TELEGROUP

technical seminar

Tuesday May 14th
Auditorium “Pompeu Fabra”
Barcelona

Enginyers Industrials de Catalunya

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Gestinel S.L.

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POWER FACTOR CORRECTION
as a contribution on Energy Efficiency

Mr. Niccolò Bagnoli | Sales Director
Eng. Peter Litrico | Sales Engineer

Program of Seminar

Company Profile | 2019

- Who we are
- Values
- Quality; Company certifications
- Quality; Products certifications
- Our business; Power Factor Correction
- International presence
- References

Who we are

TELEGROUP born in the mid-80's from an idea of Mr. Fabiano Bagnoli, who is still in the Managing Director, and already founder of a well-known electrical installation Company in Tuscany, exactly in Sambuca, a small town surrounded in the hills of Chianti, from ever a territory synonymous of history, culture and art all over the world.

Right away, TELEGROUP focused its activities in the development, manufacture and sales of Low-Voltage Power Factor Correction Systems, which still represent the core business of the Company.

In a few years, focusing its sales strategy on high quality solution, TELEGROUP was established on the national market as a company synonymous with great reliability.

The will and perseverance in the name of quality have has been awarded with several projects for both Italian and international End Users, leaders in their fields, who have chosen TELEGROUP's solutions for developing and implementing Power Factor Correction Systems in their Facilities.

Today, after 30-years of activity, TELEGROUP approaches the market as dynamic and innovative Company, both on the Italian and International market, with a Sales Network that covers more than 30 countries worldwide.

Our Values

Passion

TELEGROUP, as well as a company, is a family of people who every day, with strength, determination and enthusiasm, provide professional services both for the satisfaction of customers, and for the achievement of ever more ambitious goals.
Decision, dynamism, cohesion, shared objectives … just passion for our company.

Knowledge

Over thirty years of activity in the sector, where have been faced several application with totally different characteristics, today allow our company to be able to intervene in an highly qualified way from any type of user.

Innovation

Development and implementation of the product range, marketing and commercial activities, , technical training; all these features make TELEGROUP a cutting-edge reality, always vigilant on business expansion and new opportunities.

Quality

It recognized nationally and internationally and in critical applications, our solutions have become a must for many prestigious End Customer, who for the efficiency of its plants demand only the best..

Service

Our service is personalized, dedicated and efficient both in the after-sales step, which especially in the pre-sales stage, through a selection guide to the Customer, for offering the best and proper solution.

Quality

Company Certifications

TELEGROUP is a company certified according to standards ISO 9001: 2015, ISO 14001: 2015, BSOHSAS 18001: 2007, SA 8000: 2008, issued by DNV, one of the most accredited Certifier worldwide.

All company process, from design and procurement to production and testing, until the sales stage and assistance, have been certificated according to the regulations and therefore represent further evidence of the quality process of TELEGROUP.


DNV·GL

MANAGEMENT SYSTEM CERTIFICATE

Certificate No: 149937-2014-ASA-ITA-SAAS

Initial certification date: 11 February 2014
Expiry date of last certification cycle: 11 February 2017
Date of last recertification: 10 November 2016

Valid: 5 March 2017 - 11 February 2020

This is to certify that the management system of

TELEGROUP S.r.l.
Via Leonardo Da Vinci, 100, Località Sambuca - 50028 Tavarnelle Val di Pesa (FI) - Italy

has been found to conform to the Social Accountability Management System Standard:
SA 8000:2014

This certificate is valid for the following scope:
Design, manufacture and trade of power factor correction systems and power conversion systems.

Place and date: Barendrecht, 6 March 2017

For the issuing office: DNV GL - Business Assurance, Zwolseweg 1, 2994 LB, Barendrecht, Netherlands

D.P. Koek
Management Representative

Quality
Products Certifications

Following its policy of expansion worldwide, during the years, TELEGROUP has acquired the following international Certificates:

GOST Certificate

Acquired in 2012 for Power Factor Correction systems with three-year extension, necessary for the sale of equipment in the Russian market

UL Certificate

Acquired in several occasions during the years for Power Factor Correction Systems and needed for exporting to the USA market.

Certificate of conformity (SASO)

Acquired in 2015 for Power Factor Correction System, the SASO Certificate is needed for exporting in the Kingdom of Saudi Arabia

All products are designed and manufactured in compliance with the international reference standard and in particular, all TELEGROUP's Power Factor Correction system range complies with:

EN 61921 EN61439-1 IEC 60831-1 IEC 60831-2 EN 61642 EN 5008,1-2

TELEGROUP carried out and passed the Type Tests at KEMA laboratories for its Low-voltage Power Factor Correction systems.

- IEC 61439-1 Clause 10.11 - Verification of the short-circuit withstand strength – 50 kA for 1 second – direct connected on the busbars, not conditioned from MCCB
- IEC 61439-1 Clause 10.10 – required from TELEGROUP - Verification of Temperature-rise at elevated ambient temperature (52°C ambient temperature)

Core-business

L.V. Power Factor Correction Systems

Over thirty years of experience, thousands of kVar installed in Italy and in major international markets worldwide, supplying leaders End Users, TELEGROUP is the Italian excellence in the manufacturing of Low-Voltage Power Factor Correction Systems.

A range of products divided into several types and able to satisfy any application from 230 V up to 800 V 50 Hz and 60 Hz.

With the use of Three-Phase Capacitors technology, made in Germany from a worldwide leader manufacturer, with insulation in Resin and Nitrogen Gas (N2), TELEGROUP is able to offer a highly efficient and more reliable product with respect to the technologies of Capacitors Single-phase, and at the same time compact due to the small size of these capacitors.

International Presence

Our Quality Worldwide

Thanks to an extensive network of distribution, which includes 20 agencies in Italy and over 25 partner abroad, TELEGROUP includes the installation of its products in over 40 countries worldwide.

Direct Export Market

Albania, Angola, Austria, Ausrtralia, Belgium, Bulgaria, Chile, Croatia, Estonia, France, England, Ireland, Northern Ireland Germany, Ghana, Jordan, Greece, Lebanon, Malta, Morocco, Mauritania, Mexico, Nigeria, New Zealand, Portugal, Romania, Saudi Arabia, Serbia, Spain, Switzerland, Sweden, Turkey, Tunisia.

Indirect Export Market

Algeria, Argentina, Egitto, Ethiopia, Indonesia, Iran, Iraq, Kenya, Perù, Poland, Russia, Singapore, USA

Main References

Heavy Industry, Hospitals, Telecommunication, Renewable Energy….

During his thirty years of history, both in Italy and in the World, TELEGROUP has had and still has the opportunity to serve customers of different applications Finals, which benefited in terms of saving energy and costs, as a result installation of our products.

Part 1 | Power Factor Correction

Basic Principles

- What is Power Factor
- What is Power Factor Correction
- Methods of Compensation
- Reactive Power Calculation

What is Power Factor
Cos phi

An Electrical Power System is composed from:

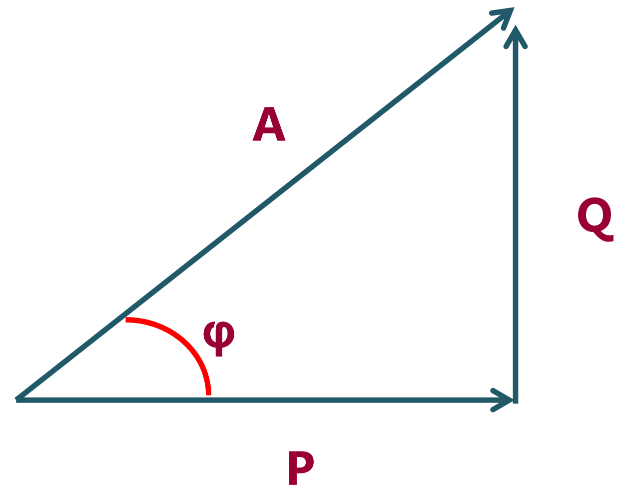
- Resistive Loads
- Inductive Loads

All Inductive Loads, for its standard operation, need to produce different powers:

- Active Power (working power), measured in kW
  It performs the useful work of Loads

- Reactive Power (no-used power) kVAr
  It produce the needed magnetic fields for the operation of Loads

- Apparent Power, measured in kVA
  (Summation of Active Power + Reactive Power)



What is Power Factor

Cos phi

Comparing an Electric System with a glass of Beer, we can noted that:

-Glass of Beer is Apparent Power (kVA)
-Beer is Active Power (kW)
-Froth is Reactive Power (kVAr)

This is the best sample for showing that major is the impact of Reactive Energy, lower is the Power Factor (Cosphi)

A poor Cosphi (< 0,90 usually) in the Electric Systems, means technical and economical disadvantages.

Froth

Beer

Electric System with optimal PF

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What is Power Factor Correction

Methods of Compensation

A Power Factor Correction System, through Capacitors, produces the needed Reactive Energy for compensating the Electric System and bring back the Cosphi at the optimal value (usually > 0,90)

How?

Where?

