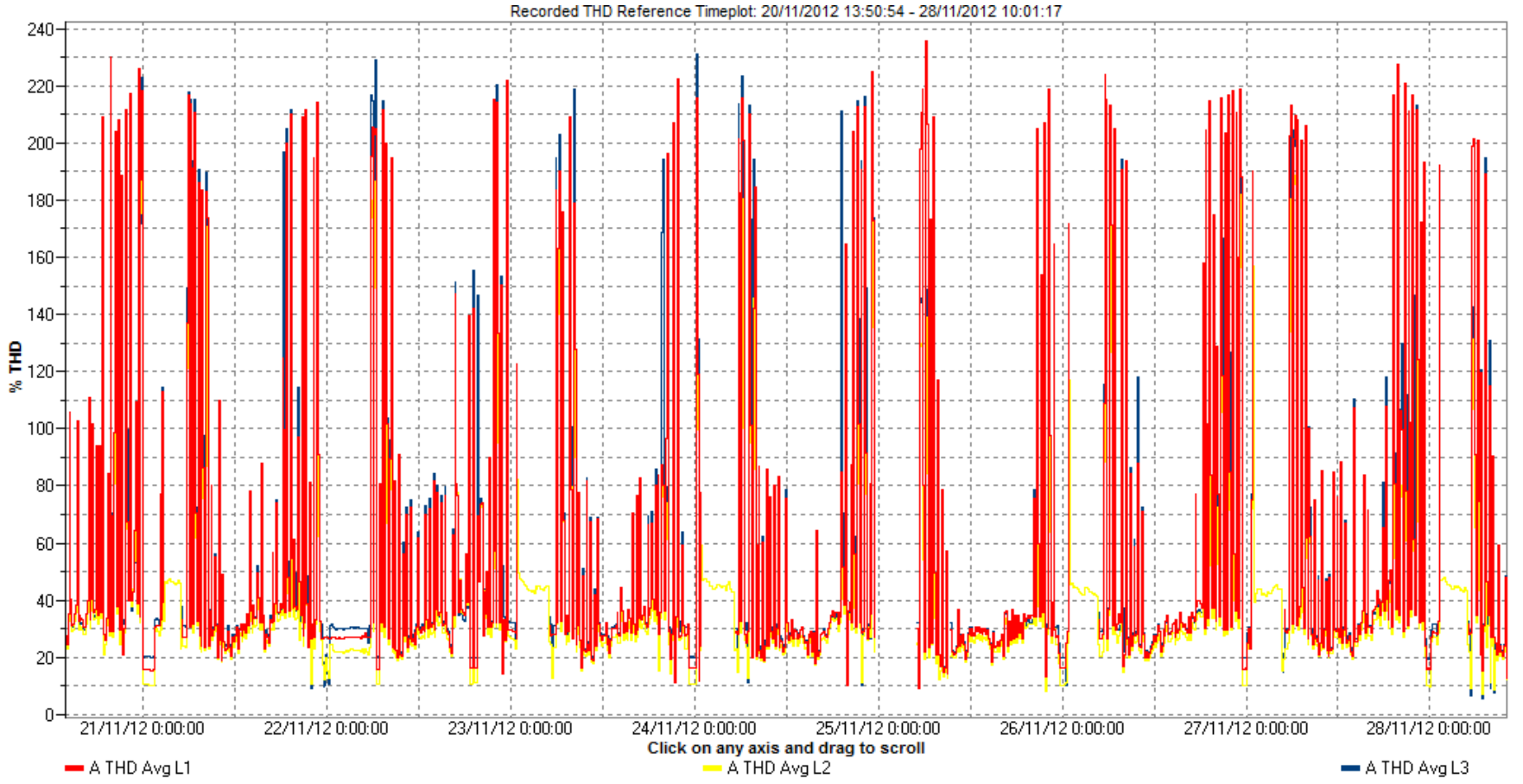
POWER QUALITY PROBLEMS

- Harmonics (VTHD)



