Harmonics and UPS

An Online Continuing Education Course for Engineers

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Harmonics and UPS

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UPS equipment, like most static converters, takes energy from an AC network through rectifiers. Typically, these rectifiers are equipped with thyristors, and they generate harmonics. This course highlights the need for a standardized coexistence between polluting and polluted equipment. Also, the course elaborates on which harmonic currents and voltages are generated by conventional (classic) rectifiers (thyristor Graetz bridge rectifier) and provides different solutions that are designed to minimize harmonic impact.

Power Harmonics in Electrical Networks

Consequences Caused by Harmonic Currents

Harmonic currents that are made by certain devices, for example, static converters, discharge lamps, and arc furnaces (in the case their number is significant, or their rating is higher in comparison with the power of the source) can seriously affect the operation of other devices installed in the same electrical network.

Effects caused by harmonic currents are:

- Extra heating particularly in line conductors, transformers, and condensers,
- Vibrations and noises in electromagnetic devices,
- Interference with communication and protection/signaling devices,

Also, a distorted voltage can obstruct the service of some receivers such as regulators and static converters. Therefore, one of the factors describing the quality standard of electricity supply is its voltage distortion rate.

Requirement for standardization

Since electricity is treated as a product, the producer is completely responsible for damages caused by the higher levels of harmonics. That is why electricity distributors, to guarantee a quality level acceptable to all clients, set limits to disturbances generated by some consumers. To accomplish this, it is mandatory to determine:

- Maximum distortion rate allowing proper functioning of most installations (compatibility level),

- Maximum disturbance rate for each user, so that the cumulative effects of different disturbances allow operational compatibility between all the installations. Therefore, if this compatibility is required between consumers, it must also exist within each consumer's installation unit.

Hence, the end user is burdened with a level of disturbances generated by his own equipment. For this reason, it is important that manufacturers clearly declare the disturbance levels generated by their equipment. Standards are needed to determine acceptable levels of harmonic disturbances for the supply networks as well as for polluters.

Operational Compatibility and Emission Levels

Limits need to be defined for each consumer to avoid the necessity to complete systematically controlled verifications when the equipment is put into operation.

For the same level of current disturbance, the voltage distortion ratio, at the interconnection point, depends on the network impedance at that point. The disturbance that is proportional to the power taken by each user and for each range of voltage i.e., LV, MV, and HV, needs to be recognized. Emission levels must be considered in domestic and industrial installations.

- Domestic applications - In the LV voltage level, where the energy distributor is not able to control the situation, disturbance levels that have to be observed in equipment are set in line with standards.

Standard harmonic emission values are provided in Table 1 and Table 2.

Table 1. Compatibility levels for harmonics voltages (in % of nominal voltage at a fundamental frequency) in HV power network and MV and LV networks

Odd harmonics non-multiples of 3			Odd harmonics multiples of 3			Even harmonics		
	Harmonic voltage %		Harmonic order n	Harmonic voltage %		Harmonic order n	Harmonic voltage %	
	LV/MV	HV		LV/MV	HV		LV/MV	HV
5	6	2	3	5	2	2	2	1.5
7	5	2	9	1.5	1	4	1	1
11	3.5	1.5	15	0.3	0.3	6	0.5	0.5
13	3	1.5	21	0.2	0.2	8	0.5	0.2
17	2	1	>21	0.2	0.2	10	0.5	0.2
19	1.5	1				12	0.2	0.2
23	1.5	0.7				>12	0.2	0.2
25	1.5	0.7						
>25	0.2+12.5/n	0.1+2.5/n						

Global distortion rate: 8% in LV and MV network – 3% in HV networks

Table 2. Current harmonic component limits in domestic installations ($I_n \leq 16A$)

Harmonic order	Max. permissible harmonic current (in A)
Odd harmonics	
3	2.3
5	1.14
7	0.77
9	0.4
11	0.33
13	0.21
15 ≤ n ≤ 39	0.15 x 15/n
Even harmonics	
2	1.08
4	0.43
6	0.3
8 ≤ n ≤ 40	0.23 x 8/n

Industrial networks - There are so far no agreed international standards for this particular application. Nevertheless, an agreement emerges on the concept of stages.

