A Group brand

legrand

TECHNICAL GUIDE

AUTOMATIC CAPACITOR BANKS

ALPES TECHNOLOGIES

ALPES TECHNOLOGIES

The Legrand Group offers a range of products and services for **power factor correction** and controlling the quality of electrical energy.

Reactive energy compensation is used to **increase** the available power and **improve** the building's energy performance.

These solutions fit naturally in the Legrand group's global **energy efficiency** approach, which aims to offer ever more solutions for improved management of electricity, reduce consumption and contribute towards supplying high-quality energy.

The aim of this technical guide is to advise best practice when designing automatic capacitor banks with ALPIVAR³ and ALPICAN capacitors.

To meet these needs,
Legrand offers a whole range of products

LEGRAND ENERGY EFFICIENCY

CONTENTS

APPLICABLE STANDARDS

The design of a capacitor banks should comply with the conditions in the latest current edition of the standards mentioned below and the specific conditions mentioned in this guide.

STANDARDS FOR ASSEMBLIES

IEC 61921: Power capacitors - Low-voltage power factor correction banks

IEC 61439-2: Low-voltage switchgear and controlgear assemblies - Part 2: Power switchgear and controlgear assemblies

IEC 60529: Degrees of protection provided by enclosures (IP code)

STANDARDS FOR POWER COMPONENTS

IEC 60831: Shunt power capacitors of the self-healing type for a.c. systems having a rated voltage up to and including 1000 V

Part 1: General – Performance, testing and rating – Safety requirements - Guide for installation and operation

Part 2: Ageing test, self-healing test and destruction test

IEC 60947: Low-voltage switchgear and controlgear

Part 2: Circuit-breakers

Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters

IEC 60076-6: Power transformers – Part 6: Reactors

IEC 62208: Empty enclosures for low-voltage switchgear and controlgear assemblies - General requirements

STANDARDS FOR REACTIVE ENERGY CONTROLLERS

IEC 61010-1: Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 1: General requirements

IEC 61000: Electromagnetic compatibility (EMC)

Part 6-2: Generic standards - Immunity standard for industrial environments

Part 6-3: Generic standards - Emission standard for residential, commercial and light-industrial environments

UL 508: Industrial control equipment

CSA C22.2 No. 14: Industrial control equipment

The purpose of this workshop specification is to help assembly manufacturers by summarising the basic construction concepts and describing the certification approach as outlined in standard EN 61439, March 2012 edition.

The workshop specifications can be downloaded from our website www.legrand.com/EN. The list can be found in the appendix on page 65.

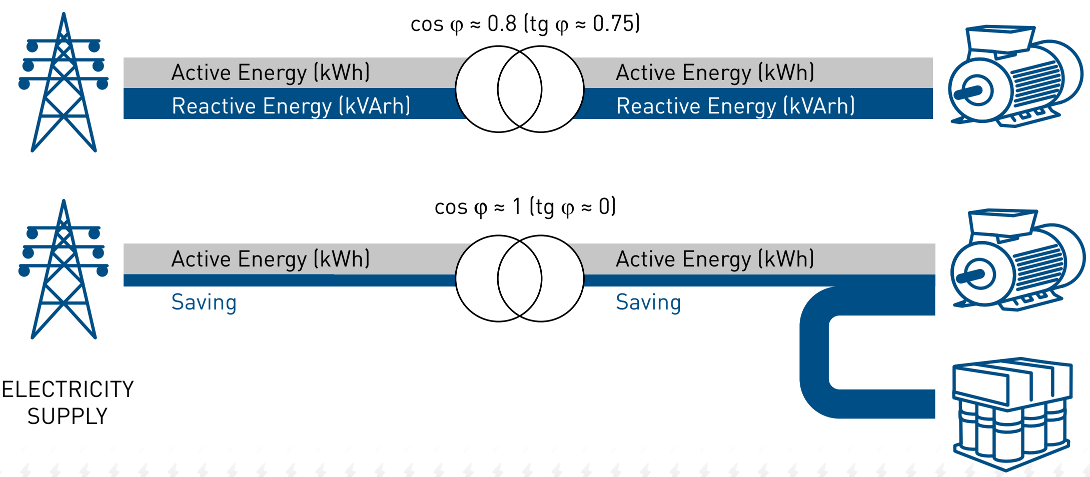



ALPES TECHNOLOGIES

POWER FACTOR CORRECTION

Broad outlines

An AC electrical installation incorporating receivers such as transformers, motors, fluorescent tube ballasts or any other receivers whose current is phase-shifted in relation to the voltage, consumes reactive energy. This reactive energy (expressed in kilovar-hours - kvarh) is billed in the same way as active energy by energy suppliers. Reactive energy therefore results in more power being used and thus contributes to higher electricity bills. For these reasons, reactive energy needs to be supplied as close as possible to the loads, to prevent it being called on the grid. Capacitor banks can improve the power factor of an electrical installation by giving it a proportion of the reactive energy it consumes.



ADVANTAGES

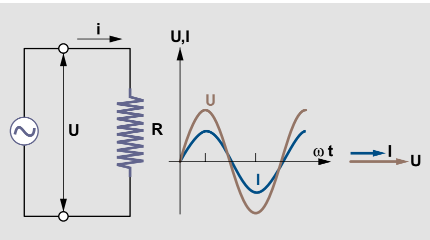
By supplying reactive energy on demand, capacitor banks can:

- Increase the power available to the distribution transformers
- Optimise the electricity supply contract
- Limit energy losses in cables due to the Joule effect
- Avoid the penalties applied

by electricity suppliers (or receive bonuses in some countries)

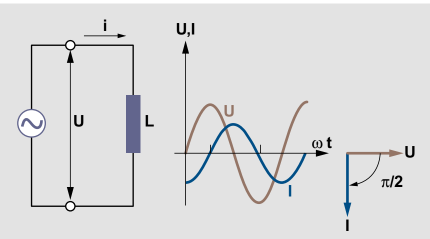
LOAD TYPES

Resistive loads consist of pure R resistors. For this type of load, the current generated is in phase with the voltage.



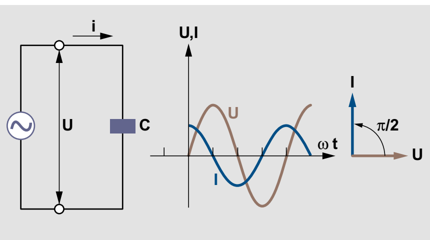
Inductive loads consist of inductances, such as asynchronous motors and ballasts in fluorescent tubes.

If we consider a purely inductive load L, the current generated always lags 90° behind the voltage.



Capacitive loads always consist of capacitors, mainly capacitor banks.

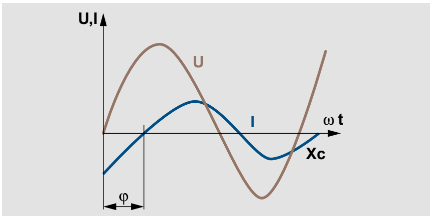
If we consider a purely capacitive load C, the current generated always leads the voltage by 90°.



PHASE SHIFT

In an AC electrical installation, depending on the type of electrical load (resistive, inductive, capacitive), a phase shift of varying size occurs between the current and the voltage.

The symbol for this phase shift is "φ".



POWER FACTOR

By definition, the power factor of an electrical installation (PF) is equal to the active power P (kW) over the apparent power S (kVA).

PF = P (kW)/S(kVA)

Usually PF - Cos φ

a good power factor is:
- high cos φ (close to 1)
- or low tg φ (close to 0)

A power factor of 1 will result in no reactive energy consumption and vice versa.

Energy metering devices record active and reactive energy consumption. Electricity suppliers generally use the term tg ø on their bills.

Cos φ and tg φ are linked by the following equation:

$$\cos \varphi = \frac{1}{\sqrt{1 + (\text{tg } \varphi)^2}}$$

Harmonics

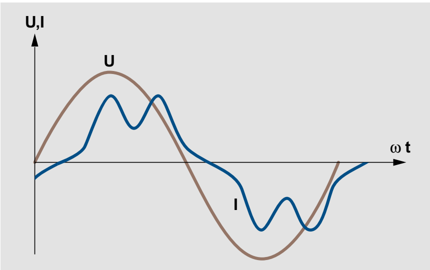
In recent years, the modernisation of industrial processes and the sophistication of electrical machines and equipment have led to major developments in power electronics: These systems represent "non-linear" loads for electrical supplies.

NON-LINEAR LOADS

A load is said to be "non-linear" if the current it draws is not sinusoidal when it is powered by a sinusoidal voltage.

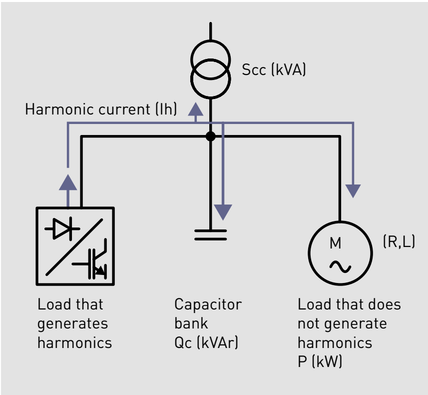
Non-linear loads distort the electrical signals of the current and the voltage.

This type of receiver does generate harmonic currents.



Type of non-linear load:

- Examples of single-phase loads: Low voltage (energy saving) bulb, fluorescent tube, electronic ballast, medical equipment, television sets, computers, printers, photocopiers, inverters, etc.
- Examples of three-phase loads: Variable speed drives for motors, rectifier (AC-DC converter), welding machine, arc furnace used in metallurgy, battery charger, PLC, UPS, etc.