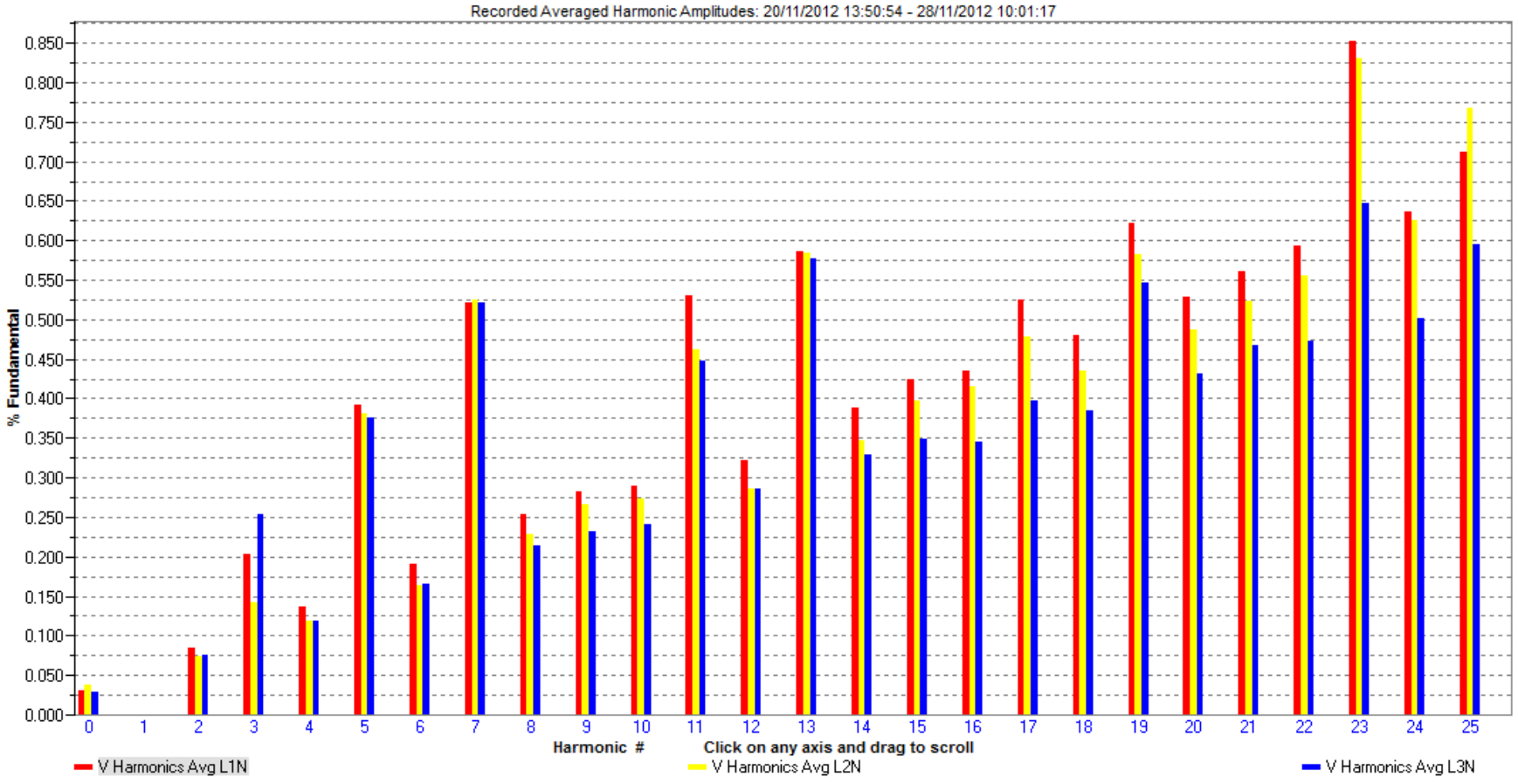
POWER QUALITY PROBLEMS

- Harmonics (ITHD)



POWER QUALITY PROBLEMS

- Harmonics (Individual)