→

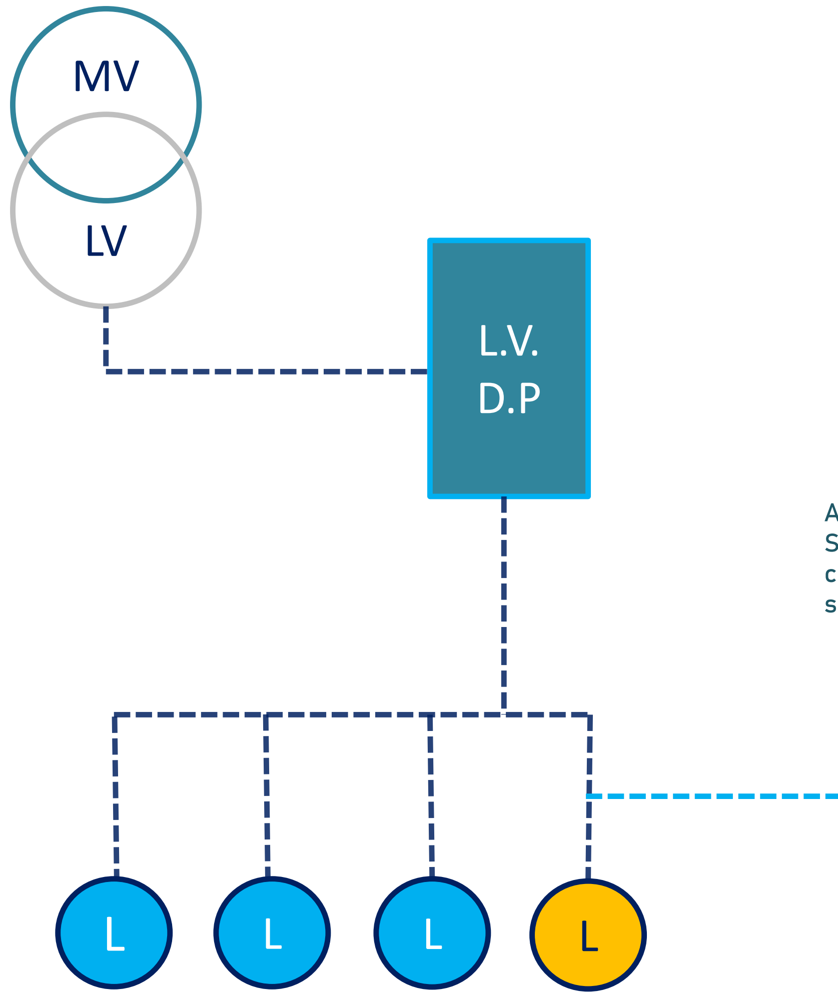
3 thypologies of compensation

- Distributed PFC
- Centralized PFC
- Mixed PFC

Distributed PFC

Automatic PFC for the compensation of variable loads

This solution is realized connecting the Capacitor Bank, directly to variable load that needs to be compensated.



Some examples:

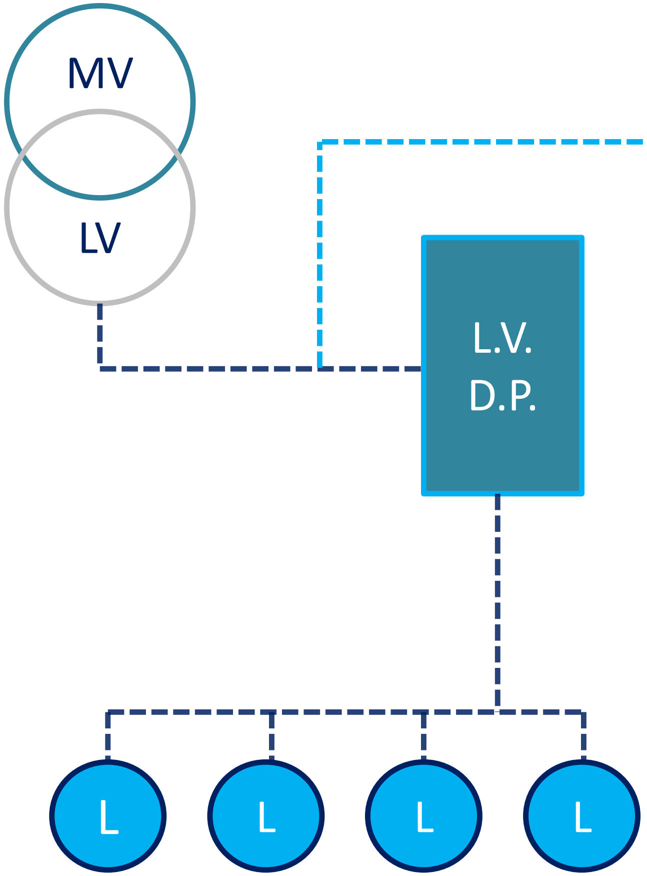
- Tissue Rewinder
- Mills for Ceramic Industries
- Packaging Lines

Automatic PFC System for the compensation of a single variable load

Centralized PFC

Automatic PFC for the "upstream" compensation of electric systems

The Centralized Power Factor Correction, is undoubtedly the most used type, since in most of the plants there is not a constant reactive power absorption, for example on account of work cycles in which machines are used with different electrical characteristics.

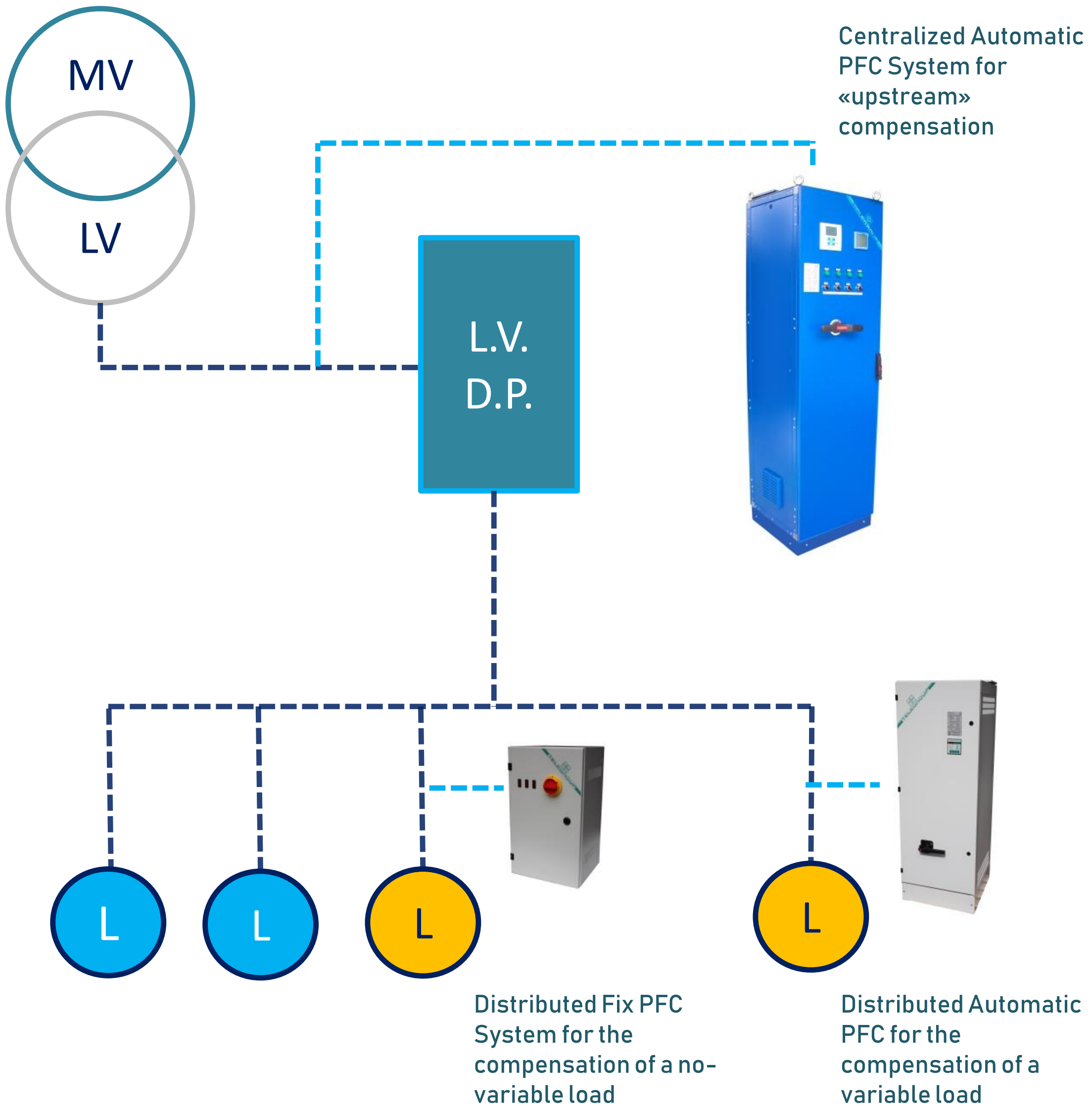


Automatic PFC System for the «upstream» compensation

Mixed PFC

Big powers, maximum efficiency

This solution, is essentially a compromise between the two solutions of the Distributed Power factor correction and the Central and exploits the advantages.



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Reactive Power Calculation

Automatic PFC System

For sizing the power of an Automatic PFC System, is absolutely needed to be in possession of the following Data:

- Active Power (kW)
- Actual Power Factor (Cosphi)
- Required Power Factor (Cosphi)

$$Q = P \cdot k$$

Q is the Reactive Power
P is the Active Power
K is the coefficient between the Actual Cosphi and the Required Cosphi

Example

- Active Power 500 kW
- Actual Power Factor (Cosphi) 0,70
- Required Power Factor (Cosphi) 0,98

Calculation: 500 kW x 0,817 (value from the Cosphi Table) = 408 kVAR

This value is the needed Reactive Power, but is ever necessary to oversize the Power with the nearest available Power. In this case, we could suggest 450 kVAR Automatic PFC System

Reactive Power Calculation

Table of Coefficients

Fattore di Potenza iniziale Actual Power Factor Cos phi	**Coefficiente moltiplicativo "K", da applicare alla Potenza Attiva** Multiplication coefficient "K", to be applied to the Active Power **Fattore di Potenza Desiderato | Desired Power Factor**						
	0,90	**0,92**	**0,94**	**0,95**	**0,96**	**0,98**	**1,00**
0,30	2,695	2,754	2,817	2,851	2,888	2,977	3,180
0,35	2,192	2,250	2,313	2,348	2,385	2,473	2,676
0,40	1,807	1,865	1,928	1,963	2,000	2,088	2,291
0,45	1,500	1,559	1,622	1,656	1,693	1,781	1,985
0,50	1,248	1,306	1,369	1,403	1,440	1,529	1,732
0,55	1,034	1,092	1,156	1,190	1,227	1,315	1,518
0,60	0,849	0,907	0,970	1,005	1,042	1,130	1,333
0,65	0,685	0,743	0,806	0,840	0,877	0,966	1,169
0,70	0,536	0,594	0,657	0,692	0,729	0,817	1,020
0,75	0,398	0,456	0,519	0,553	0,590	0,679	0,882
0,80	0,266	0,324	0,387	0,421	0,458	0,547	0,750
0,85	0,135	0,194	0,257	0,291	0,328	0,417	0,620
0,90	-	0,058	0,121	0,156	0,193	0,281	0,484
0,95	-	-	-	-	0,037	0,126	0,329