These non-linear loads inject currents with a non-sinusoidal waveform onto the supply. These currents are formed by a fundamental component of the supply frequency, plus a series of superimposed currents, multiple frequencies of the fundamental which are known as harmonics.

EFFECTS OF HARMONICS

The immediate effects of harmonics (losses due to Joule effect):

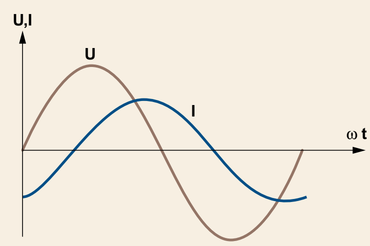
- Deterioration of the power factor
- Reduction in the motor power
- Cable, transformer, motor overloads
- Increased noise in the motors
- Recording error in the meters
- Oversizing of the supply capacitance cables
- Contactors not working correctly
- Interference in the electronic systems
- Etc.

Medium and long-term effects:

- Shorter life of motors and transformers
- Deterioration of capacitor banks
- Accelerating ageing of insulation and dielectrics
- Derating of transformers and motors
- Etc.

Linear loads: A load is said to be "linear" if the current it consumes is sinusoidal when it is supplied with sinusoidal voltage.

This type of receiver does not generate harmonics.



HARMONIC ORDERS

The FOURIER decomposition (harmonic analysis) of the current consumption of a non-linear receiver shows:

- The fundamental, a sinusoidal term at the 50 Hz mains supply frequency
- The harmonics, sinusoidal terms whose frequencies are multiples of the fundamental frequency

According to the equation:

$$I_{rms} = \sqrt{I_1^2 + \sum_{h=2}^{n} I_h^2}$$

Σ: sum of all the harmonic currents from harmonic 2 (50 Hz x 2) to the last harmonic order n (50 Hz x n)

These harmonic currents circulate in the source.

The harmonic impedances of this source then give rise to harmonic voltages, according to the equation:

$$Uh = Z_h \times I_h$$

The harmonic currents induce most of the harmonic voltages causing the overall harmonic distortion of the supply voltage.

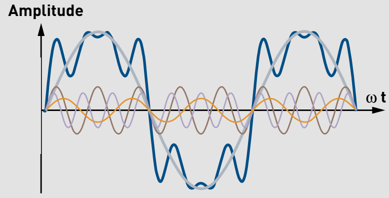
$$V_{rms} = \sqrt{U_1^2 + \sum_{h=2}^{n} U_h^2}$$

Note: The harmonic distortion of the voltage generated by construction defects in the windings of alternators and transformers is generally negligible

The electricity supply frequencies are 50 Hz or 60 Hz, called the fundamental frequency (f1). Harmonic components have a frequency (fn) which is a multiple of the fundamental frequency (f1).

$$f_n = n \times f_1$$

where n is the harmonic order



- Resultant.
- Fundamental.
- Order 3: additional current of 150 Hz (3 x 50 Hz).
- Order 5: additional current of 250 Hz (5 x 50 Hz).
- Order 7: additional current of 350 Hz (7 x 50 Hz).
- Etc.
- Order n: additional current of xxx Hz (n x 50 Hz).

SPECIAL CASE OF 3RD ORDER HARMONICS

The main loads generating 3rd order harmonics are single-phase diode rectifiers with capacitive filtering.

Three-phase, non-linear, symmetrical, balanced loads, with no connection to the neutral do not generate any 3rd order harmonics, nor any harmonic orders that are multiples of 3.

Three-phase, non-linear, symmetrical, balanced loads, with connection to the neutral do generate 3rd order harmonic currents and harmonic currents in the neutral conductor in orders that are multiples of 3.

Single-phase loads such as high power lighting (stadium lighting power, for example) also generate 3rd order harmonics.

The rms value of the neutral current can be greater than that of the phase current, which on average means that the neutral conductor cross-section must be twice that of the phase conductor cross-section.

- The design of Legrand's isolating transformers with low losses prevents 3rd order harmonics (see Legrand catalogue).
- SAH type – 135 Hz capacitor banks are sized to operate in conditions with high levels of 3rd order harmonics.

ALPES TECHNOLOGIES

Harmonics (continued)

TOTAL HARMONIC DISTORTION

The total harmonic distortion is used to quantify the distorted global sinusoidal signal using the following theoretical formulas:

Individual THD

$$\sigma_n\,(\%) = \frac{X_n}{X_1} \times 100$$

X_n = rms value of the fundamental (voltages or current)
X_1 = rms value of the nth harmonic order (voltages or current)

Global THD

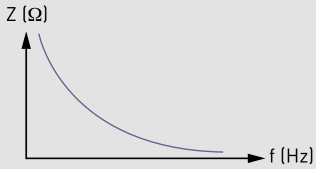
$$THD\text{-}U(\%) = \frac{\sqrt{\sum_{n=2}^{n} U_n^2}}{U_1} \times 100$$

$$THD\text{-}I(\%) = \frac{\sqrt{\sum_{n=2}^{n} I_n^2}}{I_1} \times 100$$

IMPACT OF HARMONICS ON CAPACITORS

The capacitor bank reactance is inversely proportional to the frequency, and its ability to cancel out harmonic currents decreases significantly when the frequency increases. This leads to an increase in the current drawn by the capacitors and causes a temperature rise which accelerates capacitor ageing and can even lead to their destruction in extreme cases.

$$Z_C = \frac{1}{C\omega} = \frac{1}{C\,2\pi f}$$



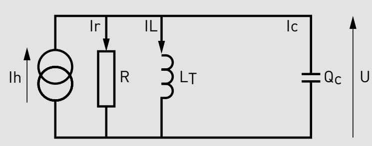
Alpivar³ capacitors have the capacity to resist harmonics exceeding the requirements of standards IEC 60831-1 & 2

- permissible overvoltage up to 1.18*Un
- permissible overvoltage up to 2*In

THE PHENOMENON OF RESONANCE

The phenomenon of electrical resonance between the capacitor banks and the electricity supply corresponds to amplification of the existing voltage and current harmonics (increase in the THDu % and THDi %) due to electrical resonance between the capacitor banks and the inductances in the system upstream.

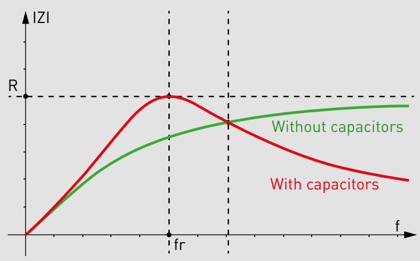
This outline diagram of an electrical installation with capacitor bank and a load that generates harmonics can be drawn as below:



SCC: transformer short-circuit power
LT: transformer short-circuit inductance, because the influence of the load inductances and the short-circuit inductance of the distribution network seen from the upstream terminals of an MV/LV transformer is negligible.

$$Z = \frac{1}{\sqrt{\left(\frac{1}{R}\right)^2 + \left(\frac{1}{L_T\omega} - C\omega\right)^2}}$$

$$f_0 = \frac{1}{2\pi\sqrt{L_T C}} = f_1\sqrt{\frac{S}{Q}}$$



Hence the supply impedance seen from the main LV distribution board

At frequency far, corresponding harmonic currents are generated. Circulating across the various impedances of the installation they generate an increase in the harmonic voltages and therefore in the level of THDu %.

Amplification is seen through the typical curve of impedances in the system as a function of the frequency. It shows the amplified value compared to the initial supply value without capacitors.

At resonance fo all the nth order current Io generated by the circuit that is causing interference passes into the resistor R, thus meaning that nearly all this current is drawn by loads consuming active power

The direct consequence of this resonance is an increase in the harmonic voltages, and therefore in the level of THDi.

Legrand EMDX³ measurement control units provide you with optimum monitoring of your installation. See the Legrand catalogue.

ESTIMATE OF PARALLEL RESONANCE BETWEEN THE CAPACITORS AND THE SOURCE

To find out the harmonic frequency (Fn) of order n with a risk of resonance in the system le and the amplification factor (Fa) of the harmonic currents in the capacitors and in the source (transformers), use the formulas below:

$$S_{CC} = \frac{ST}{U_{CC}}$$

$$F_n = f_1 \times \sqrt{\frac{S_{CC}}{Q_C}} \qquad F_a = \frac{\sqrt{S_{CC} \times Q_C}}{S}$$

Scc: transformer short-circuit power
Ucc: MV/LV transformer short-circuit voltage
Qc: capacitor bank reactive power
f1: fundamental frequency (50 Hz in France)
ST: power in kVA of the MV/LV transformer (or MV/LV transformers where there are two or more transformers in parallel)
S: active power of loads that do not generate harmonics (non-polluting)

The higher the source short-circuit power (Scc), the further the resonance frequency is from dangerous harmonic frequencies.

The higher the power (P) of non-polluting loads, the lower the harmonic current amplification factor.

EXAMPLE

Transformer power: ST = 1000 kVA where UCC = 6 %

Load power: S = 750 kW

Capacitor bank power: QC = 350 kVAr

Thus:

Transformer short-circuit power:

$$S_{CC} = \frac{1000}{6} \times 100 = 16{,}666 \text{ kVA}$$

Risk of resonance frequency:

$$F_n = 50 \times \sqrt{\frac{16{,}666}{350}} \text{ Hz} \approx 50 \times 6.90 \text{ Hz} \approx 354 \text{ Hz}$$

Max level of amplification of harmonics:

$$F_a = \frac{\sqrt{16{,}666 \times 350}}{750} \approx 3.22$$

IMPORTANT:

In this example, the installation demonstrates a risk of resonance with the 7th order harmonic. To avoid this risk, use a capacitor bank with detuned reactor. See next section.