POWER QUALITY PROBLEMS

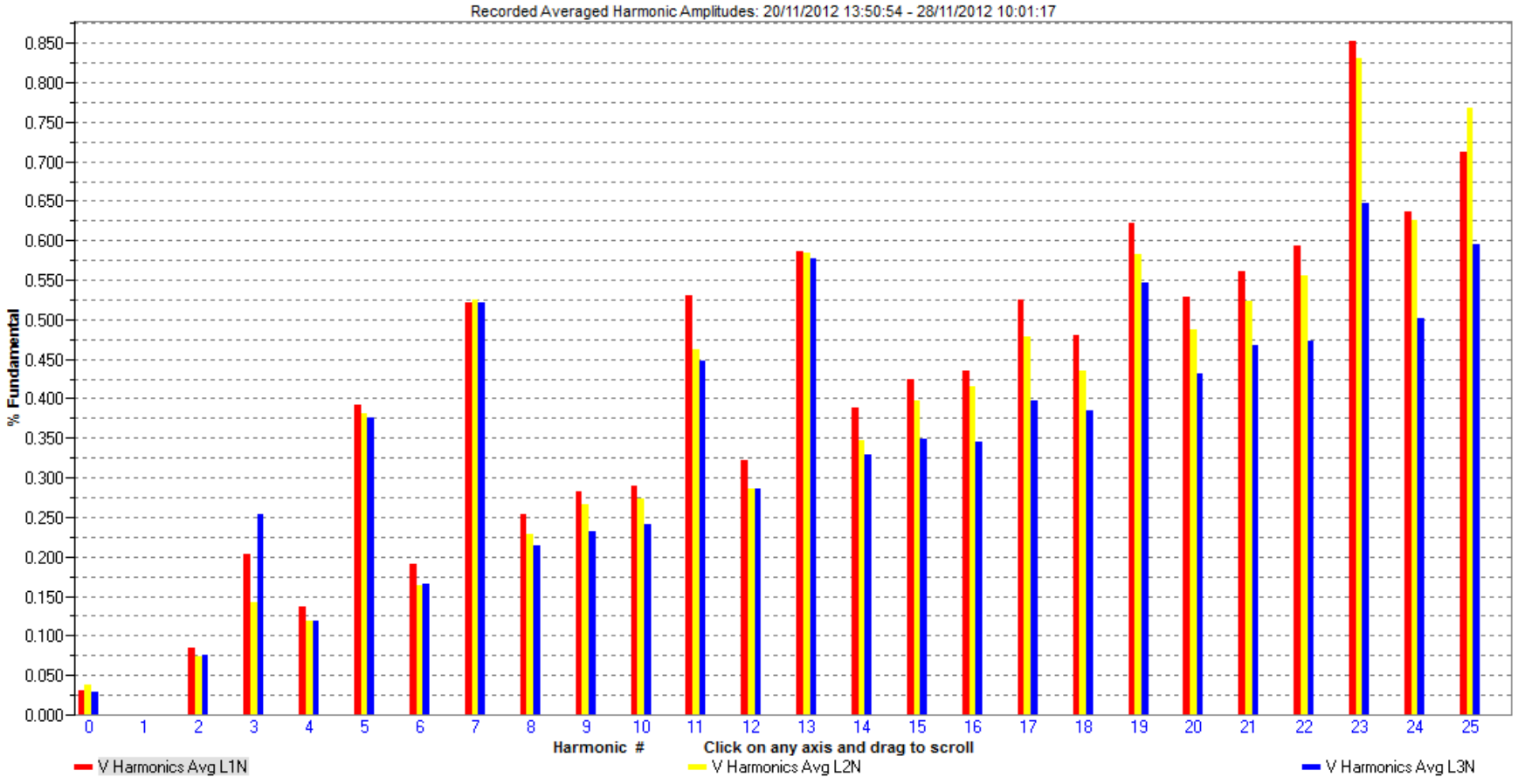
- Direct current (DC) offset

  - The presence of a dc voltage or current in an ac power system is termed dc offset.

  - Duration: ≥ 10 minute (steady state)
  - Voltage magnitude: ≤ 0.1 %
  - Cause: dc voltage or current
  - Possible Effects: excessive heat in transformers, increase in transformer core vibration, electrolytic erosion of earth electrodes and other connectors