Reactive Power Calculation

Fix PFC Systems

Power (kVA)	Type	
	Oil kVAr Vacuum	Resin kVAr
100	5	2.5
160	7	4
200	7.5	5
250	8	7.5
315	10	7.5
400	12.5	8
500	15	10
630	17.5	12.5
800	20	15
1000	25	17.5
1250	30	20
1600	35	22
2000	40	25
2500	60	35
3150	60	50

Part 2 | Reactive Energy penalties

How the Penalties are charged in Spain

- Legislation
- Case Study
- Payback

Reactive Energy in Spain
Orden ITC/688/2001

There are two different rates for low voltage:

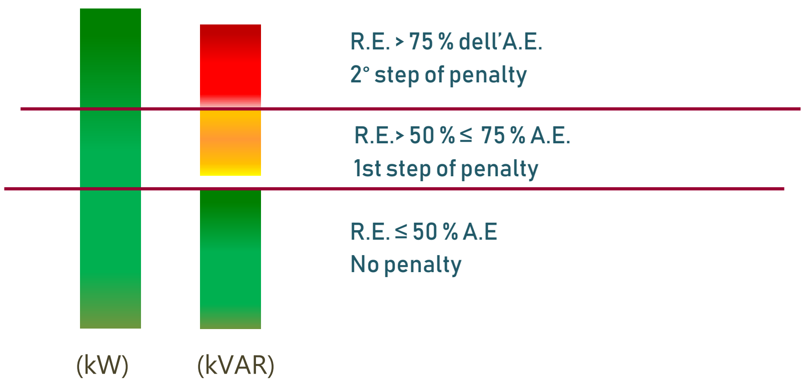
Rate 2.0A: SIMPLE RATE

applicable to contractual power (Pc) that are not above 15 kW.
The end users pay Reactive Energy > 50% of Active Energy during the billing period.
Required Cosphi 0.90

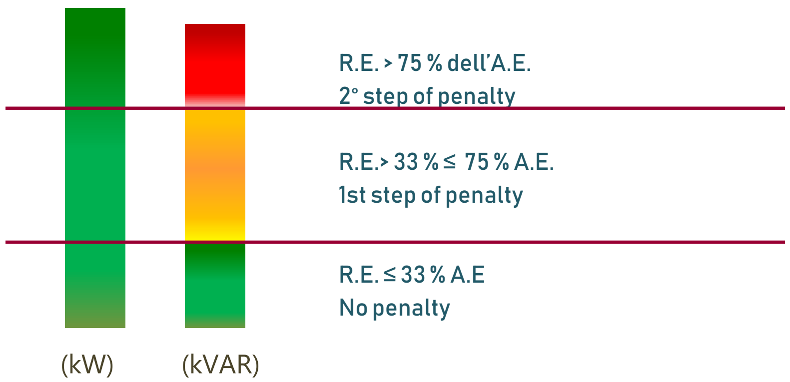
Rate 3.0A: GENERAL RATE

Applicable to any contractual Power (Pc) that is above 15 kW.
The end users pay Reactive Energy > 33% of Active Energy during the billing period.
Required Cosphi 0.95

Rate 2.0A: SIMPLE RATE



Rate 3.0A: GENERAL RATE



Reactive Energy in Spain

Tariffs €/kVArh

Cosphi	€/kVArh
Cosphi <0.80	0,062332€
0.80≤Cosphi≤0.95	0,041554

Reactive Energy in Spain

Case Study | Penalty for Reactive Energy

Plant Data / Monthly consumption

RATE 3.0A
Power consumption: 450 kW
Active Energy: 79.200 kWh
Reactive Energy: 52.000 kVArh
Cosphi: 0,83

Reactive Energy «allowed» (free) 33 % of Active Energy consumption
= 79.200,00 kWh x 0,33 = 26.136 kVArh

Calculation of R.E. Penalty

Excess consumption (>33%) at 0,041554 €/kVArh
= (52.000 kvarh) – (26.136 kvarh)
= 25.864kvarh x 0,041554 €/kVArh
= 1.074,75 €

Total Penalty

1.074,75€/month

12.897,00 €/year

Reactive Energy in Spain

Case Study | Payback

Power of Automatic PFC System

Power consumption: 450 kW | Cosphi 0,83 | Target Cosphi 0,98

Using the Formula at page 19, we deduct that for compensating a PF from 0,83 to 0,988 on a power of 450 kW, it's necessary a Reactive Power of 232 kVAr

Since it's ever better to oversize the power of a 15 % - 20 % (the active power maybe could change during the year), we'll propose an Automatic PFC System of 275 kVAr

Payback

In the worst case, we suppose that this systems, due to the typologies of its loads, has an high content of Harmonic Distortion and we'll go to propose an Automatic PFC System Detuned at 189 Hz, 275 kVAr at 400 V, as our G48Filter Series.

The final price to the End User, including installation, will be between 7.500 € and 7.800,00 €

Considering the Monthly Reactive Energy Penalty of 1.074,75 €, the Payback of the PFC will be made in 7-8 months

In a 5-years prospect, thanks to the PFC investment, the End User will save a total of 64.485,00 € from its Energy bill

Is the PFC a good investment?

Actually, on the electric market panorama, Power Factor Correction is the safest and fastest investment for the End Customers, with a standard payback in 7– 8 months.

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Part 3 | Power Factor Correction

Configuration and Key components

- Reference Standards
- Capacitors
- PFC Controller
- Contactors or Thyristor Modules
- Switch Disconnector
- Case Study

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Reference Standards

Low-voltage Power Factor Correction Systems

EN 61921
Low-voltage Capacitor Banks

EN 61439-1
Low-voltage assembled Switchgear - Part 1

IEC 60831-1
AC Power Capacitor up to 1000 V – Part 1

IEC 60831-2
AC Power Capacitor up to 1000 V – Part 2

EN 61642
Industrial a.c. networks affected by harmonics. Application of filters and shunt capacitors

UNI EN 50081-2 – CE Mark
All TELEGROUP products are CE marked as per the reference standard.

Automatic PFC Systems

Configuration

Sheet steel Enclosure
Painted with epoxy dust paint, colour RAL7035 (IP30 standard, IP54-55 on request)

Microprocessor PFC Controller
For the insertion of Capacitor Banks through Contactors or Thyristor Modules

Busbars
Aluminium busbars system (copper on request)

Transformer
For the splitting of power circuit from auxiliary circuit.

Protection Device
Switch Disconnector with door interlock, sized 1,3 times the nominal current of PFC as per EN61921 standard

Ventilation System
Natural or Forced (in reference to the typologies)

Modular Rack

NH protection Fuses 100 kA

Three-Phase Capacitors insulated with Nitrogen Gas (N2) or Oil

Three-Pole Contactors or Thyristor Switch Modules

Detuning Chokes for the protection of Capacitors from Harmonic distortion (3°, 5°, 7° harmonic)

Capacitors

Typologies | 3Phase and 1phase

The Capacitors, are the real engine of a Power factor Correction system.

Without top-quality capacitors, the remaining components do not make sense to operate.

Before explaining the differences between Three-phase and Single-phase Capacitors, it's necessary also to make an additional division before, between well done Capacitors and not-well done Capacitors.

The single-phase Capacitors technology, now abandoned internationally but still used in some Countries, is an archaic construction system as dangerous and risky.

TELEGROUP, despite the quality of its single-phase capacitors were excellent, following the choice of its partner, from over 15 years produces its PFC System using only Three Phase Capacitors.

Picture 1

Picture 2

Capacitors

Typologies | Why prefer 3 Phase instead of 1phase?

Types	In case of fault…	Space reduction…	Wiring, human error and overheating	Maintenance	Economic Benefits?
Three-Phase Capacitors	In case of fault on a phase, all the Three-Phases will are concurrently disconnected; it's especially proper in case of Detuned PFC System, since this will not create any displacement between Capacitors and Detuning Chokes.	Looking on Picture 1 and Picture 2, in both case is showed a Capacitor Bank 25 kVAr at 400 V. The space reduction is clear but for giving an idea about bigger PFC powers, TELEGROUP realize Standard PFC system in one cabinet up to 750 kVAr and Detuned PFC System in one cabinet up to 400-500 kVAr.	In the Picture 1, it's clear that for a 25 kVAr three-phase Capacitor, are necessary only 3 cables. This add value allows a less overheating inside the cabinet and an easier connection during the wiring, reducing the human errors close to zero.	It will be easy to recognize the damaged Capacitor and, thanks to the easy 3-wire connection, the replacement will be very fast, easy and safe.	In addition to the technical risk, realizing PFC system using single-phase instead of three-phase Capacitors. Has also a fake economic benefit. It's purely fake because even if the price of 3, or 9, single-phase Capacitors is a little bit cheaper of one Three-phase of the same power, this benefit it's lost during the manufacturing of a PFC System, for all the explained reasons. No technical benefits, no economic advantages, there are no reason for preferring single-phase to Three-phase Capacitors.
Single-Phase Capacitors	In case of fault on one phase, the Capacitor will not disconnect the other two phases, continuing to operate. This will create a "not true" operation of Capacitor and an hard displacement of the capacitance especially in the Detuned PFCs. It could happen that on three different phases, it would be three different detuning frequency, due to the fault phase.	For realizing the same powers with single-phase Capacitors, respecting all the indication about distances and air circulation from the reference standard, are necessary two cabinets.	Looking on the Picture 2, we can note that for realizing 25 kVAr using single-phase Capacitors, are necessary until 9 Capacitors, with different capacitance. This will force to have until 18 cables to wire, that from one side greatly increasing the margin of human errors and from the other side increase the overheating inside the cabinet	in that cases, it's needed to measure the current of each Capacitor of each bank and, for being safe, it's ever suggested to replace all the Capacitor of a bank (delta o star connection). This will mean to disconnect all the wiring of the bank/banks, replace the Capacitors and re-wire all the banks carefully, for the reason mentioned about wiring.	

Capacitors

The Power of PFC must be indicated on its operating Voltage....

Some PFC manufacturers, following a commercial way that technical has no sense, refer the power in kVAr of PFC Systems not at the Rated Voltage of the Network, but at the Rated Voltage of Capacitors.