Harmonics (continued)

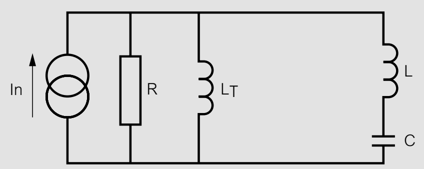
PROTECTING CAPACITORS USING DETUNED REACTORS

On mains supplies with a high level of harmonic pollution, Legrand recommends capacitor banks with detuned reactors SAH type or SAH reinforced type.

The detuned reactor performs a dual role:

- Increasing the capacitor impedance in relation to the harmonic currents
- Shifting the parallel resonance frequency of the source and the capacitor to below the main frequencies of the harmonic currents that are causing interference

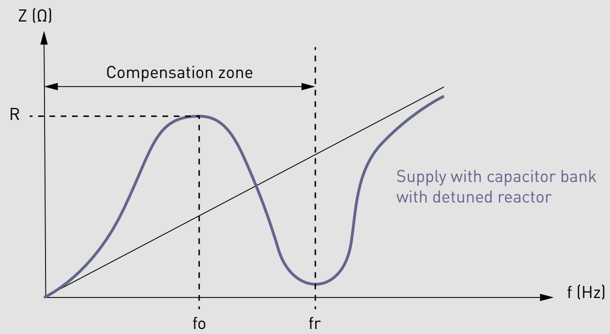
Adding the reactor impedance



$$fo = \frac{1}{2\pi\sqrt{(L_T + L)C}} \qquad fr = \frac{1}{2\pi\sqrt{LC}}$$

fo: Parallel resonance frequency (anti-resonance)

fr : Serial resonance frequency for the branch between the capacitors and the detuned reactor



- The detuned reactor and capacitor assembly is capacitive for frequencies below fr, so allows reactive energy compensation.
- The detuned reactor and capacitor assembly is inductive, so prevents amplification of the harmonics.

The serial frequency (fr) chosen must be below the first harmonic order present in the circuit.

The most commonly used reactor tuning frequencies are:

Tuning* frequency (Hz)	Blocking factor (P %)	Tuning number (n)
215	5.4	4.3
189	7	3.78
135	14	2.7

* with network frequency 50 Hz
n: tuning number, n =fr/f1
p (as a %): blocking factor; this is the ratio between the reactor inductance X_L compared to the capacitor inductance X_C.

$$p = \frac{X_L}{X_C} = \frac{1}{n^2} = \left(\frac{f}{f_r}\right)^2$$

SAH type capacitor banks with 135 Hz reactor are recommended for an installation with 3rd order harmonics, for example if Ih3 > 0.2*Ih5.

Ih3: 3rd order harmonic currents

Ih5: 5th order harmonic currents

To make a correct assessment of the risks of capacitor bank resonance in your installation, we recommend the following procedure:

1 - Take measurements over a significant period (minimum one week) of the voltages, currents, power factor, level of harmonics (individual and global THD-U/THD-I).

2 - Size the capacitor bank appropriately for its reactive energy compensation requirements, based on these measurements and your electricity bills.

3 - For each step power rating (physical or electrical) to be provided in the capacitor bank, calculate the resonance harmonic orders: where S is the short-circuit power at the capacitor bank connection point, and Q is the power rating for the step concerned.

4 - If one of the calculated harmonic orders corresponds to one of the harmonics in the installation (with accuracy of ±10 %), it may be necessary to use detuned reactors in order to shift the resonance to a harmless frequency range.

ALPES TECHNOLOGIES

SELECTING THE COMPENSATION SOLUTION

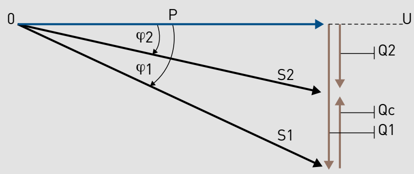
Determining the reactive power

To determine the appropriate capacitor bank power (kVAr) to compensate for the reactive energy required by the installation, use one of the following methods:

- Measurement of the reactive power and cos φ with measurement control units (such as those in the Legrand EMDX³ range) or with network analysers for complete diagnostics of the various phenomena.
- Analysis of the electricity supplier's bills according to the subscription type (subscribed demand, reactive energy billed in kVArh and tg φ).
- Estimated total amount of reactive energy needed for all loads in the installation, especially motors and transformers according to the manufacturer's data.
- In the context of future installations, compensation is frequently required right from the commissioning stage.

In this case, it is not possible to calculate the capacitor bank using conventional methods (electricity bill). For this type of installation, it is advisable to install a power capacitor bank equal to approximately 25 % of the nominal power of the corresponding HV/LV transformer.

Power diagram



P: Active power
S1 and S2: apparent powers (before and after compensation)
Qc: capacitor reactive power
Q1: reactive power without capacitor
Q2: reactive power with capacitor

Equations

$$Q2 = Q1 - Qc$$
$$Qc = Q1 - Q2$$
$$Qc = P.tg\ \varphi 1 - P.tg\ \varphi 2$$

$$Qc = P(tg\ \varphi 1 - tg\ \varphi 2)$$

φ 1 phase shift without capacitor
φ 2 phase shift with capacitor

Taking the initial power factor and the desired power factor, we get a value which we can use to calculate the reactive power in kVAr.

EXAMPLE

- ST transformer = 1000 kVA
- Actual transformer load a = 75 %
- Load cos φ_1 = 0.8 (tan φ_1 = 0.75)
- cos φ_2 to be obtained = 0.96 (tan φ_2 = 0.29) --> k = 0.459 (see table opposite)

QC (kVAr) = P (kW) x (tan φ_1 – tan φ_2) = ST x a x cos φ_1 x k

QC = 1000 x 0.75 x 0.8 x 0.459 = 275 kVAr

The table opposite is used to calculate the reactive power to be compensated. It also gives the equivalence between cos φ and tg φ.