POWER QUALITY PROBLEMS

- Direct current (DC) offset

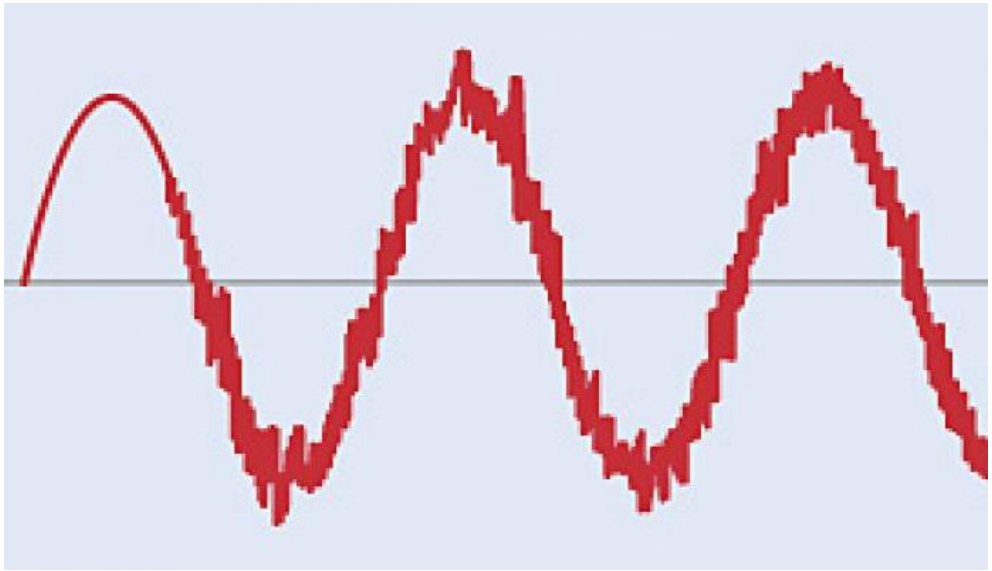


POWER QUALITY PROBLEMS

- Noise
  - An unwanted electrical signal of high frequency from other equipment
  - Cause:
    - arching at motor brushes
    - radio transmitters
    - opening of electrical contacts
    - welders
    - Firing of silicon-controlled rectifiers (SCRs)

POWER QUALITY PROBLEMS

- Noise
  - Possible Effects: Can produce false signals in electronic circuits leading to:
    - Processing errors
    - Incorrect data transfer
    - Printer errors



