FAQ3 – Efficient motors –

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This FAQ give a short explanation to the following questions:

"How to choose an electric motor? "

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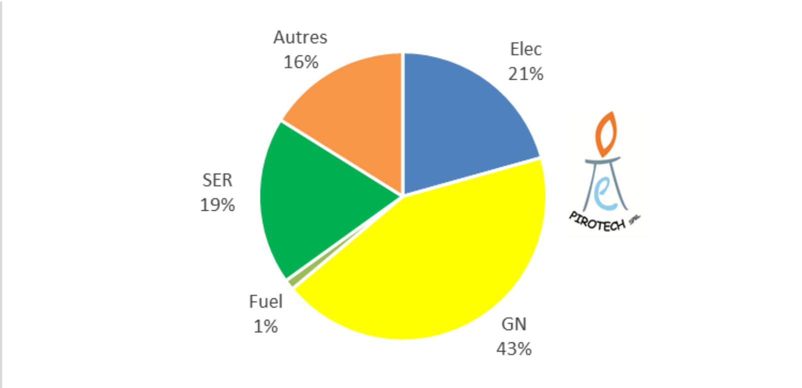
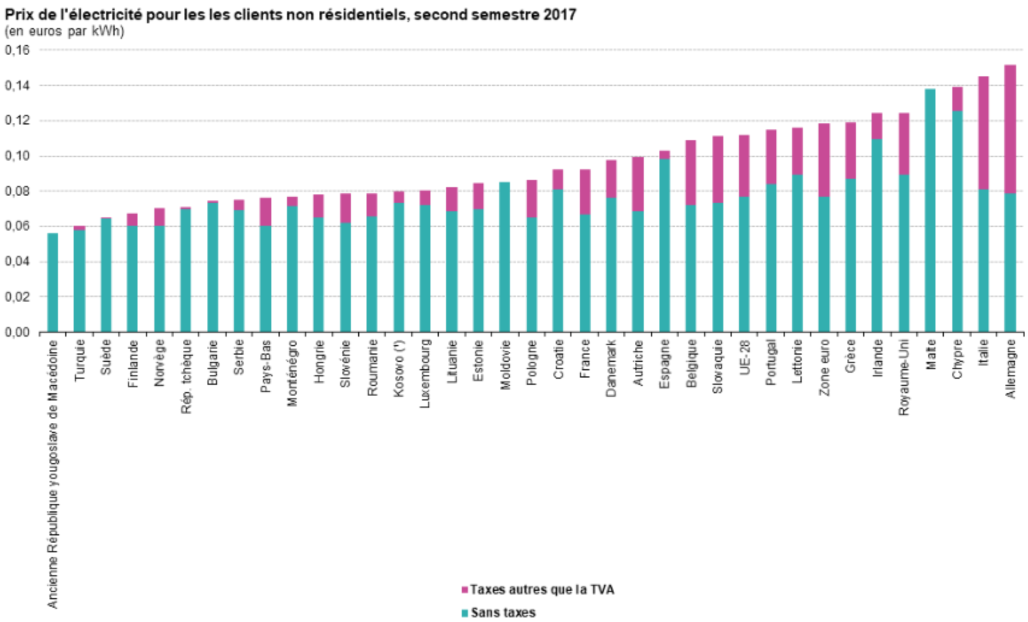
Introduction

Energy consumption in industries (Belgium) :



This picture represents the energy consumption in Belgium industries. In this document, we will talk about the 21% of the total of energy consumption, the electricity.

Prices of electricity for different countries:



The price of Belgium is twice the price of Turkey. So, it means that energy savings are less attractive in Turkey: it is more difficult to carry on cost effective projects