It' unfortunately usual to find PFC description like the follow one:

«Automatic Power Factor Correction System 500 kVAr at 550 V»

Why at 550 V if the Voltage Net is 400 V?

Benefits? «........» no one, maybe disadvantages...

Which are the disadvantages?

$$Qc = Qn \frac{U^2}{Un^2}$$

Qc = Power of PFC at Network voltage
Qn = Power of PFC at Rated voltage
U = Network Voltage
Un = Rated Voltage of Capacitors

If we consider the example, we have:

$$500\ kVAr \frac{400\ V^2}{550\ V^2} = Qc\ 264\ kVar$$

It means that on a 400 V Net (standard for Europe, excluding special cases), the PFC 500 kVAr with Capacitors 550 V will be a 264 kVAr at 400 V, or better - 48 % of Reactive Power

Table of Comparison of power reduction
415 V on 400 V = - 8 %
440 V on 400 V = - 18 %
450 V on 400 V = - 21 %
460 V on 400 V = - 25 %
500 V on 400 V = - 36 %
525 V on 400 V = - 42 %
550 V on 400 V = - 48 %

Capacitors

Why use Capacitors at 500 or 550 V?

In an electric system 400 V 50 Hz, it's not absolutely necessary to realize a Power Factor Correction System using Capacitors with Rated Voltage 500 or 550 V.

This "fantasy style" of construction has came out for a purely misleading commercial strategy, for trying to divulgate that:

"higher is the Voltage of Capacitor, higher is its strength in presence of harmonic distortion"

NO!!

From the technical side, this argumentation has no sense.

Why?

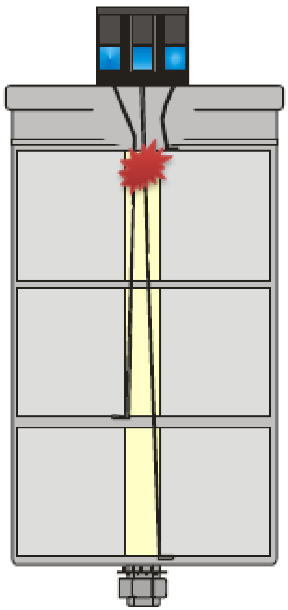
- On 400 V electric system with a poor harmonic distortion , a well-done Capacitor 440 V is absolutely able to operate; if it will fail, it will be not due to its Voltage, but due to its construction.
- On a 400 V electric system with an high content of harmonics, is it sufficient and safe to install higher voltage Capacitors? NO!! The Capacitors are most sensitive to current harmonics instead of voltage harmonics ; in addition, on a current harmonic corresponds a voltage harmonic, that generate a permanent temperature-rise
- In case of resonance, the higher Voltage of Capacitors will not save them from the damage.

Single-Phase
500,550 V
THDi > 30-35 %

Capacitors

Temperature rise in standard Operation

HOTSPOT:



Example

Capacitor 25 kVAr at 400 V 50 Hz

Rated Current (Ir)	62.6 A (36.1A/ph)
Dielectric loss factor	2×10^{-4}
Series Resistance (Rs)	0.7 mΩ
Thermal Resistance (Rth)	2.4 K/W
Dielectric Power losses	P_{VD} $Q_C \times \tan\delta_0 = 5W$
Current Power Losses	P_{VR} $I^2 \times R_S =$ 2.7W
Total Losses Pv(tot)	7,7 W

Temperature-rise above ambient temperature in standard operation

= Pv(tot) x Rth

= **18,5° C**

Capacitors

Temperature-rise with Current (THDi) and Voltage (THDv) Harmonics

Example

With a current harmonic (THDi) of order "h" (it could be 3rd, 5th, 7th ecc..) we've the following results:

- Current on each Capacitor, delta connected, is: $I_{ch} = Ih / \sqrt{3}$
- The voltage on each Capacitor is: $U_h = \dfrac{I_{ch}}{2\pi f_h C \times 10^{-6}}$ $\quad C = 3C_{fase}$
- The reactive power of the Three-phase Capacitor, connected to the harmonic, is: $Q_h = 3 I_{ch} U_h$
- The Dielectric losses connected to the harmonic are: $P_{vdh} = Q_h tg\delta$
- The Resistive losses connected to the harmonic are: $P_{vrh} = I_h^{\,2} R_s 10^{-3}$
- The Total losses connected to the harmonic are: $P_{vdh} + P_{vrh} = P_{vtoth}$
- The temperature-rise, from the standard temperature, will be: $P_{vtoth} R_{th} = \Delta T$

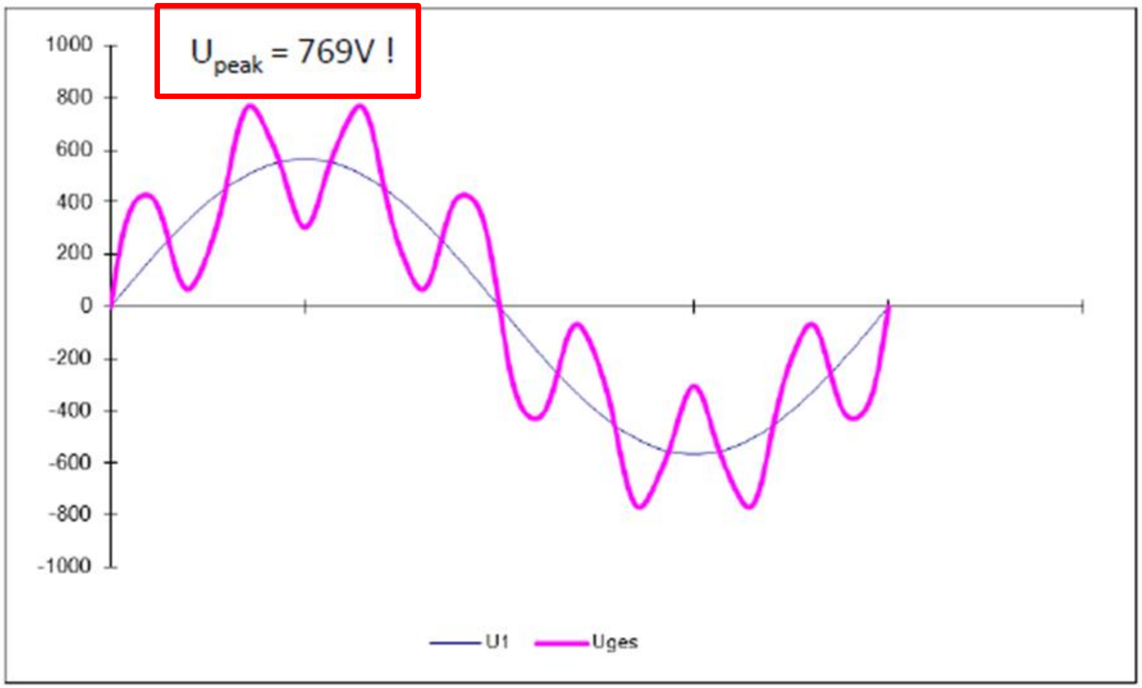
In presence of voltage harmonic (THDv), the result is the same

therefore: $I_{ch} = U_h \, 2\pi f_h C \cdot 10^{-6}$ $\qquad Q_h = 3 I_{ch} U_h$

Capacitors

Temperature-rise in presence of Resonance

Example of parallel Resonance with MV/LV Transformer 1000 kVA with an impedence of 6% (standard) and a Power Factor Correction System 350 kVAr; the resonance will be close to the 7 th harmonic



Effects on Capacitors

Ic = 227 A (3,64 In)

Pv(tot) = 39,7 W

Temperature-rise?

+ 95°C

Instead of a standard temperature of about 60 C°, the temperature inside the Capacitor will be about

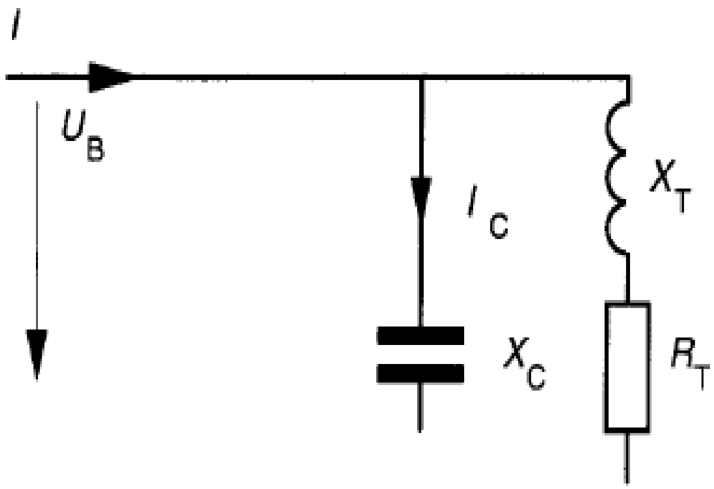
140°C

= DESTRUCTION

Capacitors

EN 61642 | Example of Parallel Resonance

Example of parallel Resonance with MV/LV Transformer and a Power Factor Correction System.



Rated Voltage: 400 V

MV/LV Transformer: 1000 kVA (6%)

Power Factor Correction System: 160 kVAr

300 kVA apparent power

Ub: Voltage on busbar system

Ic: current on Capacitors

Considering the above data, the resonance will be close to the 11 th harmonic so not one of the most relevant which are 3 rd, 5 th and 7 th.

Capacitors

EN 61642 | Example of Parallel Resonance

Tab. 2 **Numerical results of impedances, voltages and currents at characteristic harmonic orders of a parallel resonance circuit in the presence of a harmonic current source**

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IcA (1) = fundamental current
IcA (11) = current on 11° harmonic
DF(B) = Voltage Harmonic Distortion (THDv)
Ic eff. = Current on Capacitors
Ic/Icn = Overload on Capacitors

h	X_T Ω	X_C Ω	Z Ω	I A	I (%) %	U_B V	U_B (%) %	I_C A
1	0,010	–,000	0,010	433	100,0	—	—	231
5	0,048	–0,200	0,064	87	20,0	10	2,4	28
7	0,067	–0,143	0,127	62	14,3	14	3,4	55
11	0,106	–0,091	0,490	39	9,1	33	8,3	212
13	0,125	–0,077	0,192	33	7,7	11	2,8	83
17	0,163	–0,059	0,091	25	5,9	4	1,0	39
19	0,182	–0,053	0,073	23	5,3	3	0,7	32

DF (B) % = 9,8

$R_T = X_T/Q_T = X_T/8$
(semplificato_simplified)

$I_{C\ eff.} = 334A$
$I_C/I_{CN} = 1,45$

Capacitors

EN 61642 | Example of Parallel Resonance

Which are the effects?