POWER QUALITY PROBLEMS

- Noise

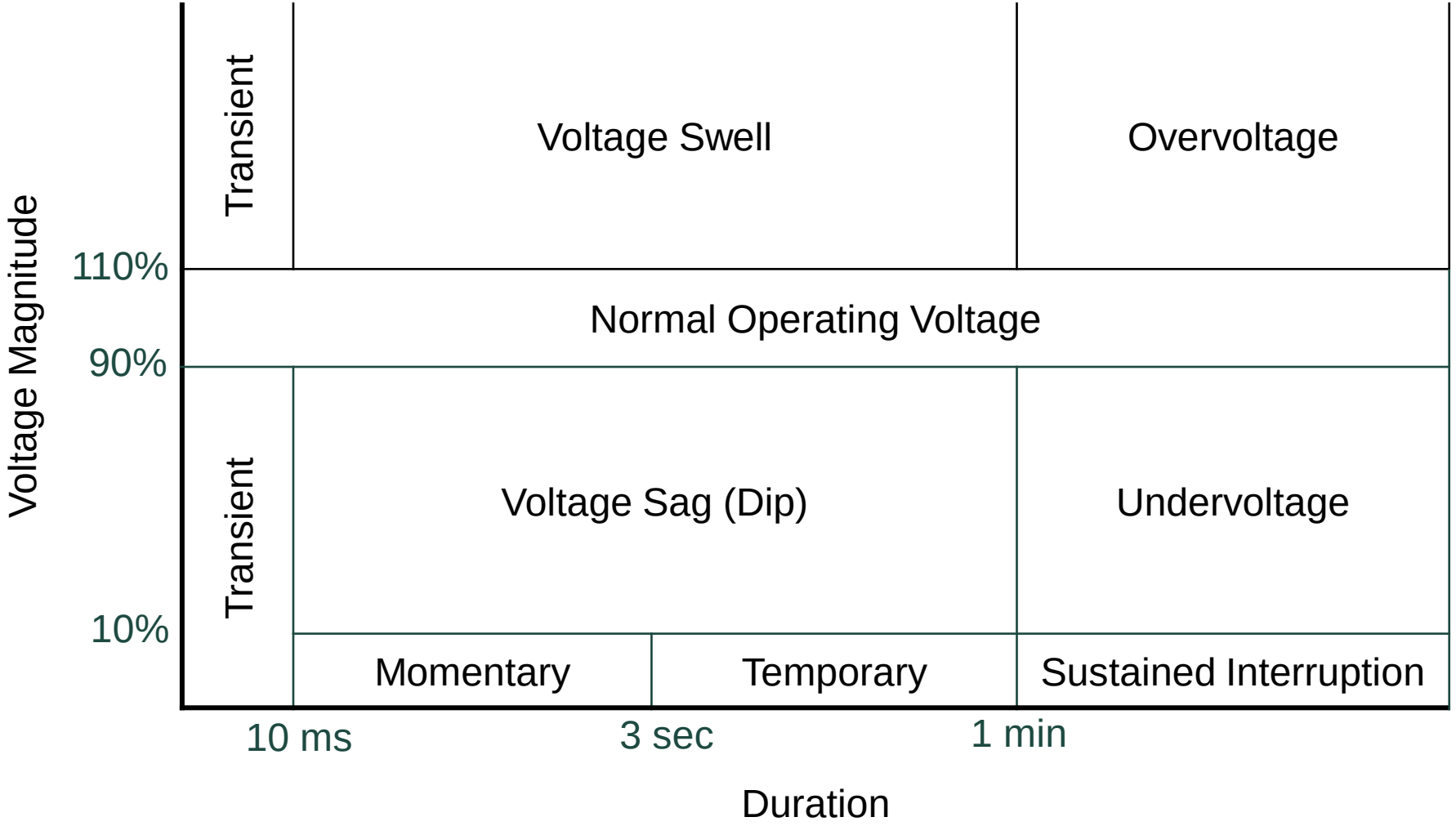
SUMMARY OF PQ PROBLEMS

Categories		Duration (Definition)	Voltage/Current Magnitude (Definition)
Power Interruption	Momentary	10 ms – 3 s	< 10% nominal voltage
	Temporary	> 3 s – 1 min	< 10% nominal voltage
	Sustained	> 1 min	< 10% nominal voltage
Overvoltage		> 1 min	≥ 110% nominal voltage
Undervoltage		> 1 min	≤ 90% nominal voltage
Voltage Unbalance		Continuous	≥ 2% between the phases
Current Unbalance		Continuous	≥ 30% between the phases
High Neutral to Earth Voltage		Continuous	≥ 3 V
Neutral to Earth Voltage Impulse		≤ 70 ms	≥ 20 V
Surges (Transients)		< 10 ms	≤ 20 kV
Voltage Dip (Sag)		10 ms – 1 min	10% - 90% nominal voltage
Voltage Swell		10 ms – 1 min	≥ 110% nominal voltage

SUMMARY OF PQ PROBLEMS

Categories	Duration (Definition)	Voltage/Current Magnitude (Definition)
Voltage Fluctuations	Intermittent	≥ 6% nominal voltage
THD (Voltage)	Continuous	Good: ≤ 5%
THD (Current)	Continuous	Good: ≤ 20%
DC Offset	Continuous	Good: ≤ 0.1%

SUMMARY OF PQ PROBLEMS



Power Acceptability Curve

- Today, most electronic equipment use solid-state electronic circuits. Electronic equipment is very sensitive to voltage changes because it operates at very low voltage level.
- Voltage changes can cause damage to the electronic components, computer hard disks to reboot, lock up (hang), software malfunction and communication errors.

