LABWORK - HARMONIC DISTURBANCES

This labwork proposes to highlight harmonics, the "low frequency" disturbances that appear in electrical installations, by visualizing them and measuring their electrical characteristics, and then to implement solutions to reduce or eliminate these phenomena and their consequences.

Part One: Preliminary questions

1) CHARACTERIZATION OF THE PHENOMENON

We study here the appearance of harmonic disturbances, their consequences on the power grid and the means to get rid of them them. A Schneider document is attached to help you answer the following questions (see part M – “Harmonic management”):

1.1) **Define** what a nonlinear load is and **give** examples.

1.2) **Explain** why these loads pollute and affect a network.

1.3) **Indicate** the consequences of this pollution on the devices and the network.

1.4) **Give** solutions to get rid of these disturbances.

1.5) **Prepare** the second part (draw diagrams, think about operating procedures, prepare tables in a spreadsheet and measurement graphs).

Second part: experiments

2) POWER GRID VOLTAGE QUALITY

In this part of the labwork, we will see the extent of the pollution of the electricity network.

This operation requires the use of a dangerous voltage of 230VAC.

The test aims at visualizing the voltage signal delivered by the electrical network and its harmonic spectrum. It uses an oscilloscope and a voltage probe that isolates the measurement from the network and attenuates the voltage. The results should take into account the probe settings.

*The available oscilloscope allows, through its FFT calculation module, to display of the Fourrier transform in amplitude. This display is made up of lines whose abscissa is "**n.f**" where "n" is the rank of the considered harmonic and "f", the frequency of the fundamental and whose ordinate is the gain "G_n" of the effective voltages expressed in dBV.*

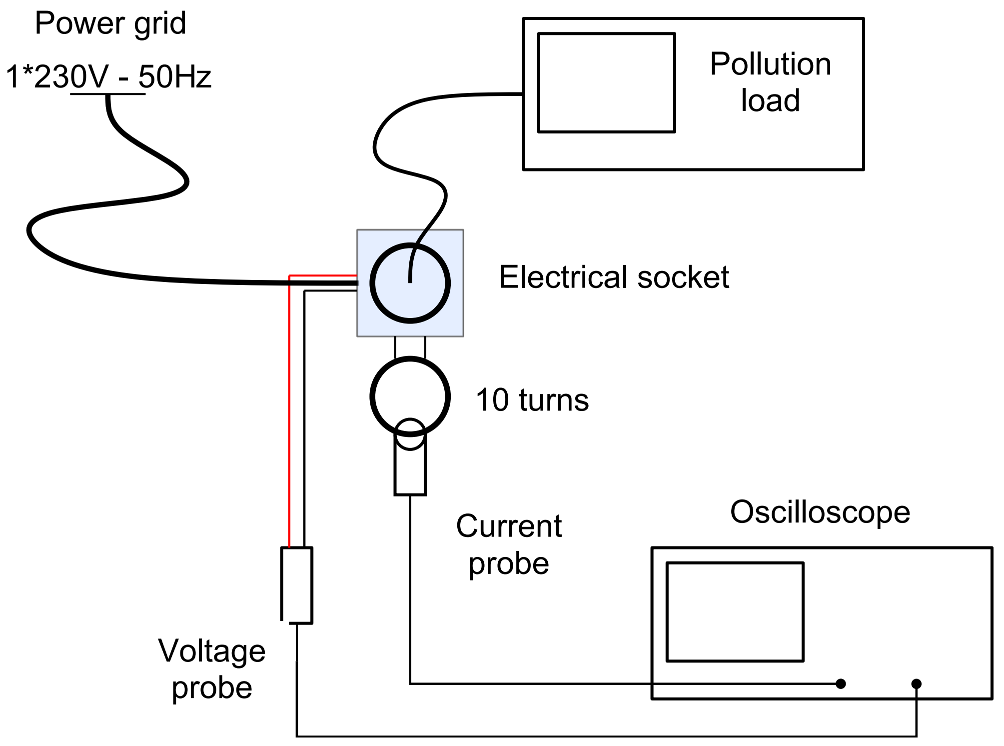
$$G_n = 20.log\left(\frac{V_n}{1\,V}\right)$$

The direct measurement of the gain of each line is done using the cursors:

- ***Press** the "cursor" key.*
- ***Choose** the "amplitude" type.*
- ***Move** the cursprs using the adjustment buttons for each channel.*
- ***Record** the value in dB of each relevant line.*

Diagram of the measurement set-up

Handling requires the use of a dangerous voltage of 230VAC.