1. If the frequency is close to the resonance frequency, also a low current can determines an elevated current on Capacitors. Looking on the example, for h=11 (11th harmonic), the Capacitor has a current of 212 A (+90% of its standard rated current), despite the current on the busbar system is 39 A

2. An elevated current value, causes a voltage drop on the busbar system, which determine a voltage harmonic distortion. In the example, for h=11 (11th harmonic) the voltage harmonic distortion is 8,3 % (Thdv)

3. The current RMS on Capacitors is 1,45 In (permanent) its rated current. This is overload situation since the limit is 1,3 In. It would be "possible" to realize a Capacitor wish such features but in any case the problem will be not solved since the THDv is over 8 % only for a single harmonic order (not the most dangerous)

4. The amplification of the above mentioned phenomena, happen not only when the frequency coincides with resonance frequency, but also when it's close to it

The above mentioned values are in reference to 11 th harmonic, so what could happen with a resonance in 5 th harmonic?

Increasing the Voltage of Capacitors would be a proper solution? **NO!**

Capacitors

Insulation

3 types, which is the best one?

While the winding of any capacitor, both Single-phase and Three-phase, is achieved through a metallized polypropylene film, the insulation (filling), can be realized in 3 systems.

Viscous Resin/Oil and metalizzed paper, are 2 «classic» insulation systems for both Single and Three-phase Capacitors.

Anyway, these insulation systems, do not ensure at 100 % to avoid some risks:

- infiltration of air/humidity inside the cylinder, which is the main cause of Capacitors breakage.
- flammability and fire propagation

Solution? →

The insulation through Nitrogen (N2) Gas, only for Three-Phase Capacitors, is actually the safest, most reliable and strongest way for a proper filling and for avoiding any risk on infiltration of hair and flammability.

Capacitors

Why Nitrogen (N2)?

Filling process in 6 steps

The main problem to be solved in a manufacturing process of Capacitors, is certainly represented by humidity.
It requires a proper attention during the filling phase, since the presence of humidity within the cylinder, substantially compromises the life of the capacitor.

With the filling of the cylinder through the Nitrogen (N2), the possible presence of humidity, it's completely ruled out, since it's a totally "dry type gas" (humidity free)

In fact, it's also used in other specific areas, precisely for the removal of the same moisture from various conductors.

In addition, since Nitrogen is a not flammable Gas, also the possibility, in case of fault, of fire propagation is totally avoided.

These features means that already from the manufacturing process, this type of Capacitor is realized according to a perfect process, which obviously is reflected during its application.

Step 1
Windings (pre-assembled) are placed in the cylinder

Step 2
The lid (fix) is placed on the cylinder and the wiring is passing from the holes in the terminals

Step 3
The Capacitors are placed in the "drying room".

Step 4
2 terminals are welded, leaving open only the *central terminal.*

Step 5
The Capacitors are filled with Nitrogen (N2) Gas from the *central terminal and it immediately closed*

Step 6
The Capacitors are placed in *"tested room", for detecting the Gas leakage*. Hermetical sealing is the measurement that prevents leakage and test verifies the sealing.

Capacitors

Key features of Nitrogen (N2) Gas

Rated Voltage (Uc): from 230 to 800 V

Rated Frequency: 50 – 60 Hz

Operating temperature: - 40° C / D

Insulation : Nitrogen Gas (N2)

Execution: Three-Phase

Discharge resistors: Included

Dielectric Losses: < 0,2 W / Kvar

Reference Standards: EN 608311-2 / UL N. 810

Temperature Class

Cat.	Max. ambient temperature		
	Max.	Average 24h	Average 365 days
B	45°	35°	25°
C	50°	40°	30°
D	55°	45°	35°
60°	60°	50°	40°

Overvoltage

Uc	Hz	Uc Max					
		24 h	8 h	30 min	5 min	1 min	Picco
440 V	50/60	440 V	490 V	510 V	530 V	575 V	1350 V
480 V		480 V	530 V	560 V	580 V	625 V	1450 V
525 V		525 V	580 V	600 V	630 V	680 V	1600 V

Overcurrent

The overcurrent value, can't be generalized to all Capacitors.

The overcurrent value of all TELEGROUP Capacitors (excluding Test Values up to 10 In), is from 1,5 and 3 In

Nitrogen Gas (N2) Capacitors

a benefit for projecting, manufacturing and installing

	Nitrogen Gas (N2) Capacitors		Resin/Oil and Paper Capacitors	
Risk of Humidity	ZERO	Nitrogen is a free humidity Gas	HIGH	the above insulation materials do not ensure the possibile presence of humidity.
Expected life	> 150.00 hours	The 3Phase+(N2) Gas «combo», is actually the safest and most realiable technology; it's usual for us to find 10-12years old PFCs with the same current values.	< 80.00 hours	This value is especially referred to single-phases capacitors; the mentioned technical disadvantages + no proper manufacturing process + type of insulation, generate a drastic reduction of operating life.
In case of fault	NO fire, NO damages	It's not possibile to talk about «explosion», since in case of fault, the Capacitor will just eject the N2 Gas, without damaging or compromising other components	Risk of fire, damages on components	For single-phases; displacement of capacitance bank, risk of fire, damaging of all components For three-phases; risk of fire, damaging of all components.
Flammability	ZERO	Nitrogen Gas is a not flammable Gas	HIGH	For its nature, the above materials are flame propagators.
Risk of fire	ZERO	Thanks to the above features	HIGH	Due to the above features
Mounting	Vertical / Horizontal	Thanks to the properties of N2 Gas and thanks to the last step of production (Step 6 leakage test)	Only Vertical	Leakage of insulation material in horizontal position.
Ecology	TOTAL	The dispose of N2 Gas Capacitors is the same of a Coke can; free and ECO	It depends from the insulation material	
Toxicity	ZERO		It depends from the insulation material	

Nitrogen Gas (N2) Capacitors
the results have awarded our choice

TELEGROUP was the first Company in Italy to marry entirely both the Three-Phase technology, abandoning the Single-phase type, and the typology of Nitrogen Gas filled (N2) Capacitors.

From the first use by TELEGROUP of the first Capacitor with Nitrogen insulation, have passed about 13 years.
After a test period of approximately 4 years, thanks to the great results and customer satisfaction obtained using these Capacitors, we decided to develop, an entire PFC range with all Series, both standard and Detuned, using Nitrogen Gas Capacitors.

This choice has been profitable and satisfying, especially for critical application as:
Automotives, Heavy Industries, Chemicals, Ceramics, Paper-mills, Banks, Data-centers…

Key numbers

kVAr realized since 2003

6 millions

Fault of Capacitors

0,00001 %

Warranty from 2014

24 months

Who chose it

FCA, MARAZZI, DS Smith, ALCANTARA, ABB, gsk, AstraZeneca, SAINT-GOBAIN

Control Device

Automatic Microprocessor PFC Controller

In an Automatic Power Factor Correction System, the Controller is, together with the Capacitors, the fundamental element.

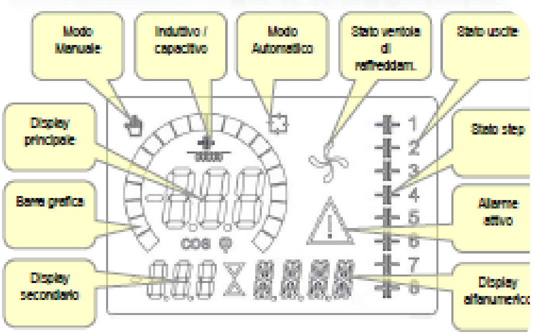
The main function of this component, is the verification of the load current phase shift, which simultaneously combines the engagement or disengagement of the capacitor banks. All this, with scope for a near unity power factor.

Through the control of Microprocessor, the PFC Controllers of PCRL and PCRJ Series, are able to perform many operations, including the management of the use of batteries, thanks to which it is able to optimize both the function and life of the capacitors.

- Backlit LCD display with icons, with texts available in 6 or 10 languages
- PCRL5/7, 5 - 5 outputs as standard, exp up to 7
- PCRL8/14, 8 outputs as standard, exp up to 12
- PCRJ8/14, 8 outputs as standard, exp up to 14
- USB, RS23, RS485 and Ethernet, available with Expansion Modules EXP

Control Device

Automatic Microprocessor PFC Controller



General features

Over 100 parameters to set and manage

- Automatic recognition of the current sense
- Operation on 4 Quadrants for Cogeneration systems
- High measurement accuracy True RMS (TRMS)
- THDi and THDv measurement up to 15^{th} order
- Use in MV systems through Voltage Transformer
- Measuring of the Reactive Power installed on each step
- Selectable Maintenance Program
- Different use of Capacitor banks, calculated on the previous operations
- EXP module for protection Capacitors from a single-harmonic
- Current input: Single phase connection 1 A or 5 A (configurable)
- IP54 front panel protection
- Working temperature -20 / + 60 ° C

TELEGROUP

Control Device

Automatic Microprocessor PFC Controller

Alarms

Alarm	Descritpion	Display indication	On the terminal for general Alarm	Disconnection	Delay and «reaction time»
A01	Undercompensation	●	●		15 min
A02	Overcompensation	●			120 s
A03	Lower current in the electric system	●		●	5 s
A04	Higher current in the electric system	●			120 s
A05	Lower voltage in the electric system	●	●		5 s
A06	Higher voltage in the electric system	●	●		15 min
A07	Current overload on Capacitors	●	●	●	180 s
A08	Higher temperature	●	●	●	30 s
A09	No Voltage release	●		●	0 s
A10	Higher THDv	●	●	●	120 s
A11	Higher THDi	●	●	●	120 s
A12	Maintenance	●			0s
A13	Faulty step/bank	●	●		0s

Control Device

Automatic Microprocessor PFC Controller

PCRJ Master

In big plants with special necessities, it would be needed a division of Power Factor Correction system, in more systems.