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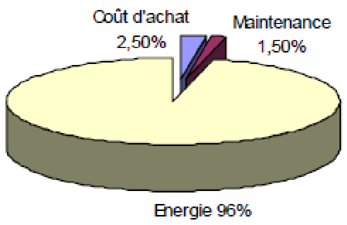
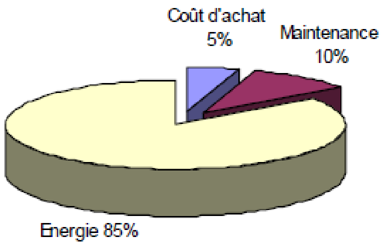
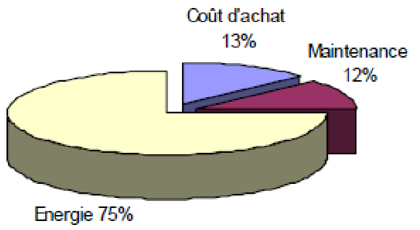
Cost allocation:

		
Motors	Pump	Compressed air

Cost allocation is divided in three parts:

- Invest cost in blue
- Maintenance in purple
- Energy consumption in yellow

Regardless of the technology used, energy consumption is always the most part during all of life. For that reason, energy savings are recommended because we have a money back guarantee.

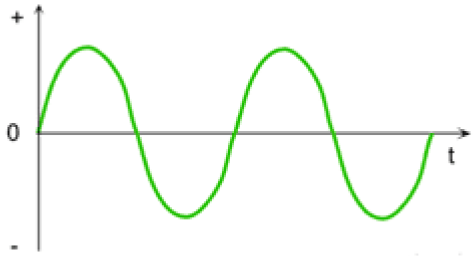
What is electricity?

Electricity has two components:

- The current that corresponds to an orderly movement of electrons
- The tension that corresponds to a "level" difference that drives electrons

There are two kinds of current:

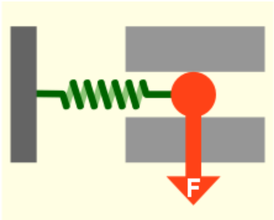
- Direct current (DC)
- Alternative current (AC): electrons travel alternately in one direction and then in the other at regular intervals



Historically, alternative current is easier to carry over long distances and the losses of tension transformation are reduced.

Active and reactive electricity

The electrical energy of an alternating current is composed:



- an "active" part transformed into heat or movement;
- a "reactive" part generated by the magnetic circuits of electrical machines (to compensate);

Only active energy is measured and taken into account in the invoices (kWh). Reactive electricity has to be compensated.

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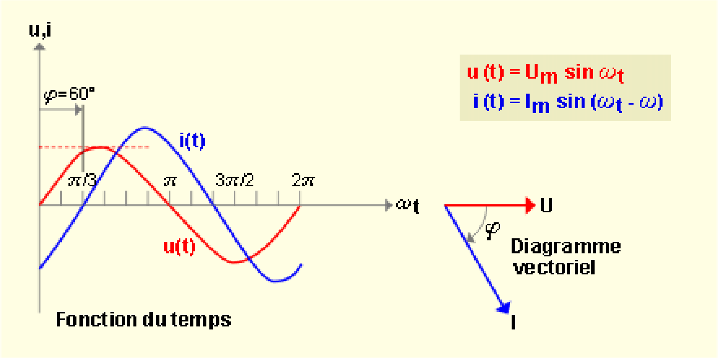
Phase shift:



There is a phase shift between the current and the tension. Phase shift is represented by the angle phi. We need to have a cos phi close to 1. If cos phi is equal to 1, current and tension are in phase. The electricity power is more efficient.

A few cos phi values:

- *100% charge asynchronous engine: cos phi = - 0.85*
- *50% asynchronous engine with a charge: cos phi - 0.73*
- *fluorescence lamps: cos phi - 0.5*
- *induction heating: cos phi - 0.5*

Absorbed power (= measured current):

Absorbed power : P = U * I * cosφ /1000 [kW]

If tension - 230V and monophase:
P (kW) = I (A) * 230 (V) * cosφ / 1000

If tension - 400V and three-phases:
P (kW) = I (A) * 400 (V) * root square (3) * cosφ / 1000

If you need more power, you need to have a higher current or a a higher tension. You have also more power if three phases are used (* √3.

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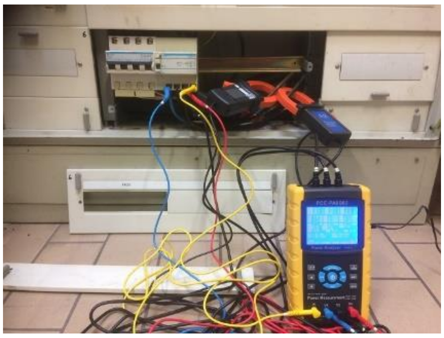
Be careful with measurement!!!