Power Acceptability Curve

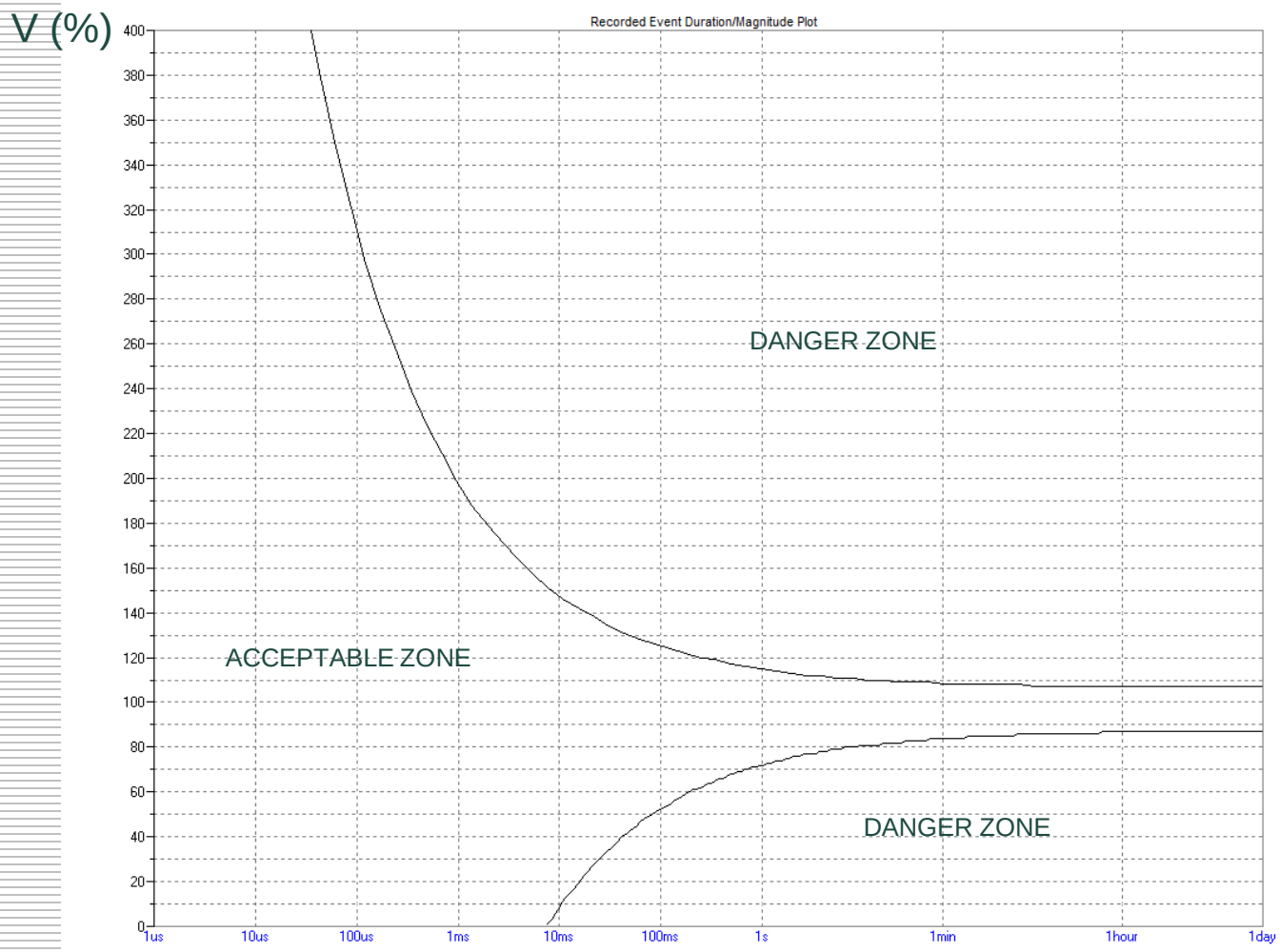
- One of the most frequently used to display voltage changes is called Power Acceptability Curve or Tolerance Curve.
- Power Acceptability Curves represent minimum voltage threshold levels that equipment will operate satisfactorily when the power supplied is within the specified and acceptable standards.

Power Acceptability Curve

- The curves are:
  - CBEMA - Computer Business Equipment Manufacturers Association
  - ITIC - Information Technology Industry Council
  - SEMI F47 - Semiconductor Equipment and Materials International F47
  - ANSI - American National Standards Institute