2.1) **Visualize** the distortion of the voltage signal. **Check** the characteristic quantities of the network (voltage and frequency).

2.2) **Visualize** and then **record** the voltage spectrum up to a reasonable value of "n".

2.3) Using a spreadsheet, **plot** the harmonic spectrum of the network voltage and **calculate** the THDU.

2.4) **Conclude** on the pollution of the network by comparing the results of the measurements carried out with the values recommended by the **NF EN 50160 standard (appendices).**

3) CURRENT CONSUMED BY A POLLUTANT LOAD

This part of the PW studies the pollution of two non-linear loads.

The test set-up remains the same. The same safety precautions should be taken.

The test aims at visualizing the current absorbed by a nonlinear load supplied by the electrical grid and its harmonic spectrum. It uses an oscilloscope, a voltage probe and a current probe. The results should take into account the settings of the two probes.

Loads are non-linear loads intended to be powered by a 2 P + T 16A power socket. They obey the constraint of low-frequency conducted disturbances specified by the NF EN 61000.3.2 standard. The non-linear loads are a low-energy lamp and an analog oscilloscope.

For the lamp:

3.1) **Visualize** and then **record** the voltage and current signals. **Determine** the non-linearity of the load and **give** the class of the load according to the **NF EN 61000-3-2 standard** (appendix).

3.2) **Evaluate** the phase shift angle between the network voltage and the current absorbed by the load

3.3) **Visualize** and then **record** the harmonic spectrum of the current absorbed by the load up to a reasonable value of "n".

3.4) Using a spreadsheet, **plot** the harmonic spectrum of the current and **calculate** the THDI.

3.5) **Calculate** the power supplied by the fundamental.

3.5) **Conclude** on the pollution caused by the load by comparing the results of the measurements carried out with the values accepted by the standard and on the comparison between the power calculated and the power announced by the manufacturer.

For the analog oscilloscope:

3.6) **Visualize** and **record** the voltage and current signals. **Determine** the non-linearity of the load and **give** the class of the load according to the **NF EN 61000-3-2 standard** (appendix).

3.7) **Visualize** and then **record** the harmonic spectrum of the current absorbed by the load up to a reasonable value of "n".

3.8) Using a spreadsheet, **plot** the harmonic spectrum of the current and **calculate** the THDI.

3.9) **Conclude** on the pollution caused by the load by comparing the results of the measurements carried out with the values recommended by the standard.

5) IMPLEMENTING AN ACTIVE FILTER

Chapter 8.4.1 of the Poly EMC

Paragraph 8.4.1 of the EMC handout specifies the principle of active filtering in Figure 99. A current source takes from the mains the opposite of the harmonic currents consumed by the load modeled as a current generator.

This current source is controlled by reading the current of the load, from which the fundamental term by selective notch filtering. Thus, when the harmonics vary or fluctuate, the correction adapts. This is the origin of the adjective “active”.

There is an active harmonic compensator called SINEWAVE from MGE UPS which performs the function presented above. Interspersed between the network and the load, the compensator provides access to the current **in the form of three cable loops**:

- The first loop called "SOURCE" carries the current from the grid.
- The second loop called "CHARGE" carries the load current.
- The third loop called "SINEWAVE" carries the compensation current.

This arrangement enables all three currents to be observed on an oscilloscope using a current clamp.

5.1) **Connect** the analog oscilloscope to the back of the active filter and **then turn on** the active filter.

5.2) **Pinch** successively the "CHARGE" loop, the "SOURCE" loop and the "SINEWAVE" loop to the front of the active filter.

5.3) In all 3 cases, **display** and **photograph** the oscillogram and the spectrum of the current.

5.4) **Conclude** on the effectiveness of the active filter.