- Stage 1: Automatic acceptance - This acceptance depends on the network voltage level and applies to equipment of low power in comparison with the contracted power. For example, one rule is to have a disturbance causing power that is less or equal to 1 % of minimum short-circuit power at the interconnection point, during normal operation.

  This tolerance can be extended in the case the total disturbing power is lower than:

  - 4 MVA in HV range,
  - 500 kVA in MV range,
  - 40 kVA in LV range.

- Stage 2 - Acceptance with reservations – In situations when the limits are surpassed, the energy producer typically defines a maximum distortion rate at the interconnection point. In situations when these levels are likely to be surpassed, the distributor/supplier would reserve the right to ask for complementary measures of compensation to be resorted to, if the distortion rate was surpassed.

- Stage 3 - Acceptance - Provisional.

When the limits presented in Stage 2 are surpassed but without exceeding the compatibility level - due to the non-generation of harmonics by other users - a provisional authorization permit may be allowed.

Thyristor Graetz Bridge Rectifier

UPS equipment consist of an AC/DC converter (i.e., rectifier), a battery bank (which can be charged by the rectifier or with an appropriate current charger) and a DC/AC converter (i.e., inverter). Typical UPS configuration is shown in Figure 1. Typically, as the input converter is expected to give a charge or to keep the charge of the battery at a constant voltage and to supply the needed power to the inverter, it typically uses thyristors connected in the form of a Graetz bridge circuit. Other types of rectifier circuits exist but the three-phase Graetz bridge configuration is the most typically used, especially in high powered UPS units.

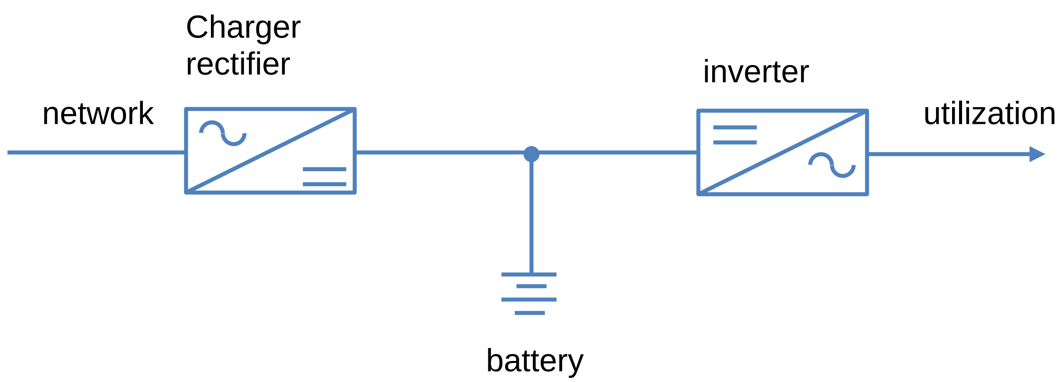

Figure 1. Circuit connection of a charger rectifier

Harmonic Currents Produced by a Graetz Bridge Rectifier

The rectifier presented in Figure 2 is connected to a high value inductance which serves as filter to the DC current, $I_{d,}$ to ensure that the latter is perfectly smooth. Firstly, the source impedance is considered to be zero. The line currents I_1, I_2 and I_3 assume in turn the value (and the shape) of the DC current I_d. Each thyristor provides current transfer during 1/3 of a period. Assuming that source impedance is zero, the current establishes itself instantaneously at its value I_d, as soon as one thyristor starts to transfer current.

Currents provided by the source have a rectangular waveform as shown in Figure 3. The spectrum is composed of current harmonics:

$$I_n = \frac{I_1}{n}$$

where n = 6 k±1, k taking values 1, 2, 3... (whole numbers) and I_1 being the effective value of fundamental, i.e. $I_1 = 0.78\ I_d$.