Even if the measure is good, be careful because it doesn't mean that you have really the image of energy saving.

Example: electricity measure on cooling unit

Current transformers

Operation

The goal of a transformer is to convert electrical energy from one voltage to another voltage.. For transport, losses are reduced with a high voltage.

Functional principle:

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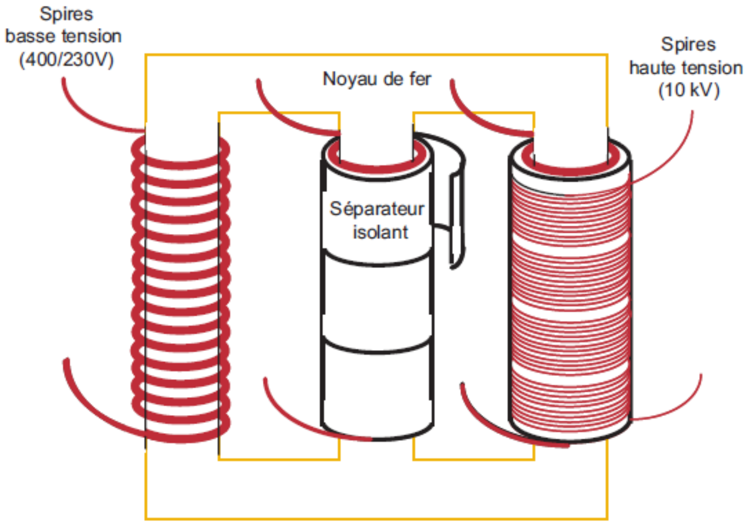

The electricity energy is circulated in a coil. This electric current produced a magnetic current through an iron core. Then, the “magnetic current” is still transformed into an electric current with a lower voltage in another coil. The first coil has more wires than the second coil in a transformation from high to low voltage.

There are two kinds of transformers:

- Oil-cooled
- Air-cooled (“dry”)

Oil-cooled are more efficient because energy is conducted easier by oil.

Losses in transformers:

- Unloaded losses or iron losses (continuously)

  To reduce unloaded losses, coils must be manufactured perfectly.

- Loaded losses: copper charge losses or losses (variation in i²)

- Auxiliary losses
- Harmonic losses

Example of losses values :

Tableau 1 : Pertes d'un transformateur (normes HD428 et HD538 du CENELEC[1])

Power	Oil	Loaded (HD428) jusqu'à 24kV[2]		Air S…)	Oil	Un Loaded HD428) jusqu'à 24kV[2]		Air … 8)
	Liste A	Liste B	Liste C	12kV primaire	Liste A'	Liste B'	Liste C'	12kV primaire
(kVA)	(W)	(W)	(W)	(W)	(W)	(W)	(W)	(W)
50	1 100	1 350	875	N/A	190	145	125	N/A
100	1 750	2 150	1 475	2000	320	260	210	440
160	2 350	3 100	2000	2700	460	375	300	610
250	3 250	4 200	2 750	3 500	650	530	425	820
400	4 600	6 000	3 850	4 900	930	750	610	1 150
630 /4 %[3]	6 500	8 400	5 400	7 300	1 300	1 030	860	1 500
630 /6 %[3]	6 750	8 700	5 600	7 600	1 200	940	800	1 370
1 000	10 500	13 000	9 500	10 000	1 700	1 400	1 100	2000
1 600	17 000	20 000	14 000	14 000	2 600	2 200	1 700	2800
2 500	26 500	32 000	22 000	21 000	3 800	3 200	2 500	4300

1. CENELEC = Comité Européen de Normalisation Électrotechnique www.cenelec.org
2. Des valeurs différentes s'appliquent pour 36 kV
3. 4 % et 6 % réfèrent à l'impédance de court-circuit

With this value table, you can calculate energy saving when you switch from a dry to an oil. You can also calculate the energy spend of the power transformer.