Initial power factor			Capacitor power to be installed, in kvar per kW of load, to increase the power factor to cos φ_2:										
cos φ_1	tg φ_1	cos φ_2:	0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99	1
		tg φ_2:	0.48	0.46	0.43	0.40	0.36	0.33	0.29	0.25	0.20	0.14	0.0
0.40	2.29		1.805	1.832	1.861	1.895	1.924	1.959	1.998	2.037	2.085	2.146	2.288
0.41	2.22		1.742	1.769	1.798	1.831	1.840	1.896	1.935	1.973	2.021	2.082	2.225
0.42	2.16		1.681	1.709	1.738	1.771	1.800	1.836	1.874	1.913	1.961	2.002	2.164
0.43	2.10		1.624	1.651	1.680	1.713	1.742	1.778	1.816	1.855	1.903	1.964	2.107
0.44	2.04		1.558	1.585	1.614	1.647	1.677	1.712	1.751	1.790	1.837	1.899	2.041
0.45	1.98		1.501	1.532	1.561	1.592	1.626	1.659	1.695	1.737	1.784	1.846	1.988
0.46	1.93		1.446	1.473	1.502	1.533	1.567	1.600	1.636	1.677	1.725	1.786	1.929
0.47	1.88		1.397	1.425	1.454	1.485	1.519	1.532	1.588	1.629	1.677	1.758	1.881
0.48	1.83		1.343	1.730	1.400	1.430	1.464	1.467	1.534	1.575	1.623	1.684	1.826
0.49	1.78		1.297	1.326	1.355	1.386	1.420	1.453	1.489	1.530	1.578	1.639	1.782
0.50	1.73		1.248	1.276	1.303	1.337	1.369	1.403	1.441	1.481	1.529	1.590	1.732
0.51	1.69		1.202	1.230	1.257	1.291	1.323	1.357	1.395	1.435	1.483	1.544	1.686
0.52	1.64		1.160	1.188	1.215	1.249	1.281	1.315	1.353	1.393	1.441	1.502	1.644
0.53	1.60		1.116	1.144	1.171	1.205	1.237	1.271	1.309	1.349	1.397	1.458	1.600
0.54	1.56		1.075	1.103	1.130	1.164	1.196	1.230	1.268	1.308	1.356	1.417	1.559
0.55	1.52		1.035	1.063	1.090	1.124	1.156	1.190	1.228	1.268	1.316	1.377	1.519
0.56	1.48		0.996	1.024	1.051	1.085	1.117	1.151	1.189	1.229	1.277	1.338	1.480
0.57	1.44		0.958	0.986	1.013	1.047	1.079	1.113	1.151	1.191	1.239	1.300	1.442
0.58	1.40		0.921	0.949	0.976	1.010	1.042	1.073	1.114	1.154	1.202	1.263	1.405
0.59	1.37		0.884	0.912	0.939	0.973	1.005	1.039	1.077	1.117	1.165	1.226	1.368
0.60	1.33		0.849	0.878	0.905	0.939	0.971	1.005	1.043	1.083	1.131	1.192	1.334
0.61	1.30		0.815	0.843	0.870	0.904	0.936	0.970	1.008	1.048	1.096	1.157	1.299
0.62	1.27		0.781	0.809	0.836	0.870	0.902	0.936	0.974	1.014	1.062	1.123	1.265
0.63	1.23		0.749	0.777	0.804	0.838	0.870	0.904	0.942	0.982	1.030	1.091	1.233
0.64	1.20		0.716	0.744	0.771	0.805	0.837	0.871	0.909	0.949	0.997	1.058	1.200
0.65	1.17		0.685	0.713	0.740	0.774	0.806	0.840	0.878	0.918	0.966	1.007	1.169
0.66	1.14		0.654	0.682	0.709	0.743	0.775	0.809	0.847	0.887	0.935	0.996	1.138
0.67	1.11		0.624	0.652	0.679	0.713	0.745	0.779	0.817	0.857	0.905	0.966	1.108
0.68	1.08		0.595	0.623	0.650	0.684	0.716	0.750	0.788	0.828	0.876	0.937	1.079
0.69	1.05		0.565	0.593	0.620	0.654	0.686	0.720	0.758	0.798	0.840	0.907	1.049
0.70	1.02		0.536	0.564	0.591	0.625	0.657	0.691	0.729	0.796	0.811	0.878	1.020
0.71	0.99		0.508	0.536	0.563	0.597	0.629	0.663	0.701	0.741	0.783	0.850	0.992
0.72	0.96		0.479	0.507	0.534	0.568	0.600	0.634	0.672	0.721	0.754	0.821	0.963
0.73	0.94		0.452	0.480	0.507	0.541	0.573	0.607	0.645	0.685	0.727	0.794	0.936
0.74	0.91		0.425	0.453	0.480	0.514	0.546	0.580	0.618	0.658	0.700	0.767	0.909
0.75	0.88		0.398	0.426	0.453	0.487	0.519	0.553	0.591	0.631	0.673	0.740	0.882
0.76	0.86		0.371	0.399	0.426	0.460	0.492	0.526	0.564	0.604	0.652	0.713	0.855
0.77	0.83		0.345	0.373	0.400	0.434	0.466	0.500	0.538	0.578	0.620	0.687	0.829
0.78	0.80		0.319	0.347	0.374	0.408	0.440	0.474	0.512	0.552	0.594	0.661	0.803
0.79	0.78		0.292	0.320	0.347	0.381	0.413	0.447	0.485	0.525	0.567	0.634	0.776
0.80	0.75		0.266	0.294	0.321	0.355	0.387	0.421	0.459	0.499	0.541	0.608	0.750
0.81	0.72		0.240	0.268	0.295	0.329	0.361	0.395	0.433	0.473	0.515	0.582	0.724
0.82	0.70		0.214	0.242	0.269	0.303	0.335	0.369	0.407	0.447	0.489	0.556	0.698
0.83	0.67		0.188	0.216	0.243	0.277	0.309	0.343	0.381	0.421	0.463	0.530	0.672
0.84	0.65		0.162	0.190	0.217	0.251	0.283	0.317	0.355	0.395	0.437	0.504	0.645
0.85	0.62		0.136	0.164	0.191	0.225	0.257	0.291	0.329	0.369	0.417	0.478	0.602
0.86	0.59		0.109	0.140	0.167	0.198	0.230	0.264	0.301	0.343	0.390	0.450	0.593
0.87	0.57		0.083	0.114	0.141	0.172	0.204	0.238	0.275	0.317	0.364	0.424	0.567
0.88	0.54		0.054	0.085	0.112	0.143	0.175	0.209	0.246	0.288	0.335	0.395	0.538
0.89	0.51		0.028	0.059	0.086	0.117	0.149	0.183	0.230	0.262	0.309	0.369	0.512
0.90	0.48			0.031	0.058	0.089	0.121	0.155	0.192	0.234	0.281	0.341	0.484

ALPES TECHNOLOGIES

Dividing the reactive power into steps

When designing a capacitor bank, it is important to break down the total power Qt (kVAr) (See "Determining the appropriate capacitor bank power" section on p. 12) into several steps so as to ensure the best compromise between the number of steps and suitable regulation:

1 - Optimising the number of physical steps* while ensuring the target number of electrical steps**

*Physical steps: equivalent to the kVAr powers of the various capacitors which make up an automatic or dynamic capacitor bank and tripped individually by the contactors.

**Electrical steps = total power/smallest physical step, represents the kVAr power seen by the electrical installation.

2 – Determining the smallest physical and electrical step Q1

The smallest physical and electrical step corresponds to the total capacitor bank power Qt divided by the target number of electrical steps "n".

$$Q1 = Qt/n$$

Number of electrical steps n	Advantages	Disadvantages	Type of installation
	Precision control Alternate switching of steps with the same power rating possible with Alptec controllers, to increase the contactor and capacitor life	Higher enclosure and maintenance costs	Installation with rapidly changing reactive power
	Optimised enclosure and maintenance costs	Slow control Risk of excessive switching of the same steps following variation of the loads which could shorten the life of both contactors* and capacitors	Installation with slowly changing reactive power

* For capacitor banks with few electrical steps, we recommend increasing the step switching times.
This function is possible in Alptec controllers, refer to the controller manual.

3 – Determining the number of physical steps "P" from the desired number of electrical steps n".

a - The sum of the physical step power ratings corresponds to the total power:

$$Qt = \sum_{1}^{p} Qp$$

b - Note the maximum switching power of the CTX^3 contactors ≤ 60 kVAr at 400-440 V in order to switch the three-phase capacitors.

c – Note the maximum number of relay outputs the controllers can switch (see table on next page).

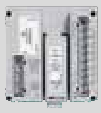
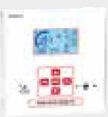
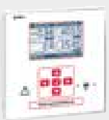
It is possible to create physical steps > 60 kVAr via simultaneous control of 2 contactors, divided between 2 different capacitors, by the same controller relay output, to which it is essential to add a time delay of 1 second minimum (see page 43).

Example: To create high-power capacitor banks > 1000 kVAr, a few 100 kVAr physical steps can be created by switching a 50 kVAr contactor-capacitor pairing twice at the same time.

The Alptec 3.2/5.2/8.2 and Alptec 8 power factor controllers provide optimal, accurate, fast regulation with the least possible number of capacitors, alternating the steps involved according to the reactive power needed.

This type of regulation:

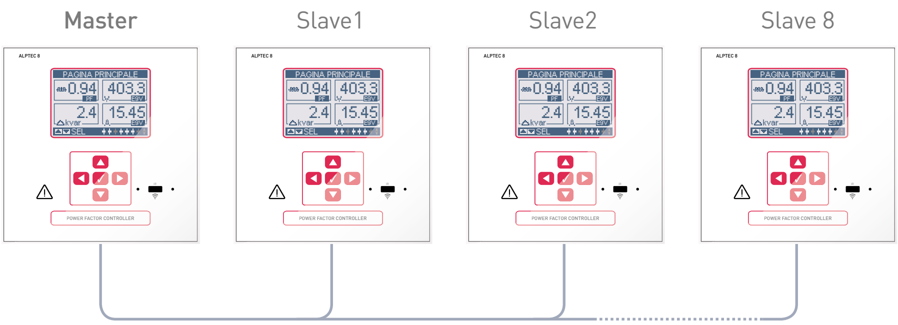
- increases the capacitor bank service life
- ensures that the capacitors and contactors age uniformly
- allows a smaller enclosure and hence lower purchase and maintenance costs of the enclosure
- saves energy by reducing energy losses due to limiting the number of steps.

Controllers		Standard number of steps up to	Maximum number of steps with expansion modules: EXT2GR EXT3GR	Maximum number of step expansion modules EXT2GR, EXT3GR and communication modules EXTRS485	Type of contactor
	ALPTEC3.2	3 steps	6 steps	1 module 	Electromechanical CTX³
	ALPTEC5.2	5 steps	8 steps		
	ALPTEC8.2	8 steps	14 steps	2 modules 	
	ALPTEC8	8 steps	18 steps	4 modules 	- Electromechanical CTX³ - Thyristor (solid state) with the EXT4GRS module

EXT2GR/EXT3GR: 2/3 relay outputs to be programmed. Used to add, for example, 2 additional steps or a signalling contact.
EXT4GRS: 4 solid state outputs to be used exclusively with ALPTEC8 for applications using solid state contactors in order to create dynamic compensation for installations with very variable loads.

ALPES TECHNOLOGIES

Dividing the reactive power into steps (continued)



For the highest power ratings requiring steps > 18 steps.

It is possible to use the same principle of physical steps > 60 kVAr by simultaneously controlling 2 contactors divided between 2 different capacitors using the same controller relay output, to which it is essential to add a long enough time delay (a minimum of several seconds).

Similarly, ALPTEC8 controllers can be used to create 1 master bank, up to 8 slave banks, resulting in a system with a maximum of 32 steps.

Practical example: Let's look at a 87.5 kVAr capacitor bank enclosure

Solution 1: 7 physical steps of 12.5 kVAr with

- 7 Alpivar capacitors of 12.5 kVAr
- 7 contactors
- 1 Alptec8.2 controller

Conclusion: Equipment and labour cost not optimised.