The PFC Controller of PCRJ Series, are able to operate as Master and Slave; the PCRJ Master, it's able to control and manage until n. 8 PCRJ Slaves.

The PCRJ Slaves, received the inputs, for switching on-off the capacitor banks, from the PCRJ Master, which takes care about the monitoring and status of each parameter of each PCRJ Slave.

PCRJ Slaves... up to 8

PCRJ Slave 1

PCRJ Slave 2

PCRJ Slave 3

Automatic PFC Systems

Number of insertion

Banks and Steps

Definition of Banks

Is the number of Capacitor Bank that are needed for realizing the total Power.
For example, on an Automatic PFC System 400 kVAr, the standard banks are:

50 – 50 – 100 – 100 - 100

Definition of Steps

Is the number of combination that the PFC Controller can make for adjusting the reactive power.
The number of Steps is calculated dividing the total power of PFC System with the first bank of PFC System.

For example, on an Automatic PFC System 400 kVAr, with standard banks 50 – 50 – 100 – 100 – 100 the number of Steps is 8 (from 400 / 50)

This is one of the most important parameters to select, the Microprocessor PFC Controller, will move the Banks in reference to the first Bank.

«Smaller is the first bank,…higher is the number of steps, better is the regulation but…there are some particular cases and limitations»

Automatic PFC Systems
Number of insertion
Banks and Steps

Particular Case 1
Automatic PFC System 400 kVAr:

- standard banks are: 50 – 50 – 100 – 100 – 100
- required banks: 50 – 50 – 50 – 50 – 50 – 50 – 100

Benefits? ZERO

Disadvantages? Higher cost

Why? the number of steps is ever 8 → «Increasing the number of Banks in a PFC System, but leaving equal the first bank, has not technical benefits»

Automatic PFC Systems

Number of insertion

Banks and Steps

Particular Case 2

Automatic PFC System 400 kVAr:

- standard banks are: 50 – 50 – 100 – 100 – 100
- required banks: 25 – 25 – 50 – 100 – 100 - 100

Benefits? Higher number of steps, better compensation

Disadvantages? Higher cost than standard

Why? the number of steps is ever 16

«Is it not recommended to size a PFC System with a number of steps > 15/16, since is's true that the compensation is better, but is already true that on big power, is not needed to compensate the little loads, since the Penalties for R.E. are calculated on the average consumptions, not on the single moment»

required banks
12,5 – 12,5 – 25 – 50 – 100 – 100 - 100

NO!!!

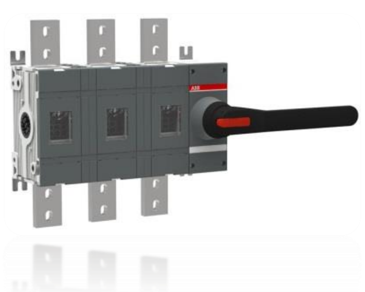
Disconnection Device
Switch Disconnector

The Switch Disconnector, is the general protection of the PFC and, as per EN 61921, must be sized 1,3 times the rated current of the panel.

TELEGROUP, complying fully with current legislation, sizing their Switches to about 1.5 times the rated current of the panel.

500 kVAr = 720 A
Isolator = 720 x 1.5 = 1080A
Switch Disconnector = 1000 A (1.4 times)

In any case, as indicated from the Reference Standards, the PFC lines, must be protected through a dedicated Automatic MCCB

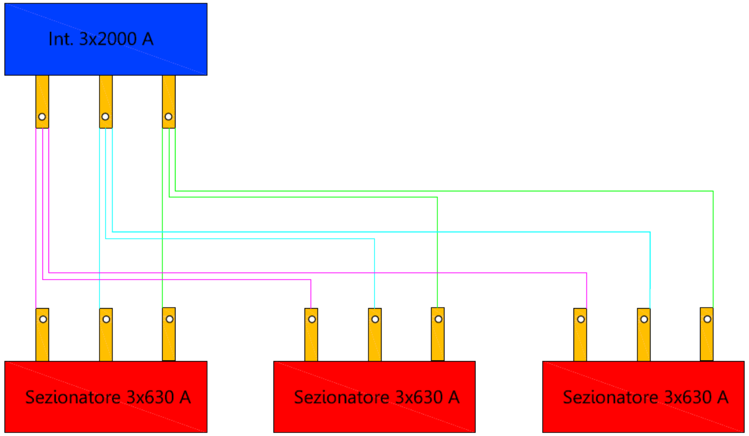


How to protect more cabinets

The PFCS with power > than 500 to 600 kVAr (according to types), are usually realized in more cabinets

Technically speaking, the best solution would be to install a single Switch Disconnector, of the appropriate current, for protecting all cabinets.

Due to the higher currents, the most part of manufacturers prefer to install a dedicated Switch Disconnector for each cabinet, that could seems a cheaper solution, but also generates problems during the installation.



Automatic PFC Systems

How to choose the better insertion

3pole Contactors

The insertion of Capacitor Banks through Three-pole Contactors, is mainly suggested for compensating typologies of loads that are able to accept an insertion time of 15 – 20 seconds.

Is the most common typology of insertion, since in most cases is not needed to have a compensation with a time less insertion time.

Thyristor Modules

Industrial Welders, Hydraulic presses, Tissue Rewinders…are just some examples where an is needed an extra rapid insertion of Capacitor Banks.

How?

The Thyristor Modules, totally electronic, allow an insertion of Capacitor Banks in a period < 1 seconds, since its insertion is at «zero crossing» of current.

Benefits?

- Reduced maintenance
- High number of insertion, without damaging
- Silent operation

Case Study

How to compensate a Tissue Rewinder machine

The Tissue Rewinder Machine, present in every Paper Mills, it is a machine used for processing, cutting and rewinding, the "mother roll" in "daughter rolls"; it works 24 hours for 365 days.

On average, each "mother roll" contains from 3 to 5 "daughter rolls", which are transformed from the Rewinder, in an incredible fast time of about 6 min / each, at a speed of 2000m per minute/ paper.

This allows Company to be able to convert about 35 "mother rolls" in "daughter rolls" (about 140) every day; our Customer is a manufacturer of coils for corrugated cardboard and packaging boxes.

The operating features of this machine, even if needed for the manufacturing process, cause a series of electric and efficiency disadvantages; during the peak period (6 minutes), we recorded very high THD values, both in current (up to 39 %) and voltage (close to 10 %), together with an incredible variation of current (from 84 Amps to 460 Amps in less than 10 seconds).

Key data of Tissue Rewinder

thdI1_Avg %	thdI2_Avg %	thdI3_Avg %	I1_Avg	I2_Avg	I3_Avg	thdV12_Avg	thdV23_Avg	thdV31_Avg
34,1	38,1	38,8	83,7	82,1	85,0	3,9	3,8	4,0
32,6	36,6	37,3	451,8	425,4	464,1	10,3	9,0	8,6
28,6	29,6	27,6	421,1	392,6	431,6	9,5	8,5	7,9

Each interval is 10 seconds

Case Study

How to compensate a Tissue Rewinder machine

Previous PFC

The machine, was already provided with an Automatic Power Factor Correction System, equipped with Contactors; due the to incredible and instantaneous variation of load, since the Contactors were not able to follow that trend, were subjected to breakage every 3-4 months.

How we solved it

The main goal, was not only to compensate the machine but also to provide a PFC able to work with a special load trend.

TELEGROUP supplied:

Automatic Power Factor Correction system 250 kVAr with the following features:

- Detuning Chokes 189 Hz
- Nitrogen Gas (N2) Capacitors
- Insertion through Thyristor modules

Thyristor modules instead of Contactors is the only one solution for compensating these typologies of application.

After 3 months from the installation, we noted that every Thyristor Modules had already made around 1500 insertions

Case Study

How to compensate a plant equipped with Photovoltaic System

The installation of a co-generation system, in our case photovoltaic system, undoubtedly offers a series of considerable advantages to the End Users, especially Industries, which will be able to produce independently a part or all of its requirements for the Active Energy, reducing the whole withdrawal from the Distribution Network.

Despite the Active Energy is produced "on site", the End Users, based on load types, however, will continue to withdraw from the Distribution Network Reactive Energy and this will result in a dramatic lowering of Power Factor.

We refer to a case that we faced in July 2015, where a final customer, following the installation of a photovoltaic system for his Facility, has become subject to the payment of the penalty for excessive reactive energy consumption.

1. Energy Data before Photovoltaic System

- Consumed Power: 950 kW
- Active Energy: 304.000 kWh/month
- Reactive Energy: 135.000 kVArh/month
- Power Factor: 0,91

2. Installation of a Photovoltaic System with a Power of 650 kW

3. Energy Data after the installation of Photovoltaic System

- Active Energy: 96.000 kWh/month (from the Net)

  **208.000 kWh are produced from Photovoltaic*

- Reactive Energy: 135.000 kVAr/month
- Power Factor: 0,57

Which are the results?

The Customer is assuming from the Net an Active Power of about 300 Kw (96.000 kWh), and he's producing the rest 650 kW with the Photovoltaic System (208.000 kWh), but parallel to it, the Consumption of Reactive Energy it's remained the same (135.000 kVArh)

Therefore, in connection with the consumption of Reactive Energy, the Power Factor reached a value such as to become the Customer subject to penalty.

Case Study

How to compensate a plant equipped with Photovoltaic System

How to solve it

In order to allow the Customer to avoid the Penalties and have an optimal Power Factor (>0,95) has been necessary to install a proper Automatic PFC System.

Considering the total power, is necessary to subtract the power produced from Photovoltaic for identiyfing the right active power to compensate,
that is the same assumed from the Net.

Total Power 950 kW – Photovoltaic Power 650 kW
= 300 kW

Since the P.F. at 300 kW is 0,57, in order to have an optimal P.F. > 0,95, it's necessary a

Reactive Power of 334 kVAr

In order to allow the PFC to work not ever at 100 %, is always better to oversize the power of 15-20 %.

In this case, we proposed an Automatic PFC System
400 kVAr.

Typology of PFC

The Inverters of Photovoltaic Systems, if not properly filtered, are routinely identified as distorting loads, that could increase the Harmonic Distortion in the Electric Systems.