Driving forces

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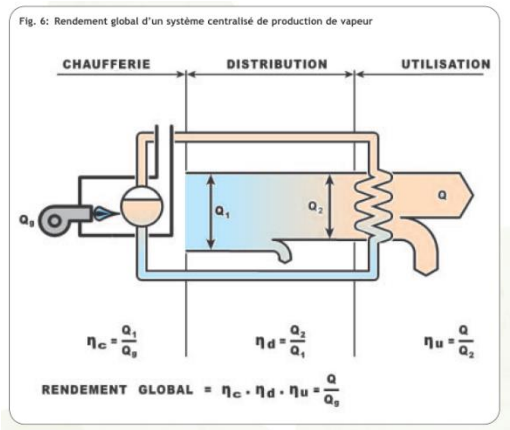
Energy transformation:

1. 100% of energy (mechanical or electrical) can be converted to work or heat

Example : heating resistance 

2. A fraction of the thermal energy can be converted into work

Example : generator, boiler



Power definition:

Amount of work provided per unit of time
Amount of energy consumed or dissipated per second

Units:

Power [W] - Energy or work/time [s] - [in J/s]
Power [kW] - energy [kWh]

Be careful, power is not equal to an energy!

Nominal power = useful power :

Nominal power: the mechanical power requested by the user - useful power

Example :

An electric motor nameplate tells us that nominal power is useful mechanical power of 10 kW, an absorbed current - 19.2 A, tension - 380 V and Cos phi - 0.91.
*The electric absorbed power is 11.5 kW = 19,2 * 380 * 0,91 * rootsquare (3)*

An electric motor nameplate

Reality: nominal power <> useful power:

In fact, nominal power is not equal to useful power. Why?

- Oversizing. Industries need to be adaptable because their productions could be increased in the future.
- Maintenance.

These consequences are not good because efficiency decreases with load rate. So, it’s better if you have a good sizing with your requirement.

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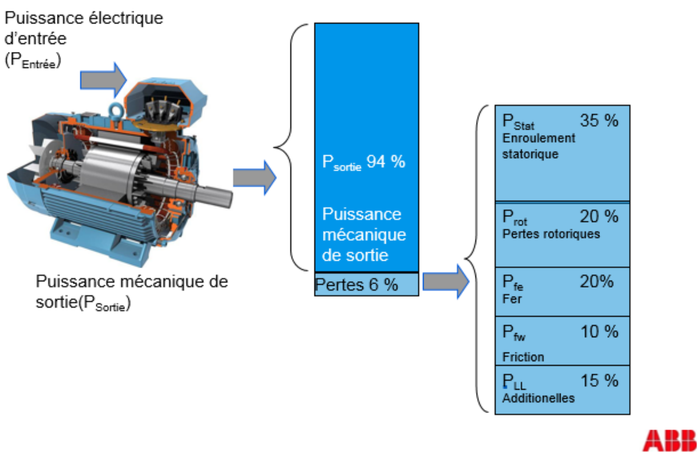
Efficiency of motors

Where do the losses come from?



Losses from motors come from several sources but in general, motors are very efficient. There is a small quantity of losses.

Engine efficiency

IEC 60034-30 specifies energy efficiency classes for asynchronous engines with a power of 0.75 to 375 kW

Standard SR CLC/TS 60034-31: 2011 Rotating electrical Machines - PART 31: Selection of Energy-Efficient Motors including variable speed applications

Classes d'efficacité des moteurs asynchrones	
IE4 - Super Premium Efficiency	Définition en projet CEI 60034-31
IE3 - Premium Efficiency	La classe IE3 est obligatoire à partir du 1er Janvier 2015 (de 7,5 à 375 kW) et 1er Janvier 2017 (0,75 à 375 kW)
IE2 - High Efficiency	La classe IE2 est obligatoire pour tous les nouveaux moteurs depuis le 16 Juin 2011
IE1 - Standard Efficiency	Depuis le 16 juin 2011 la commercialisation des moteurs IE1 n'est plus autorisée