APPENDICES

NF EN 50160 (extract)

Characteristics of the voltage supplied by public distribution networks

§ 4.2.5 - Harmonic Voltages

Under normal operating conditions, during each one-week period, 95% of the 10-min averaged rms of each harmonic voltage shall not exceed the values shown in **Table 1**. Higher voltages for a given harmonic may be due to resonances.

In addition, the overall harmonic distortion rate of the supplied voltage (including all harmonics up to rank 40) must not exceed 8%.

NOTE: The limit at Rank 40 is a convention.

Table 1 – Values of harmonic voltages at delivery points, up to harmonic rank 25, expressed as a percentage of the fundamental voltage u_1

Odd harmonics				Even harmonics	
Not multiples of 3		Multiples of 3			
Rank h	Amplitude relative u_h	Rank h	Amplitude relative u_h	Rank h	Amplitude relative u_h
5	6,0 %	3	5,0 %	2	2,0 %
7	5,0 %	9	1,5 %	4	1,0 %
11	3,5 %	15	0,5 %	6 … 24	0,5 %
13	3,0 %	21	0,5 %		
17	2,0 %				
19	1,5 %				
23	1,5 %				
25	1,5 %				

NOTE: Values for harmonics of rank greater than 25 are generally low and highly unpredictable due to resonance effects, and are not shown in this table.

NF EN 61000-2-2 (extract)

Electromagnetic Compatibility (EMC) Part 2-2: Environment Compatibility Levels for Low-Frequency Conducted Disturbances and Signal Transmission on Public Low-Voltage Power Networks

§ 3.2.7 Total Harmonic Distortion Rate:

Ratio of the RMS value of the sum of the harmonic components to the RMS value of the fundamental component (summation is limited to a defined rank, recommended notation "H") where

$$THD = \sqrt{\sum_{h=2}^{h=H} \left(\frac{Q_h}{Q_1}\right)^2}$$

- **Q** represents either the current or the voltage;
- **Q1** is the effective value of the fundamental component;
- **h** is the harmonic rank;
- **Qh** is the rms value of the harmonic component of rank h;
- H is usually equal to 50, but may be equal to 25 in cases where the risk of resonance on the higher ranks is low.

NF EN 61000-3-2 (extract)

Electromagnetic Compatibility (EMC) Part 3-2: Limits – Limits for Harmonic Current Emissions (Current Demand by Devices ≤ 16 A per Phase)

§ 4 - General

The objective of this standard is to provide limits for the emission of harmonics from equipment within its scope, so that, taking into account the contribution of emissions from other equipment, compliance with these limits provides assurance that the levels of harmonic disturbances will not exceed the compatibility levels defined in IEC 61000-2-2.
Professional equipment that does not meet the requirements of this standard may be permitted to be connected to certain types of low-voltage power supplies, if the instruction manual specifies that permission to be connected must be sought from the distributor. Recommendations for this can be found in IEC/TR 61000-3-4 or IEC 61000-3-12.

§ 5 - Classification of devices

As far as harmonic current limitation is concerned, the devices are classified as follows:

Class A: balanced three-phase appliances; household electrical appliances excluding appliances identified as belonging to Class D; tools excluding portable tools; dimmers in light for filament lamps; audio equipment.
Hardware not specified in one of the other three classes shall be considered Class A equipment.

Class B: portable tools; arc welding apparatus excluding professional equipment.

Class C: Lighting fixtures.

Class D: Appliances with a specified power of 600 W or less
personal computers and monitors for personal computers; television receivers; refrigerators and freezers with one or more variable speed drives for controlling one or more compressor motors.

§ 7.1 - Limits for Class A Equipment

For Class A equipment, the harmonics of the input current shall not exceed the values given in Table 1.

Table 1 – Limits for Class A Devices			
Odd harmonics		**Even harmonics**	
Harmonic rank n	**Maximum Allowable Harmonic Current A**	**Harmonic rank n**	**Maximum Allowable Harmonic Current A**
3	2,30	2	1,08
5	1,14	4	0,43
7	0,77	6	0,30
9	0,40	8 ≤ n ≤ 40	0.23 x 8/n
11	0,33		
13	0,21		
15 ≤ n ≤ 39	0.15 x 15/n		