Solution 2: 3 physical steps (12.5 + 25 + 50) kVAr

- 3 Alpivar capacitors of 12.5, 25 and 50 kVAr
- 3 contactors
- 1 Alptec3.2 controller

Conclusion: Equipment and labour cost optimised

		3 physical steps		
	Power kVAr	12.5	25	50
7 electrical steps	12.5	1	0	0
	25	0	1	0
	37.5	1	1	0
	50	0	0	1
	62.5	1	0	1
	75	0	1	1
	87.5	1	1	1

0 = step disconnected 1= step activated

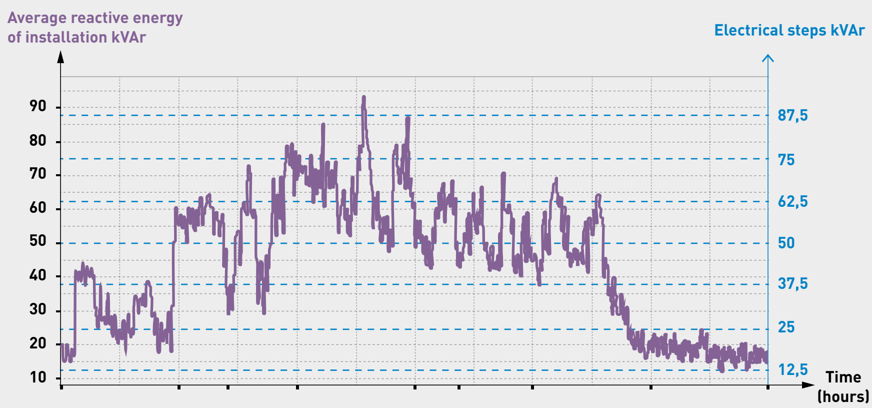
For optimum sizing of the capacitor banks, we recommend first taking measurements and carrying out an "Power Quality audit" during a period of significant activity over 1 to 2 weeks (for example: Busy production period) paying particular attention to the following points:

The max. levels of harmonics THDi % and Thdu % (see "Determining the capacitor bank type" section)

For the reactive energy range needed to achieve the target power factor, take account of the periods when there is a need for reactive energy outside sporadic demand peaks in each significant period of time to determine the smallest step Q1 and number of electrical steps n.

The Alptec 2333b analyser, ideal for existing enclosures.

Example: In a commercial installation, to achieve a power factor close to 1 we carried out an energy quality audit with a network analyser to check the reactive energy variations (in addition to the harmonic measurements) as below:



In this case, we recommended a capacitor bank of 87.5 kVAr, which corresponds to the maximum power needed to achieve the power factor in the least favourable case. And this capacitor bank is broken down into just 3 physical steps: 12.5 kVAr, 25 kVAr and 50 kVAr, allowing us to create 7 electrical steps from 12.5 kVAr to 87.5 kVAr according to the sequences shown in the example in the previous section.

ALPES TECHNOLOGIES

Determining the type of step

CAPACITORS ALPIVAR³

Alpivar³ capacitors are designed by combining individual single-phase windings, connected in a delta configuration, to produce a three-phase unit. These windings are created using two metallised polypropylene films with zinc coating on one side.

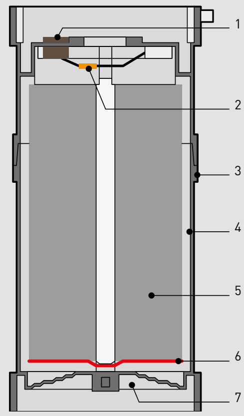
The metallisation constitutes the electrode, the polypropylene film constitutes the insulation.

They are then vacuum-coated with a self-extinguishing thermosetting polyurethane resin which forms the casing, providing mechanical and electrical environmental protection.

This vacuum coating technique for the windings gives Alpivar³ capacitors excellent resistance over time and a much longer service life than conventional units.

Vacuum sealing ensures that there is no air or moisture near the windings. This design provides excellent resistance to voltage surges and partial discharges.

This unit complies fully with environmental protection requirements (PCB-free).



1 - Socket terminals for direct connection via cables and lugs
2 - Internal discharge resistor
3 - Self-extinguishing plastic casing
4 - Self-healing coil
5 - Resin under vacuum
6 - Electrical fuse
7 - Pressure monitoring devices with visible trip indication

TECHNICAL SPECIFICATIONS

Discharge resistors
Fitted inside (except by special request), these discharge the unit in accordance with current standards (discharge time, 3 minutes)

Loss factor
Alpivar³ capacitors have a loss factor of less than 0.1 x 10-3
This value leads to a power consumption of less than 0.3 W per kVar, including the discharge resistors

Capacitance
Tolerance on the capacitance value: + 5 %
Excellent stability of the capacitance throughout the service life of the Alpivar³ capacitor

Permissible overvoltage:
1.18 x U, 12/24 hrs

Permissible overcurrent:
- S type: up to 1.5 x In
- H type: up to 2 x In

Mounting position:
indoors, vertical or horizontal

Current peak withstand:
- S type: up to 250 x In
- H type: up to 350 x In

Average service life:
- S type: up to 130,000 hrs
- H type: up to 170,000 hrs

Insulation class
- 50 Hz withstand for 1 min: 6 kV
- 1.2/50 µs impulse withstand: 25 kV

The table opposite can be used to select the capacitor according to the degree of harmonic pollution, by measuring the percentage of THDi and THDu or by estimating the percentage total power of SH/ST non-linear loads.

SAH and reinforced SAH type capacitor banks are enclosures with a detuned reactor, check compatibility with your local operator's ripple control frequency, for other tuning frequencies please consult us.

THDu measurement	≤ 3 %	≤ 4 %	≤ 6 %	≤ 8 %
THDi measurement	≤ 10 %	≤ 15 %	≤ 30 %	≤ 40 %
Range ALPIVAR[3]	Type S ALPIVAR	Type H ALPIVAR	SAH ALPIVAR	SAH-R ALPIVAR

SH/ST estimation	≤ 15 %	≤ 25 %	≤ 35 %	≤ 50 %
Range ALPIVAR[3]	Type S ALPIVAR	Type H ALPIVAR	SAH ALPIVAR	SAH-R ALPIVAR

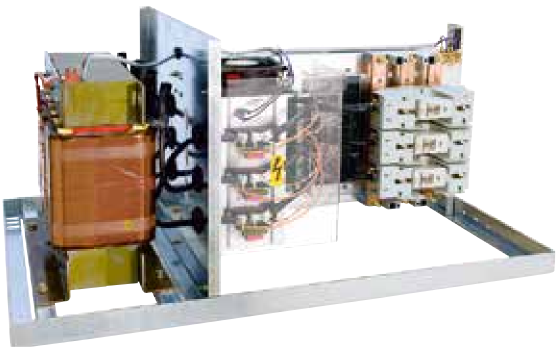
ST: power in kVA of the MV/LV transformer (or MV/LV transformers if there are two or more transformers in parallel).

SH: expanded power in kVA of the harmonic generators in the secondary of the MV/LV transformer(s) to be compensated.

THDi: percentage of total harmonic current pollution.

THDu: percentage of total harmonic voltage pollution.

To save wiring time, the Legrand group has a prewired rack offer for versions with and without reactors, consisting of capacitor + protection device + contactor + reactors depending on the model.



Determining the type of step (continued)

ALPICAN CAPACITORS

Alpican capacitors are designed by combining three individual single-phase windings, connected in a delta configuration.

The compact design provides excellent mechanical resistance and great stability. This design ensures ease of handling and longer service life.

- Conform to standards IEC 60831-1 and 2
- Compact design with an aluminium cylindrical casing in order to obtain uniform heat dissipation
- Impregnation with biodegradable semi-rigid resin
- Dual safety features: self-healing film and disconnection device in the event of a pressure surge
- Range: 2.5 to 30 kVAr - 50 Hz (3 to 36 kVAr - 60 Hz)

TECHNICAL SPECIFICATIONS

Discharge resistors
Fitted inside, they discharge the unit in accordance with current standards (discharge time, 3 minutes)

Loss factor
Alpican capacitors have a loss factor of less than 0.2 x 10-3.
This value leads to a power consumption of less than 0.45 W per kVAr, excluding the discharge resistors.

Rated frequency: 50/60 Hz

Capacitance: Tolerance on the capacitance value: - 5 % / 10 %

Max. permissible voltage:
1.1 Un up to 8 hours daily (according to IEC 60831-1 and 2)

Max. permissible current:
Up to 1.5 Ir including combined effects of harmonics (according to IEC 60831-1 and 2)

Inrush current: up to 200 Ir
Insulation class: 3/15 kV

Standards: Alpican capacitors comply with:
- International standard: IEC 60831-1 and 2

Temperature class: Alpican capacitors are designed for a standard -25D temperature class
- Maximum temperature: 55 °C
- Average over 24 hours: 45 °C
- Annual average: 35 °C
- Lowest temperature class: - 25 °C

Cooling: natural or forced

Humidity: max. 95 %

Altitude: max. 4000 m above the sea level

Mounting position: vertical

Current peak withstand: up to 200 x In

Average service life: up to 100 000 h

The table opposite can be used to select the capacitor according to the degree of harmonic pollution, by measuring the percentage of THDi and THDu or by estimating the percentage total power of SH/ST non-linear loads.

SAH and reinforced SAH type capacitor banks are enclosures with a detuned reactor, check compatibility with your local operator's ripple control frequency, for other tuning frequencies please consult us.

THDu measurement	**≤ 2 %**	**≤ 3 %**	**≤ 6 %**
THDi measurement	**≤ 5 %**	**≤ 10 %**	**≤ 30 %**
ALPICAN range (400 V mains supply)	ALPICAN (Unc 400 V)	ALPICAN (Unc 440 V)	ALPICAN (Unc 440/480 V) + SAH

SH/ST estimation	**≤ 10 %**	**≤ 15 %**	**≤ 35 %**
ALPICAN range (400 V mains supply)	ALPICAN (Unc 400 V)	ALPICAN (Unc 440V)	ALPICAN (Unc 440/480 V) + SAH

ST: power in kVA of the MV/LV transformer (or MV/LV transformers if there are two or more transformers in parallel).