CE

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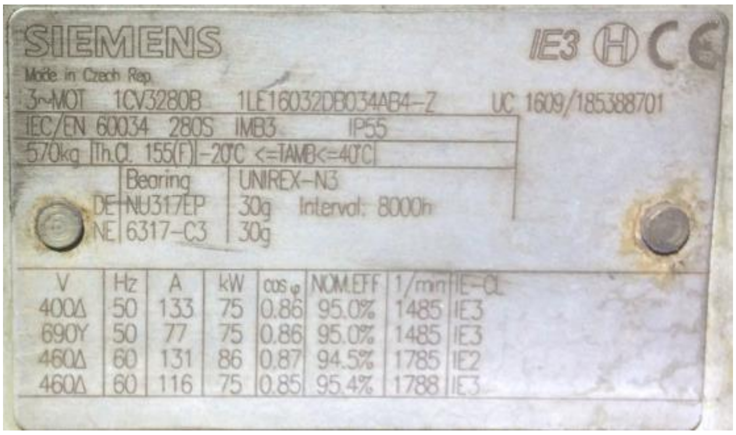
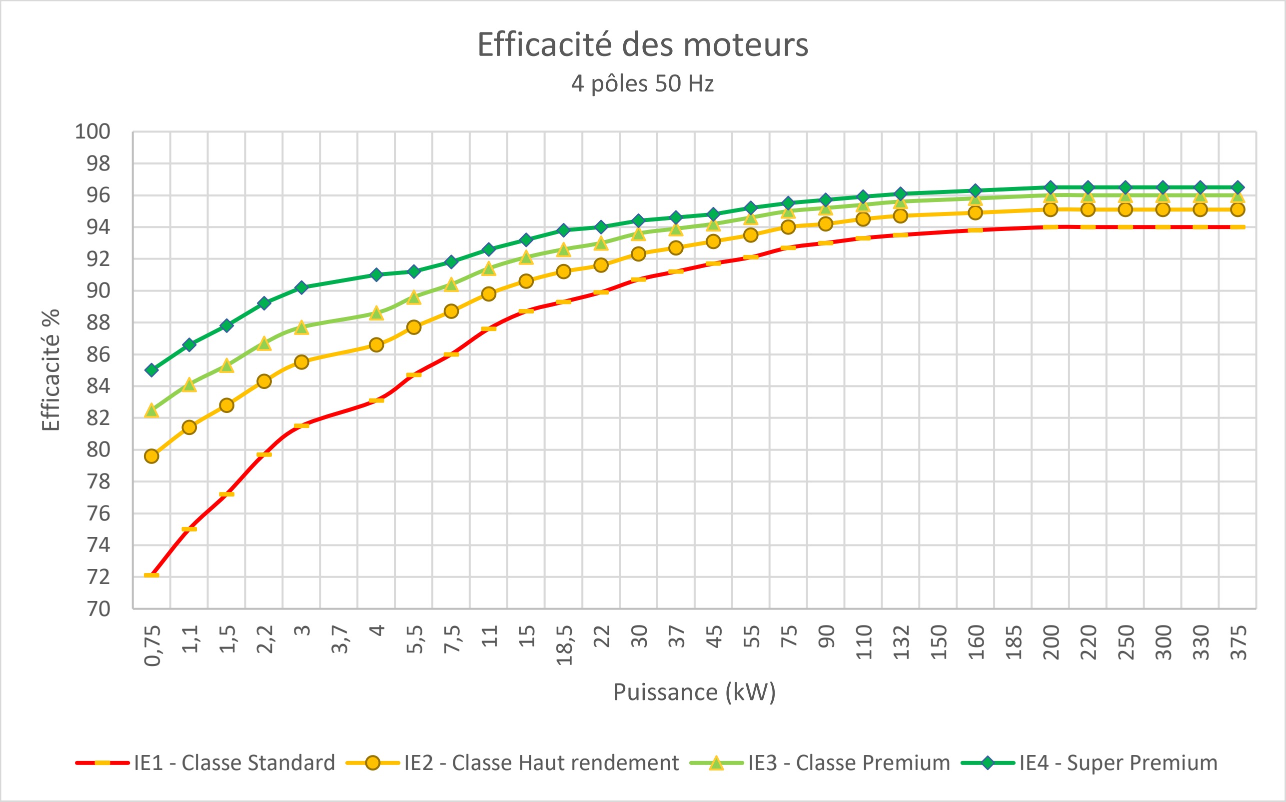
On the motor nameplate, a label CE can be figured. In this case, the motor is included in engine efficiency. There are different efficiency class for motors: IE4, IE3, IE2 and IE1. The information of the class is also figured on the motor nameplate.