Power Acceptability Curve

CBEMA - Computer Business Equipment Manufacturers Association

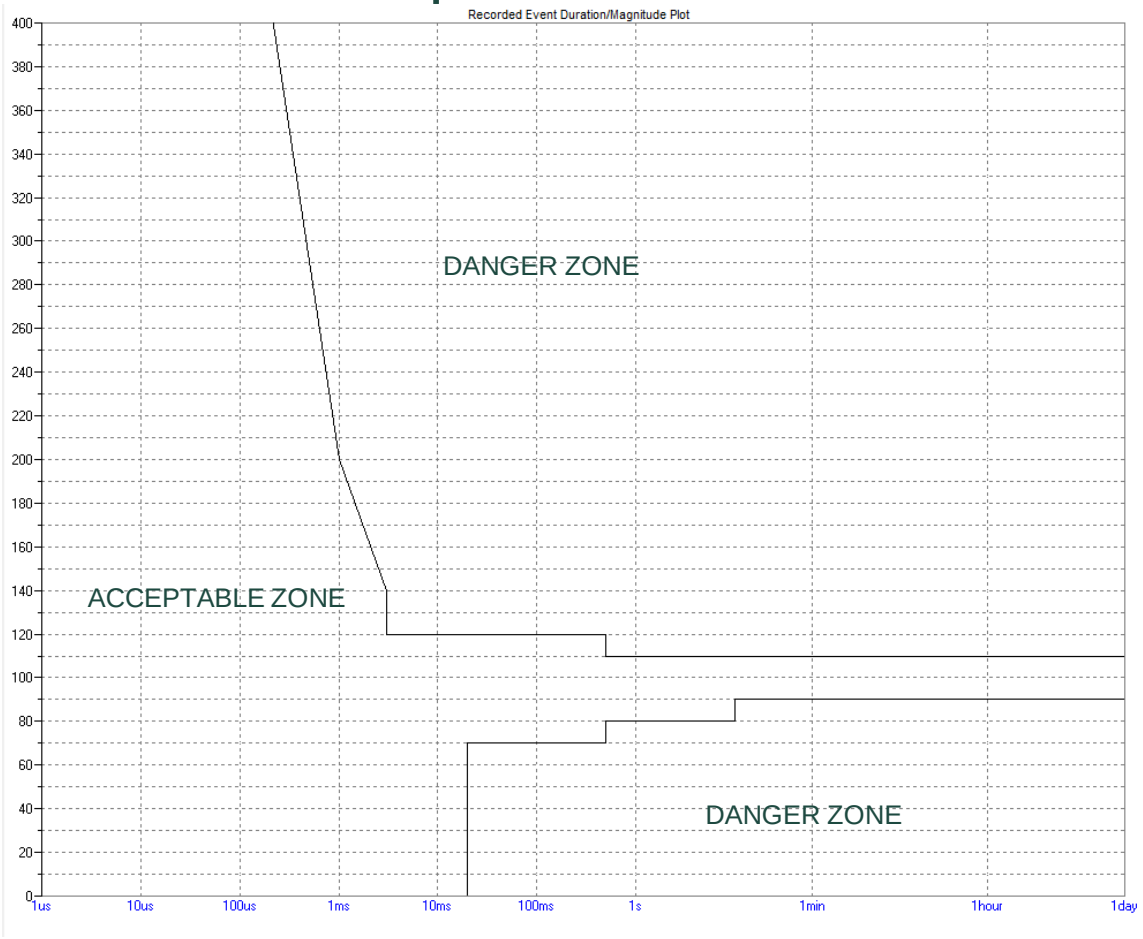


The height on the y axis shows the quality of the voltage in percent (%), that is a percent deviation from nominal voltage. The x axis shows the duration of the voltage event. These curves are divided into two zones namely, acceptable and danger zones. If voltage is inside the danger zone, data may be damaged or lost and equipment damage may occur.