SH: expanded power in kVA of the harmonic generators in the secondary of the MV/LV transformer(s) to be compensated.

THDi: percentage of total harmonic current pollution.

THDu: percentage of total harmonic voltage pollution.

Calculating the effective power by type

COMPENSATION WITHOUT DETUNING REACTOR

The nominal voltage and voltage variation level need to be taken into account depending on the quality of the electricity supply.

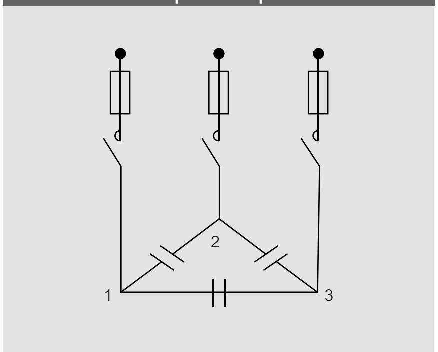
Example: to create a 25 kVAr step in a 400 V 50 Hz mains supply:

- On a stable supply, a capacitor with nominal power of 25 kVAr 400 V in the Alpivar³ range Cat. No. V2540 or Alpican Cat. No. 4 151 68.
- On a disturbed supply, it is advisable to use a capacitor with higher nominal voltage that covers the range of maximum voltage surges of the electricity supply.

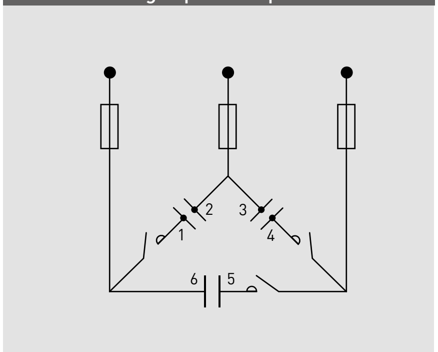
A capacitor can be used with nominal voltage 440 V and a nominal power rating calculated as follows:

$$Qn = Qrms * \left(\frac{Un}{Uc}\right)^2 = 25 * \left(\frac{440}{400}\right)^2 = 30 \text{ kVAr}$$

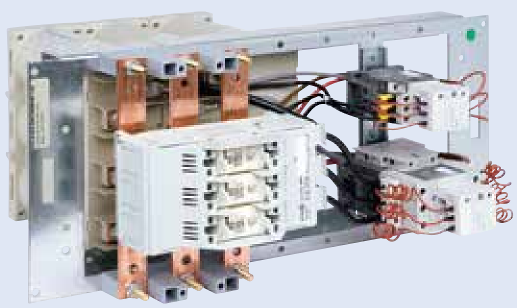
Three-phase capacitors



3 single-phase capacitors



Say a capacitor in the Alpivar³ range Cat. No. V3044 or Alpican range Cat. No. 4 151 87.

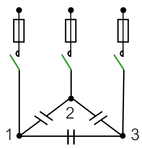


Alpimatic racks
without detuned reactor

Selection tables for ALPIVAR³ type steps (capacitor, contactor, protection device) without a detuned reactor.

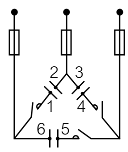
Network 400 V - 50 Hz, Max. harmonic pollution THDu ≤ 3 % ; THDi ≤ 10 %

Alpivar³ S Type, Three-phase capacitors



Effective Power at 400 V (kVAr)	Alpivar³ Capacitor Cat. No	Contactor Cat. No to be completed with coil voltage code	HRC Fuse, gG type
6,25	V6.2540	4 160 8x + 4 168 74	16 A
12,5	V12.540	4 160 9x + 4 168 74	25 A
25	V2540	4 161 2x + 4 168 74	50 A
50	V5040	(4 161 8x + 4 168 77) / (4 161 9x + 4 168 76)	100 A

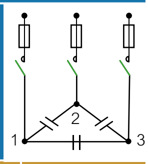
Alpivar³ S Type, 3 Single-phase capacitors



Effective Power at 400 V (kVAr)	Alpivar³ Capacitor Cat. No	Contactor Cat. No to be completed with coil voltage code	HRC Fuse, gG type
12,5	V12.540 3MONO	4 160 8x + 4 168 74	25 A
25	V2540 3MONO	4 161 2x + 4 168 74	50 A
50	V5040 3MONO	(4 161 4x + 4 168 75) / (4 161 5x + 4 168 76)	100 A
75	V7540 3MONO	(4 161 8x + 4 168 77) / (4 161 9x + 4 168 76)	160 A

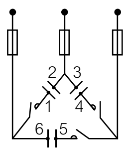
Network 400 V - 50 Hz, Max. harmonic pollution THDu ≤ 4 % ; THDi ≤ 15 %

Alpivar³ H Type, Three-phase capacitors



Effective Power at 400 V (kVAr)	Alpivar³ Capacitor Cat. No	Contactor Cat. No to be completed with coil voltage code	HRC Fuse, gG type
6,25	VH6.2540	4 160 8x + 4 168 74	16 A
12,5	VH12.540	4 160 9x + 4 168 74	25 A
25	VH2540	4 161 2x + 4 168 74	50 A
50	VH5040	(4 161 8x + 4 168 77) / (4 161 9x + 4 168 76)	100 A

Alpivar³ H Type, 3 Single-phase capacitors



Effective Power at 400 V (kVAr)	Alpivar³ Capacitor Cat. No	Contactor Cat. No to be completed with coil voltage code	HRC Fuse, gG type
12,5	V12.540 3MONO	4 160 8x + 4 168 74	25 A
25	V2540 3MONO	4 161 2x + 4 168 74	50 A
50	V5040 3MONO	(4 161 4x + 4 168 75) / (4 161 5x + 4 168 76)	100 A
75	V7540 3MONO	(4 161 8x + 4 168 77) / (4 161 9x + 4 168 76)	160 A

Coil voltage code

Control Voltage	x	Control Voltage	y
24V AC	0	24V AC	0
24V DC	1	24V DC	1
48V AC	2	48V AC	2
48V DC	3	48V DC	3
110V AC	4	100-240V AC / 100-220V AC	6
230V AC	5		
380V AC	6	400-440V AC	9
415V AC	7		

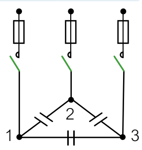
Calculating the effective power by type (continued)

COMPENSATION WITHOUT DETUNING REACTOR (CONTINUED)

Selection tables for ALPICAN type steps (capacitor, contactor, protection device) without a detuned reactor.

Network 400 V - 50 Hz, Max. harmonic pollution THDu ≤ 2 % ; THDi ≤ 5 %

Alpican Three-phase capacitors



Capacitor Voltage 400 V

Effective Power at 400 V (kVAr)	Power Capacitor at 400 V (kVAr)	ALPICAN Capacitor Cat. No	Contactor Cat. No to be completed with coil voltage code	HRC Fuse, gG type
6,3	6,3	4 151 62	4 160 8x + 4 168 74	16 A
12,5	12,5	4 151 65	4 160 9x + 4 168 74	25 A
25	25	4 151 68	4 161 2x + 4 168 74	50 A
50	50	2 x 4 151 68	(4 161 8x + 4 168 77) / (4 161 9x + 4 168 76)	100 A

Capacitor Voltage 415 V

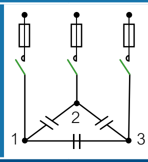
Effective Power at 400 V (kVAr)	Power Capacitor at 415 V (kVAr)	ALPICAN Capacitor Cat. No	Contactor Cat. No to be completed with coil voltage code	HRC Fuse, gG type
6	6,3	4 151 71	4 160 8x + 4 168 74	16 A
11,5	12,5	4 151 74	4 160 9x + 4 168 74	25 A
23,2	25	4 151 77	4 161 2x + 4 168 74	50 A
46,5	50	2 x 4 151 77	(4 161 8x + 4 168 77) / (4 161 9x + 4 168 76)	100 A

Coil voltage code

Control Voltage	x	Control Voltage	y
24V AC	0	24V AC	0
24V DC	1	24V DC	1
48V AC	2	48V AC	2
48V DC	3	48V DC	3
110V AC	4	100-240V AC / 100-220V AC	6
230V AC	6		
380V AC	8	400-440V AC	9
415V AC	9		

Network 400 V - 50 Hz, Max. harmonic pollution THDu ≤ 3 % ; THDi ≤ 10 %

Alpican Three-phase capacitors



Capacitor Voltage 440 V

Effective Power at 400 V (kVAr)	Power Capacitor at 440 V (kVAr)	ALPICAN Capacitor Cat. No	Contactor Cat. No to be completed with coil voltage code	HRC Fuse, gG type
8,5	10	4 151 82	4 160 9x + 4 168 74	20 A
10	12,5	4 151 83	4 160 9x + 4 168 74	25 A
20	25	4 151 86	4 161 2x + 4 168 74	50 A
40	50	2 x 4 151 86	(4 161 4x + 4 168 75) / (4 161 5x + 4 168 76)	80 A
60	75	3 x 4 151 86	(4 162 2x + 4 168 77) / (4 162 3x + 4 168 76)	125 A

Capacitor Voltage 480 V

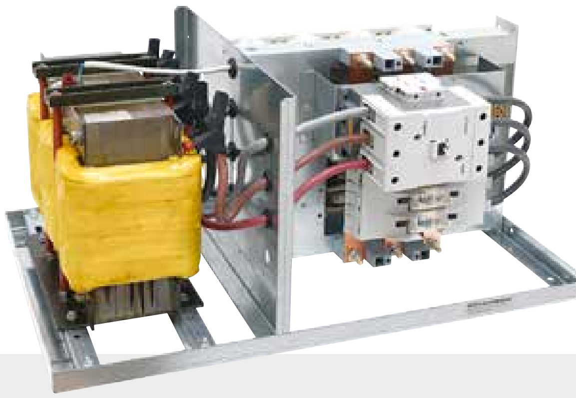
Effective Power at 400 V (kVAr)	Power Capacitor at 415 V (kVAr)	ALPICAN Capacitor Cat. No	Contactor Cat. No to be completed with coil voltage code	HRC Fuse, gG type
8,5	12,5	4 151 90	4 160 9x + 4 168 74	20 A
10	15	4 151 91	4 160 9x + 4 168 74	25 A
20	30	4 151 94	4 161 2x + 4 168 74	50 A
40	60	2 x 4 151 94	(4 161 4x + 4 168 75) / (4 161 5x + 4 168 76)	80 A
60	90	3 x 4 151 94	(4 162 2x + 4 168 77) / (4 162 3x + 4 168 76)	125 A

II COMPENSATION WITH DETUNING REACTOR

For installations with a high level of harmonic pollution, a detuned reactor should be used on each step to protect the capacitors against harmonic overloads and prevent the risk of resonance described in the previous section.