In addition, especially in relevant and big application, is always better to avoid the possibility to have a resonance, that could compromise the operation of both PFC and others loads.
.
For all these reasons, we proposed an Automatic PFC System 400 kVAr at 400 V 50 Hz, with Detuning Chokes 189 Hz (p=7%) and Three-Phase Nitrogen Gas (N2) Capacitors, G48Filter Series.

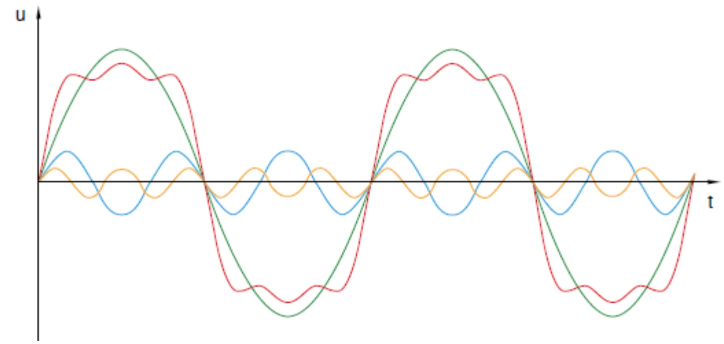
Part 4 | Harmonics in PFC

Causes, effects and detuning solutions

- Causes and Effects of Harmonics
- THDi
- How to approach harmonics
- How to size a PFC with harmonic content
- Detuning chokes and its features

Harmonics in PFC Systems
Causes and effects

A non-sinusoidal current, causes into the Network, voltage drops distorted, whereby also the voltage, at a point of the network will become distorted.
The parameter used to determine the level of harmonic distortion present in a Power Grid is the THD (Total Harmonic Distortion) and it's measured in %



The Harmonic Distortion (THD) is absolutely the worst enemy for any kind of electrical or electronic application but especially for Capacitors.

The higher THD in the Network that a Capacitor is able to support without using Detuning Chokes is 20-25 % max.

Over this value, is absolutely needed to install a Power Factor Correction System with Detuning Chokes

Harmonics in PFC Systems

Typical loads and applications

Which are the Critical Loads that create Harmonic Distortion?

-Industrial Lathes
-Laser-cut Machines
-Industrial Presses
-Industrial Welders
-Packaging Lines
-Injection Molding
-Industrial Inverters

Which are the application where the presence of Harmonic Distortion is high?

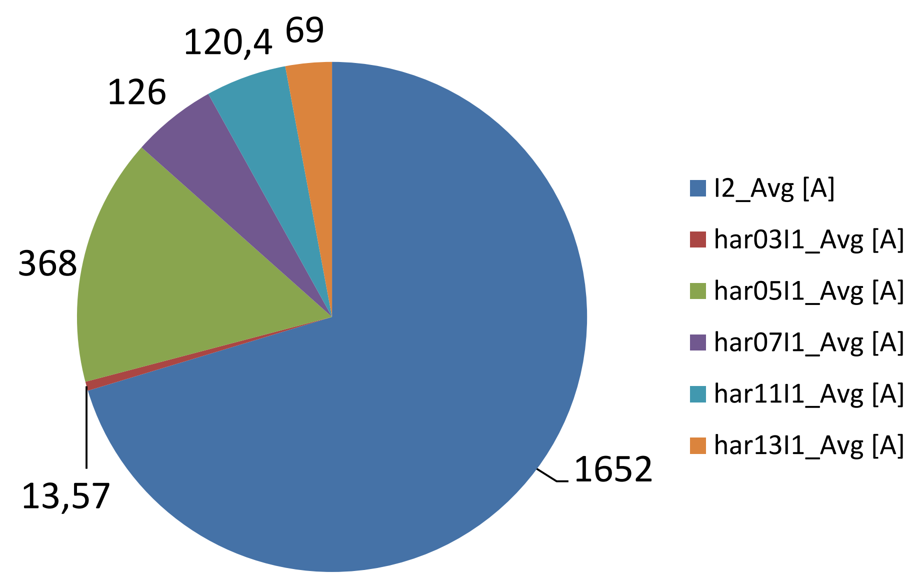
-Iron-Steel Industries
-Paper Industries
-Refineries
-Food & Beverage Industries
-Plastic Industries
-Cement Plants
-Mines Industries
-Automotive Industries
-Others….

Harmonics in PFC Systems

THDi | Fundamental Current and Harmonic Current

har01I1_Avg [A]	har03I1_Avg [A]	har05I1_Avg [A]	har07I1_Avg [A]	har11I1_Avg [A]	har13I1_Avg [A]
1652	13,57	368	125,8	120,3	69,45

Harmonic Order	Value (%)	THDi (%) Total
3 rd	0,82	25,5 %
5 th	22,80	
7 th	7,60	
9 th	0,00	
11 th	7,30	
13 th	4,20	
17 th	0,00	



Harmonics in PFC Systems

Why install detuning chokes?

In presence of a high harmonic content on the Net (THD), it is absolutely not recommended, technically flawed and “against the reference standard", to install a Power Factor Correction System without Detuning Chokes.

In such cases, it’s necessary to use Detuning Chokes for…

- respecting the EN61921, EN60831, EN 61642 Standards
- avoiding the resonance
- protecting the Capacitors and increasing their operating life

Harmonics in PFC Systems

Capacitors overloads?

In such cases is necessary to apply Detuning chokes, as also indicated from EN61921, EN60831, EN 61642 Standards

EN 60831 Art. 21

The Capacitors can't operate on rated current higher than the following listed values

The Capacitors must operate as standard until a current value of 30 % of its rated current (causing to harmonics)

It's allowed a tolerance on capacitance of 10 % until 100 kVAr and of 5 % over 100 kVAr.
Therefore, the maximum permanent current that can be absorbed from Capacitors is 1,4 time its rated current

EN 61921 Art. 5.4.4

If the Current of Capacitors will exceed the values mentioned in Art. 21, while the Voltage will remain in the allowed parameter of 1,10 Un as per Art. 20, it must be determined the most relevant harmonic, in order to find the properest solution.

The following solution can be considered:

a) Displacement of the Capacitors in others points of the electric system.

b) Connecting a Reactor in series of Capacitor, for reducing the resonance frequency of the circuit on a less value than the most relevant harmonic.

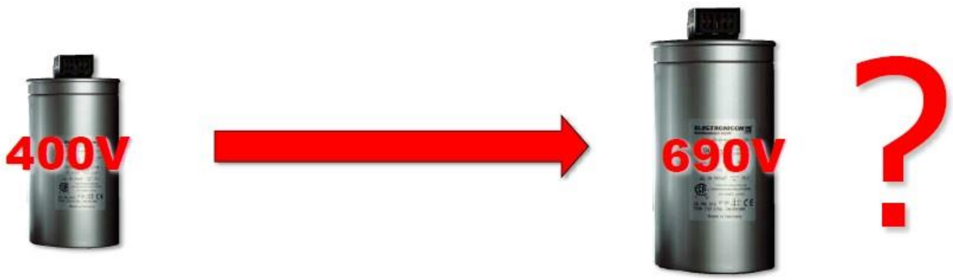
EN 61642

Please check example showed at from 39 to 41, compared to the example explained at Slide 68

Harmonics in PFC Systems

NO satisfactory solutions

Increasing the Voltage of Capacitors?



NO!

Why?

It could happen a resonance between Capacitors and Reactors, so the problem will be not solved.

The Capacitors are more sensitive on an overcurrent instead of an overvoltage

Increasing the current of Capacitors or splitting the capacitance on more Capacitors?

NO!

Why?

Even if the overcurrent could be reduced, in presence of resonance this solution will be not sufficient for solving.

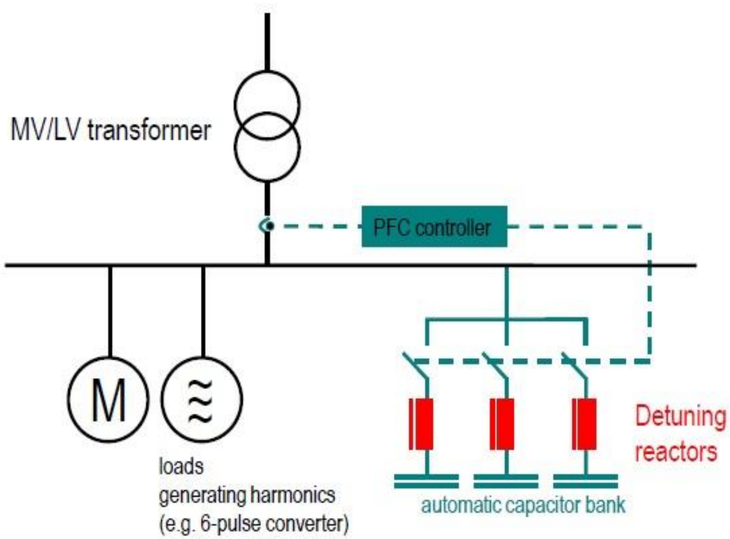
Harmonics in PFC Systems

The only one correct solution

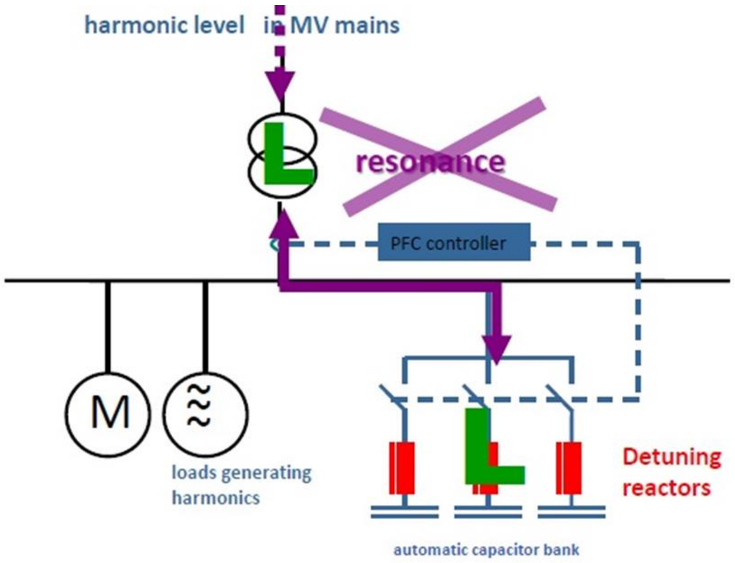
The only one solution for avoiding the resonance (and for saving the Capacitors) is to maintain the resonance frequency distant as soon as possible from the harmonics with relevant values.