Power Acceptability Curve

ITIC - Information Technology Industry Council

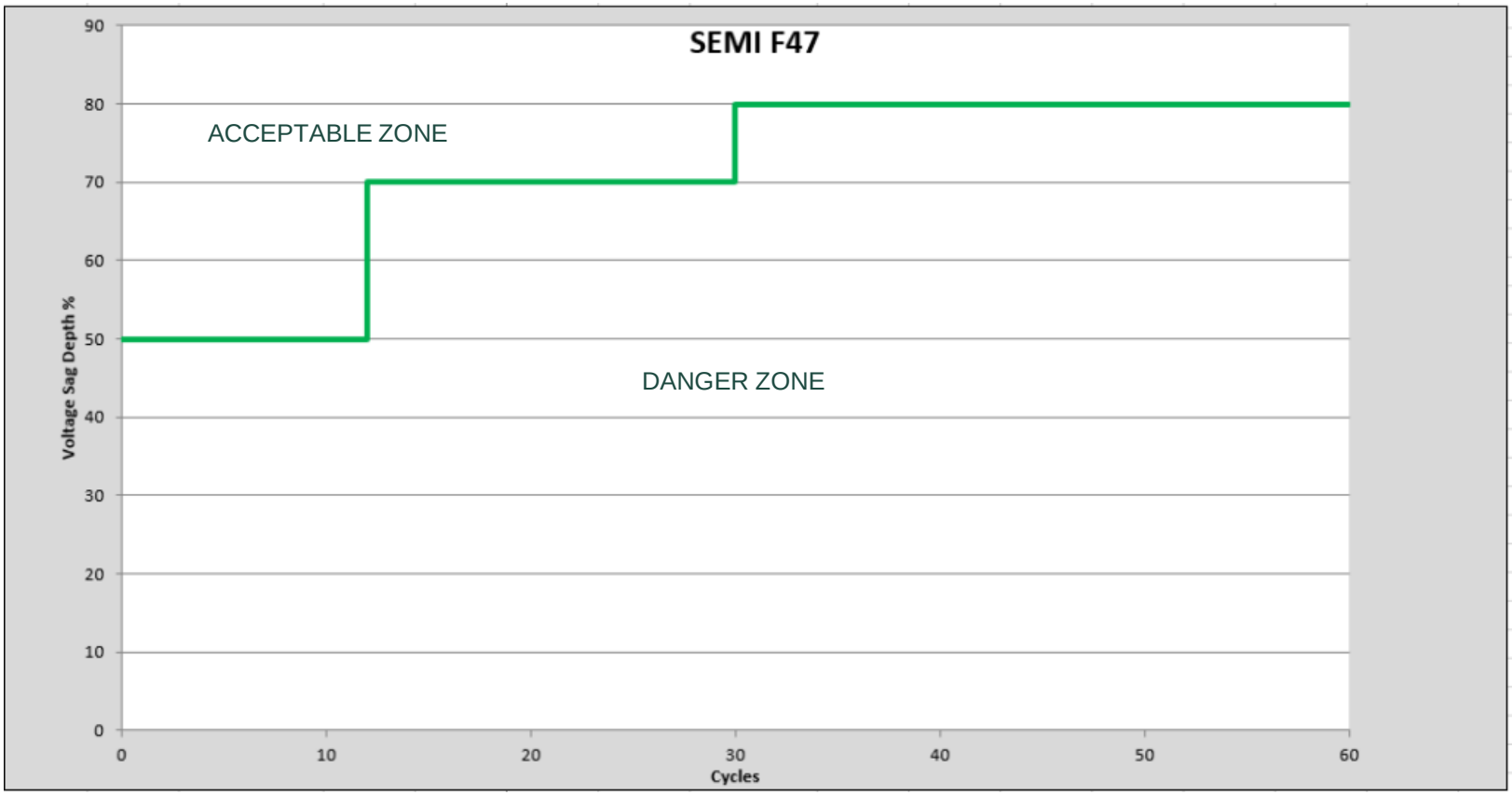
- ITIC curve is a revision of the CBEMA curve created in 2000, but the concept is similar.



Power Acceptability Curve

SEMI F47 - Semiconductor Equipment and Materials International F47

- The industry association for the semiconductor industry, has developed the SEMI F47 voltage sag immunity standard.

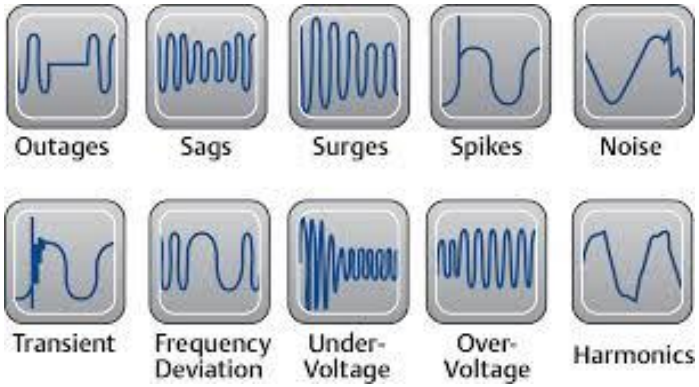


Power Acceptability Curve

ANSI - American National Standards Institute

CONCLUSIONS

- Power Quality Problems will be around for years to come.
- Voltage Quality = Supply Quality
- Current Quality = Consumption (Load) Quality
- PQ should also be checked as part of a preventive maintenance program



Thank You

Cawangan Kejuruteraan Elektrik