Reactors create a voltage surge at the capacitor terminals higher than the mains voltage, which indirectly modifies the reactive power it injects into the installation.

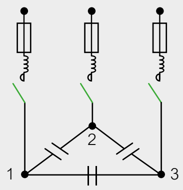
The calculation below describes the phenomenon as well as the method for determining the nominal reactive power of the capacitor to be selected, in order to obtain the desired actual reactive power.



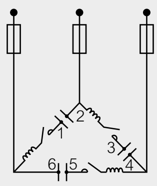
Alpimatic racks with detuned reactor

There are two options for installing the reactor:

1 - Outside the delta, using Alpivar or Alpican three-phase capacitors (3 terminals) prewired internally in a delta or star connection.



2 - Inside the delta, using Alpivar 3 single-phase capacitors (6 terminals).



Voltage surge on the terminals of capacitors with reactors

Using a reactor creates a voltage surge on the terminals of the associated capacitor, as below:

$$Uc = \frac{Us}{1-p}$$

Assuming a blocking factor

$$P = \left(\frac{f}{f_{rs}}\right)^2 < 0$$

the capacitor is therefore operating at a voltage higher than the mains voltage. Precautions therefore need to be taken when selecting the power rating and nominal voltage of the capacitor to be installed.

It is vital that the nominal voltage Un of the capacitor is permanently higher than the effective voltage UC at its terminals depending on the reactor chosen and the maximum mains voltage.

Adding detuned reactors to existing steps without checking the general capacitor status and without measuring the capacitance is strictly prohibited.

Any failure to follow these procedures and warnings to the letter can lead to premature failure, explosion, or an outbreak of fire in the equipment, and will automatically invalidate the enclosure warranty.

Calculating the effective power by type (continued)

II COMPENSATION WITH DETUNING REACTOR (CONTINUED)

Based on the nominal power Qn and nominal voltage Un of the capacitor we can recalculate the effective power of each step in the capacitor + detuned reactors pairing using the following equation:

$$Qs = \left(\frac{Us}{Un}\right)^2 * \frac{Qn}{(1-p)}$$

Particular attention should be paid when determining the smallest physical step if the total sum of all the steps' effective power corresponds to the total power of the target capacitor bank.

For optimal regulation, the power factor controllers should be configured by indicating the effective power of the capacitor + detuned reactors pairing of the smallest step, not the nominal power of the step.

See an example in our Alptec 3.2/5.2/8.2 controllers via parameter P06 and Alptec8 controllers via parameter P02.07.

A • STEP WITH THREE-PHASE CAPACITOR

This is the calculation method for a 3-PH capacitor (3 terminals).

In the examples we are looking at a 400 V 50 Hz three-phase mains supply with a high level of 3rd order harmonic pollution, so we will use 135 Hz reactors (p 14 %).

1 - Choosing the capacitor

Determining the capacitor power supply voltage:

$$Uc = \frac{Us}{1-p}$$

Example:

$$Uc = \frac{400}{1-0.14} = 465\ V$$

We should therefore choose a capacitor with nominal voltage higher than UC, so we can choose a capacitor with nominal voltage 480 V on a sufficiently stable supply.

Calculating the effective power of the step (capacitor + reactor) at 400 V:

$$Qs = \left(\frac{Us}{Un}\right)^2 * \frac{Qn}{(1-p)}$$

Example: By choosing an Alpican capacitor with nominal power of 25 kVAr at 480 V, Cat. No. 4 151 93, we get effective power supplied to the mains supply at 400 V as follows:

$$Qs = \left(\frac{400}{480}\right)^2 * \frac{25}{(1-0.14)} = 20\ kVAr$$

2 - Choosing the reactor

Determining the reactor inductance L:

The reactor value (inductance per phase) is calculated as follows:

$$L = \frac{Us^2 p}{Q_s\,(1-p)\omega} = \frac{pU_N{}^2}{Q_N\omega}$$

Example:

$$\frac{0.14x480^2}{25x10^3x2px50} \simeq 4.1\ mH$$

Determining the current I_L in the reactor:

$$I_L = \frac{Q_s}{\sqrt{3}U_s}$$

Example:

$$I_L = \frac{2000}{\sqrt{3}x400} \simeq 28.9\ A$$

Due to the harmonic currents which will be drawn by the reactor, this current should be increased as per the table on the next page.

Capacitors	Alpivar			Alpican	
Types	SAH		Reinforced SAH	SAH	
P %	7 %	14 %	7 %	7 %	14 %
I (rms)	105 %	110 %	120 %	115 %	110 %

We will therefore use:

I_L = 110 %x28.9 ≃ 31.8 A

We should therefore choose from the catalogue a reactor with the closest characteristics:

L = 4.05 mH and In = 31.4 A, Cat. No. SAH4.05-31.4A.

B • STEP WITH 3 SINGLE-PHASE CAPACITOR

In the examples we will look at a 400 V 50 Hz three-phase mains supply with a high level of 3rd order harmonic pollution, so we will use 135 Hz reactors (p 14 %).

1 - Choosing the capacitor

Determining the capacitor power supply voltage:

$$Uc = \frac{Us}{1-p}$$

$$Uc = \frac{400}{1-0.14} = 465\ V$$

Example:

We should therefore choose a capacitor with nominal voltage higher than UC, so we can choose a capacitor with nominal voltage 480 V on a sufficiently stable supply.

Calculating the effective power of the step (capacitor + reactor) at 400 V:

$$Qs = \left(\frac{Us}{Un}\right)^2 * \frac{Qn}{(1-p)}$$

Example: By choosing a capacitor with nominal power of 21.5 kVAr at 480 V, Cat. No. V21.548-3MONO, we get effective power supplied to the mains supply at 400 V as follows:

$$Qs = \left(\frac{400}{480}\right)^2 * \frac{25}{(1-0.14)} = 20\ kVAr$$

2 - Choosing the reactor

Determining the reactor inductance L:

The reactor value (inductance per phase) is calculated as follows:

$$L = \frac{3Us^2p}{Q_s\,(1-p)\omega} = \frac{3pU_N^{\ 2}}{Q_N\omega}$$

Example:

$$L = \frac{3x0.14x480^2}{21.5x10^3x2\pi x50} \simeq 14.3\ mH$$

Determining the current I_L in the reactor:

$$I_L = \frac{Q_s}{3U_s}$$

Example:

$$I_L = \frac{17500}{3x400} \simeq 14.6\ A$$

Due to the harmonic currents which will be drawn by the reactor, this current should be increased according to Table 1 (see page 27).

We will therefore use:

I_L = 110 %x28.9≃ 16.6 A

We should therefore choose from the catalogue a reactor with the closest characteristics:

L = 14.1 mH and In = 16 A, Cat. No. SAH14.10-16.0A.

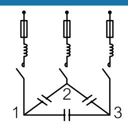
Calculating the effective power by type (continued)

II COMPENSATION WITH DETUNING REACTOR (CONTINUED)

Selection tables for ALPIVAR³ type steps (capacitor, contactor, protection device) with a detuned reactor.