Energy efficiency classes for asynchronous engines with a power of 0.75 to 375 kW:



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For all efficiency class, efficiency increases with the power of the motor. So, we have a greatest potential on energy savings in small power motors.

We can have energy savings if a standard efficiency motor (IE1) is changed into a high, premium or super premium efficiency motor (IE2, IE3 or IE4).

Example: IE1: P= 7,5 kW, efficiency = 0,86
IE3: P= 7,5 kW, efficiency = 0,90

➔Absorbed power for IE1 = 7,5 / 0,86 = 8,72 kW and absorbed power for IE3 = 7,5 / 0,9 = 8,33 kW
➔In this case, energy savings = 8,72 – 8,33 = 0,39 kW
➔0,39 kWh each hour = 0,39 / 8,7 = 4,5%

Construction of a "Super-premium" IE4 category

This new generation of magnet engines generate their own magnetic field without having to induce a current.

Advantages:

- an additional 2.5% energy gain, compared to THE IE3 engines and 0.5% for large engines
- low heat production (reduction in joules losses)
- reduced volume and weight, significant noise reduction, increased engine reliability and lifespan, requiring less maintenance

Drawbacks:

- not a direct start on line, requires a specific drive
- cos phi is proving to be severely degraded

BE CAREFUL with these new motors. There are a lot of difficulties because cosphi could be degraded. So, this problem could be a big impact for the company.

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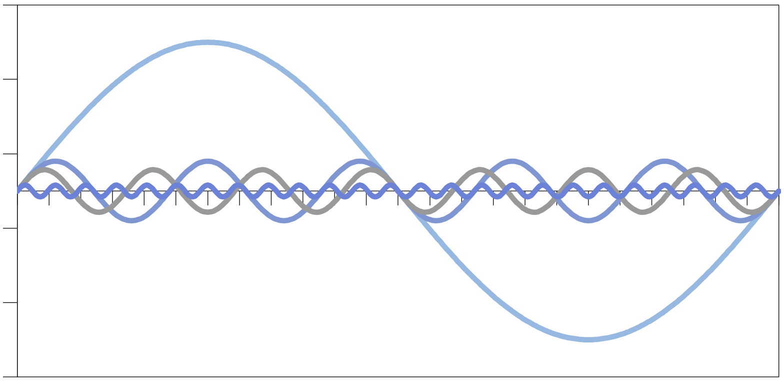
Harmonics

Definition

A harmonic is a whole multiple of a fundamental wavelength



Example: for a current network of 50 Hz, 50Hz is the fundamental frequency, 150 Hz is the 3rd harmonic, 250 Hz is the 5th harmonics, etc.

- Odd harmonics (3th, 5th, 7th, …)
- Pair harmonics (2nd, 4th, 6th, …)

Harmonics = problems for industries ! For example, a regulation signal could be disturbed by harmonics !

Where do you find harmonics ?

In many industrial equipments :

- Drive AC / DC (engines, ...)
- Non-switchable power systems (UPS)
- Different VSD variator speed drive

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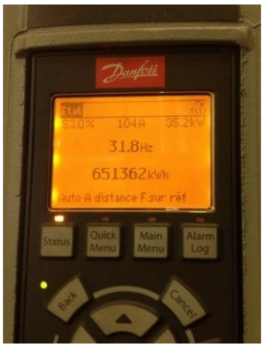

In a variator speed drive, you have a lot of harmonics ! Be careful for the regulation.

In office equipments and lighting:

- PC, Printers, Fax
- Fluorescence, LED
- …

Problems generated by harmonics

- Heat effect
- Distortion effect of the shape of the wavelength (shape, crest factor) → disturb the regulation signal

Solutions : active filters and capacitors

Capacitors are used to improve a bad cosphi

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