How? **«Filtering the Capacitor Bank»**

Solution



Effects



Harmonics in PFC Systems

EN 61642 | Example of Parallel Resonance

as in slide 40....but with the application of Detuning Chokes

Tab. 3 **Numerical results of impedances, voltages and currents at characteristic harmonic orders of a series resonance circuit with a capacitor-reactor-connection in a network with distorted supply voltage**

IcA (1) = fundamental current
IcA (11) = current on Capacitors on 11° harmonic
DF(B) = Voltage Harmonic Distortion (THDv) on the busbars
Ic eff. = Current on Capacitors
Ic/Icn = Overload on Capacitors

h	X_T Ω	$X_C + X_L$ Ω	Z Ω	U_A V	U_A (%) %	I_C A	U_B V	U_B (%) %
1	0,010	–1,000	0,990	400,0	100,0	233	404	101,0
5	0,048	0,161	0,212	12,0	3,0	33	9	2,3
7	0,067	0,373	0,443	9,6	2,4	13	8	2,0
11	0,106	0,730	0,840	6,0	1,5	4	5	1,3
13	0,125	0,896	1,026	4,8	1,2	3	4	1,0
17	0,163	1,216	1,386	2,4	0,6	1	2	0,5
19	0,182	1,374	1,563	1,9	0,5	1	2	0,4

DF (A) % = 4,4

DF (B) % = 3,5

$R_T = X_T/Q_T = X_T/8$
$R_L = X_L/Q_L = X_L/30$
(semplificato_*simplified*)

$I_{C\ eff.} = 236$ A
$I_C/I_{CN} = 1{,}02$

Effects of Detuning

- IcA on 11° harmonic is reduced from 212 A (without Detuning, slide 22) to 4 A (with Detuning)
- DF(B) is reduced from 9,8 % (without Detuning, slide 22) to 3,5 % (with Detuning)
- The Capacitors are now operating at 236 V (1,02 In), instead of operating at 334 A (1,45 In) without Detuning (slide 22)

Harmonics in PFC Systems

Estimation of the harmonic order close to the resonance

Considering a MV/LV Transformer with a power of 1000 kVA and an impedance of 6 %, if it will be installed a Power Factor Correction System of 350 kVAr on a 50 Hz Network, the harmonic order closest to the resonance can be calculated as follow:

$$O_r = \sqrt{\frac{KVA_{sc}}{kvar}} = \sqrt{\frac{1000KVA/0.06}{350kvar}} = \mathbf{6.9}$$

6,9 x 50 Hz = 345 Hz

It means that the resonance will be close to the

7° harmonic (350 Hz)

Harmonics in PFC Systems

Key features of Detuning Chokes (Reactors)

What is «p»?

With the acronym «p», is determined the relationship between the voltages across the reactor and the capacitor.

$$p = \frac{X_L}{X_C} \cdot 100$$

How is calculated the resonance series frequency (Detuning Frequency)?

$$f_r = f_n \cdot \sqrt{\frac{100}{p}}$$

Harmonics in PFC Systems

Detuning Frequencies in reference to “p” and to “Nf” (Network Frequency)

»p»	Standard for Harmonic order	Detuning Frequency 50 Hz	Detuning Frequency 60 Hz
5,67 %	7 th	210 Hz	252 Hz
7 %	5 th	189 Hz	227 Hz
14 %	3 rd	134 Hz	160 Hz

Harmonics in PFC Systems

Voltage of Capacitors. How to select it.

With the application of a Detuning Chokes in series to a Capacitor, the Voltage of Capacitor will rise, as follow:

$$U_C = \frac{U}{1-p}$$

Uc = Voltage on Capacitors downstream the Detuning Chokes
U = Network Voltage
P = Impedance of Detuning Chokes

On a 400 V system, f we consider the 3 most relevant harmonic order (3 rd, 5 th and 7 th) the Voltage of Capacitors downstream the Chokes will are the follow:

5 th Harmonic (p=7%) 189 Hz

$$\frac{400\ V}{1 - 0{,}07} = Uc\ 430\ V$$

TELEGROUP use Capacitors with Rated Voltage 480 V

Security Factor of 12 %
+ 10 % for 8/hours day

3 rd Harmonic (p=14%) 134 Hz

$$\frac{400\ V}{1 - 0{,}14} = Uc\ 465\ V$$

TELEGROUP use Capacitors with Rated Voltage 525 V

Security Factor of 13 %
+ 10 % for 8 hours/day

7 th Harmonic (p=5,67%) 210 Hz

$$\frac{400\ V}{1 - 0{,}0567} = Uc\ 424\ V$$

TELEGROUP use Capacitors with Rated Voltage 480 V

Security Factor of 13 %
+ 10 % for 8 hours/day

Harmonics in PFC Systems

How to have a rough idea about PFC selection

THDi (%)	≤ 15 %	< 15% ≤ 19 %	< 19 % ≤ 25 %	> 25 %
Series	R40	R46	G44, G48	G48Filter, R48Filter, G52Filter, R52Filter
Capacitors/ Detuning Chokes	Capacitors 440 VMKP440R No Detuning Chokes	Capacitors 460 VMKP460R No Detuning Chokes	Capacitors 440 V and 480 V No Detuning Chokes	Capacitors 480 V and 525 V Detuning Chokes 189 Hz or 134 Hz

Notes

1. With a THDi ≤ 25 %, the Nitrogen (N2) Gas Capacitors are able to operate; in any case, if the resonance phenomena, if present, will be not solved.

2. With a THDi > 25 % is absolutely necessary a PFC with appropriate Detuning Chokes; with these THDi values, installing a PFC without Detuning Chokes means a risk for the panel, a risk for the plant and is against the Reference Standards.

Part 5 | PFC Typcal installation

Key steps for a proper installation

- How to choice the C.T. (Current Transformer)
- Positioning of C.T. (Current Transformer)

PFC Typical installation
How to choice the C.T.

«The value of the PRIMARY of C.T., is not selectable is relation of the power of PFC System»

The value of the C.T., needs to be sized in relation to the total current in the electric system.

Usually, is recommended to select a C.T. with a current max1,5 time the nominal current of electric system.

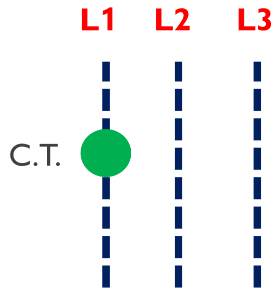
Nominal Current: 800 A
C.T. : 1200 / 5 or 1000 /5

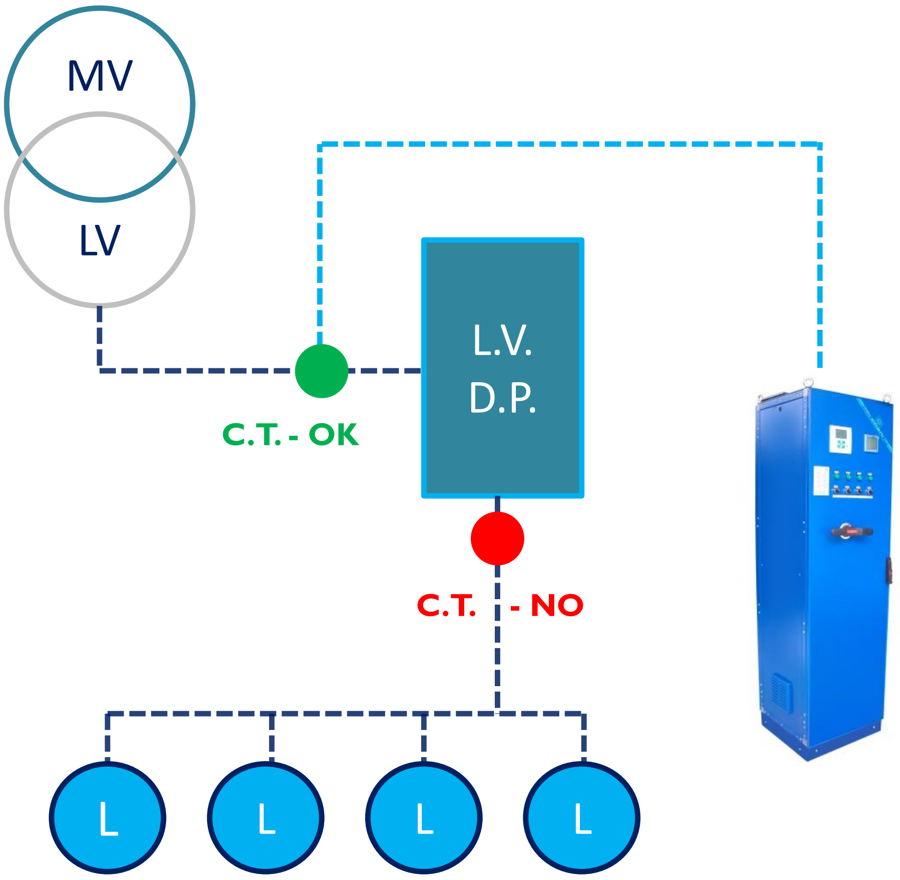
PFC Typical installation
Positioning of the C.T.

During the installation, the parameters that needs to be considered is the position of C.T. (Current Transformer)

The C.T. must be able to feel all loads of the electric system and for this, it has to be installed upstream of all loads.

In TELEGROUP's PFC System, the C.T. must be positioned on the L1 Phase, while the L2 and L3 phases, are dedicated to the Voltage signal.





Many thanks from you kind attention.

We hope that our info could give you an additional support for your daily activity.
Anyway, we'll be ever available for any doubt or further info.

See you next time…

Stay Reactive

Ciao !

TELEGROUP
we're reactive...

TELEGROUP S.r.l.
Via Leonardo da Vinci, 100
50028, Tavarnelle Val di Pesa
Firenze – Italy

T. +39 055 80 71 267
E. telegroup@telegroup.it
w. www.telegroup.it

GESTINEL

Via Augusta, 318, 08017
Barcelona, Spain
Joan Sallés
Telf. 93.206.61.20
Móv. 659.723.215
www.gestinel.com