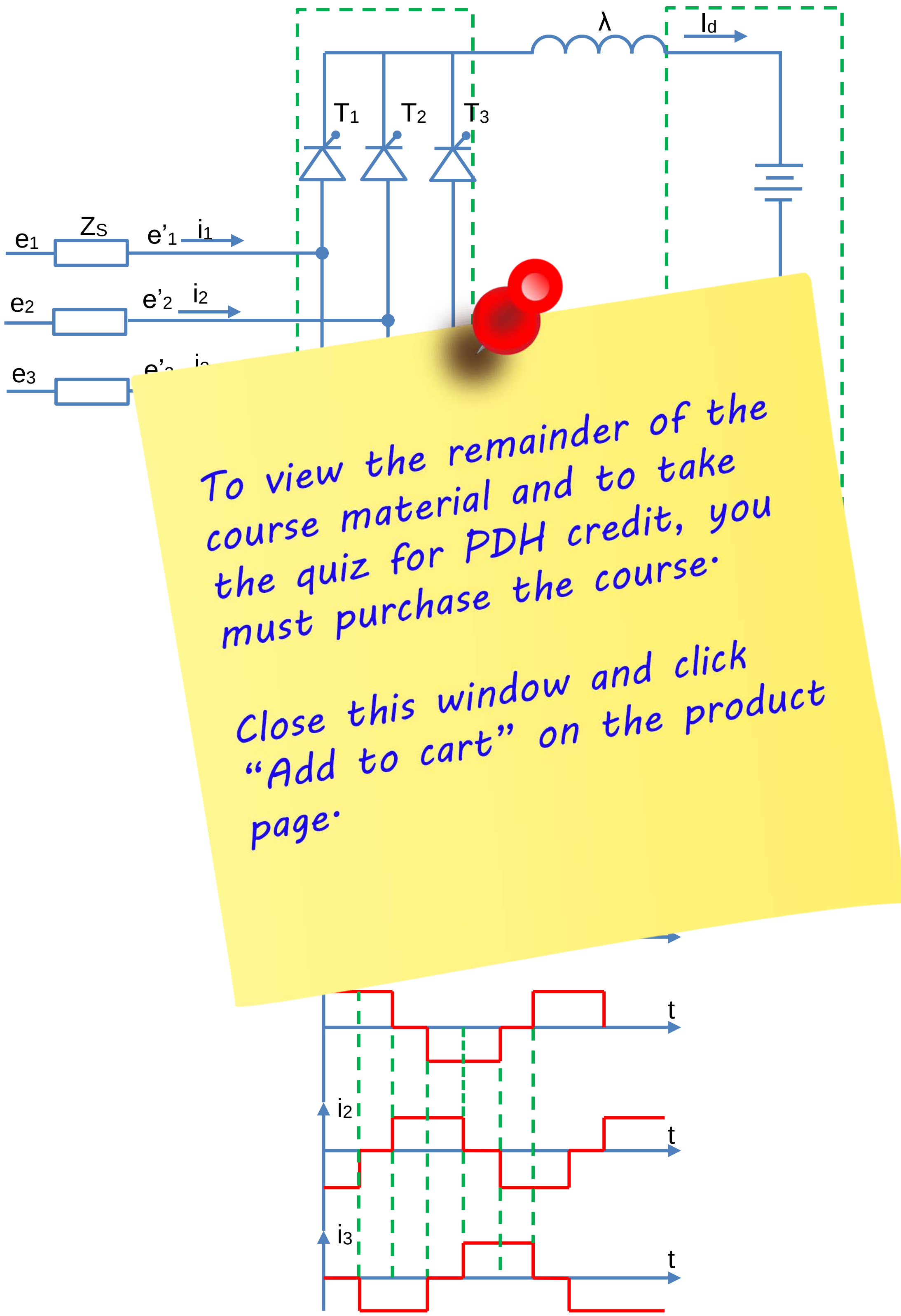

Figure 3. Theoretical currents upstream of rectifier with infinite downstream filter impedance and source