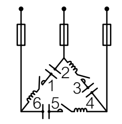
NETWORK 400 V - 50 HZ, MAX. HARMONIC POLLUTION THDU ≤ 6 % ; THDI ≤ 30 %

Alpivar³ H Type, 7 % Detuned Reactor
Three-phase capacitors



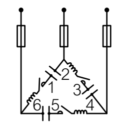
Effective Power at 400 V (kVAr)	Alpivar³ Capacitor Cat. No	Detuned Reactor Cat. No 189 Hz (p = 7 %)	Contactor ref. to be completed with the coil voltage code	HRC Fuse, gG type
13	VH12.540	SAH2.85-21.0A	4 161 0x	25 A
26	VH2540	SAH1.45-42.0A	4 161 3x	50 A
52	VH5040	SAH0.72-83.0A	4 161 8x /4 161 9x	100 A
78	VH7540	SAH0.48-123.0A	4 162 4y / 4 162 5y	160 A

Alpivar³ H Type, 7 % Detuned Reactor
3 Single-phase capacitors

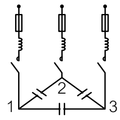


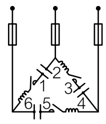
Effective Power at 400 V (kVAr)	Alpivar³ Capacitor Cat. No	Detuned Reactor Cat. No 189 Hz (p = 7 %)	Contactor ref . to be completed with the coil voltage code	HRC Fuse, gG type
13	VH12.540-3MONO	SAH8.55-12.6A	4 160 9x	25 A
26	VH2540-3MONO	SAH4.30-25.1A	4 161 2x	50 A
52	VH5040-3MONO	SAH2.15-50.0A	4 161 4x / 4 161 5x	100 A
78	VH7540-3MONO	SAH1.44-74.4A	4 162 2x / 4 162 3x	160 A

Alpivar³ 480 V, 14 % Detuned Reactor
3 Single-phase capacitors



Effective Power at 400 V (kVAr)	Power Capacitor at 480 V (KVAr)	Alpivar³ Capacitor Cat. No	Detuned Reactor Cat. No 135 Hz (p = 14 %)	Contactor ref . to be completed with the coil voltage code	HRC Fuse, gG type
17,5	21,5	V21.548-3MONO	SAH14.10-16.0A	4 161 1x	40 A
35	43	V4348-3MONO	SAH7.05-31.0A	4 161 4x / 4 161 5x	80 A
70	86	V8640-3MONO	SAH3.52-62.0A	4 162 2x / 4 162 3x	160 A

NETWORK 400 V - 50 HZ, MAX. HARMONIC POLLUTION THDU ≤ 8 % ; THDI ≤ 40 %				
Alpivar³ H Type, 7 % Detuned Reactor Three-phase capacitors				
Effective Power at 400 V (kVAr)	Alpivar³ Capacitor Cat. No	Detuned Reactor Cat. No 189 Hz (p = 7 %)	Contactor Cat. No to be completed with coil voltage code	HRC Fuse, gG type
22	VH2040	SAH1.78-38.0A	4 161 2x	40 A
44	VH4040	SAH0.90-75.0A	4 161 6x / 4 161 7x	80 A
88	VH8040	SAH0.45-150.0A	4 162 6y / 4 162 7y	160 A

Alpivar³ H Type, 7 % Detuned Reactor 3 Single-phase capacitors				
Effective Power at 400 V (kVAr)	Alpivar³ Capacitor Cat. No	Detuned Reactor Cat. No 189 Hz (p = 7 %)	Contactor ref . to be completed with the coil voltage code	HRC Fuse, gG type
11	VH1040-3MONO	SAH10.70-12.0A	4 160 9x	20 A
22	VH2040-3MONO	SAH5.36-23.9A	4 161 1x	40 A
44	VH4040-3MONO	SAH2.68-44.0A	4 161 4x / 4 161 5x	80 A
88	VH8040-3MONO	SAH1.34-87.0A	4 162 4y / 4 162 5y	160 A

Coil voltage code			
Control Voltage	**x**	**Control Voltage**	**y**
24V AC	0	24V AC	0
24V DC	1	24V DC	1
48V AC	2	48V AC	2
48V DC	3	48V DC	3
110V AC	4	100-240V AC / 100-220V AC	6
230V AC	6		
380Vs AC	8	400-440V AC	9
415V AC	9		

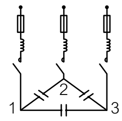
Calculating the effective power by type (continued)

II COMPENSATION WITH DETUNING REACTOR (CONTINUED)

Selection tables for ALPICAN type steps (capacitor, contactor, protection device) with a detuned reactor.

NETWORK 400 V - 50 HZ , MAX. HARMONIC POLLUTION THDU ≤ 6 % ; THDI ≤ 30 %

Alpican Three-phase capacitors

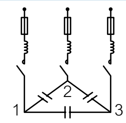


Capacitor Voltage 440 V - 7 % Detuned Reactor

Effective Power at 400 V (kVAr)	Power Capacitor at 440 V (KVAr)	Alpican Capacitor Cat. No	Detuned Reactor Cat. No 189 Hz (p = 7 %)	Contactor ref . to be completed with the coil voltage code	HRC Fuse, gG type
9	10	4 151 82	SAH4.31-16.2A	4 161 0x	20 A
11,25	12,5	4 151 83	SAH3.45-20.2A	4 161 0x	25 A
22,5	25	4 151 86	SAH1.73-40.4A	4 161 2x	50 A
45	50	2 x 4 151 86	SAH0.86-80.8A	4 161 6x / 4 161 7x	80 A
67,5	75	3 x 4 151 86	SAH0.58-121.2A	4 162 2x / 4 162 3x	125 A
90	100	4 x 4 151 86	SAH0.43-161.6A	4 162 6y / 4 162 7y	160 A

Capacitor Voltage 480 V - 7 % Detuned Reactor

Effective Power at 400 V (kVAr)	Power Capacitor at 440 V (KVAr)	Alpican Capacitor Cat. No	Detuned Reactor Cat. No 189 Hz (p = 7 %)	Contactor ref . to be completed with the coil voltage code	HRC Fuse, gG type
9	12,5	4 151 90	SAH4.31-16.2A	4 161 0x	20 A
11,25	15	4 151 91	SAH3.45-20.2A	4 161 0x	25 A
22,5	30	4 151 94	SAH1.73-40.4A	4 161 2x	50 A
45	60	2 x 4 151 94	SAH0.86-80.8A	4 161 6x / 4 161 7x	80 A
67,5	90	3 x 4 151 94	SAH0.58-121.2A	4 162 2x / 4 162 3x	125 A
90	120	4 x 4 151 94	SAH0.43-161.6A	4 162 6y / 4 162 7y	160 A

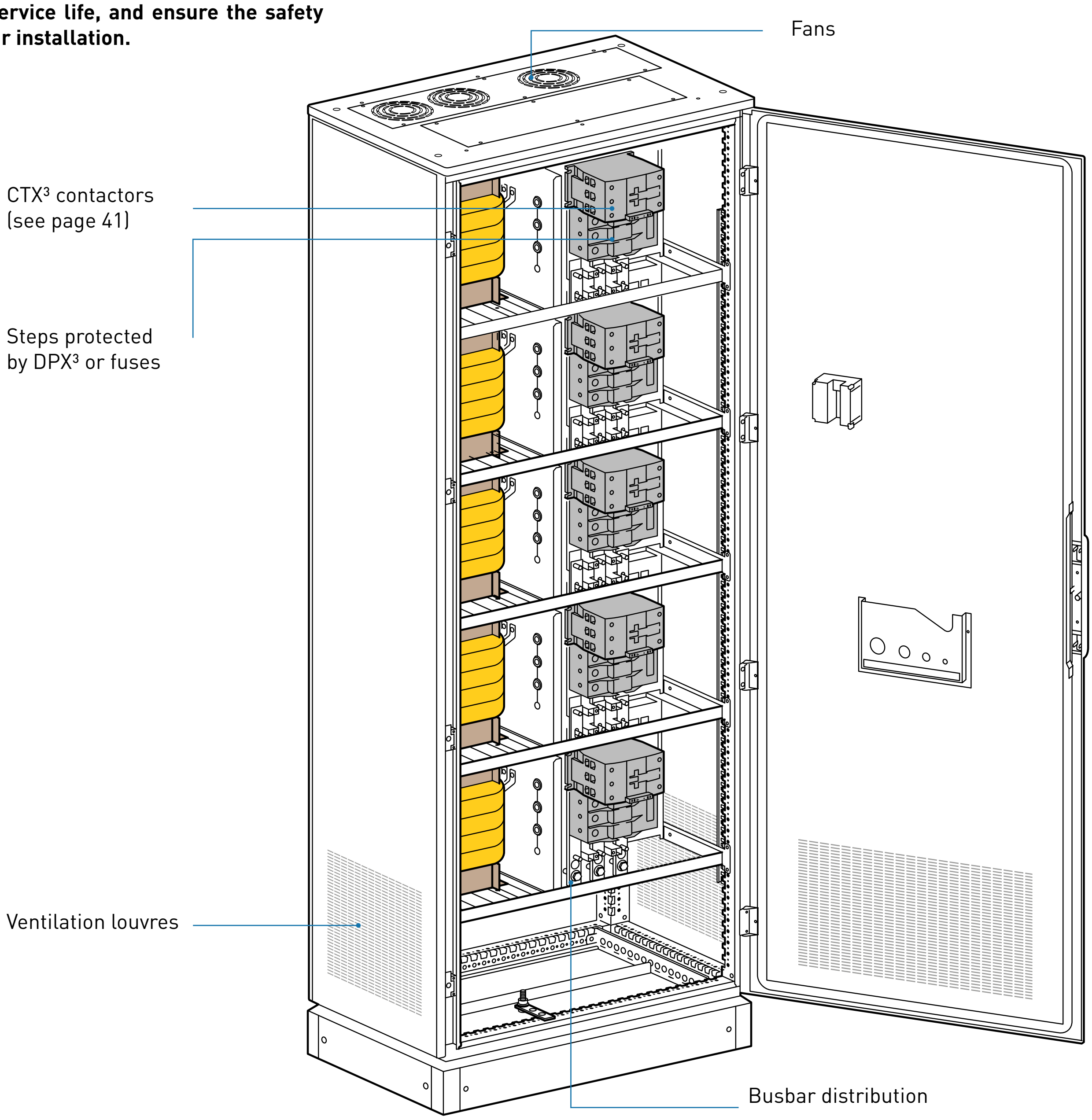
NETWORK 400 V - 50 HZ , MAX. HARMONIC POLLUTION THDU ≤ 6 % ; THDI ≤ 30 %					
Alpican Three-phase capacitors					
Capacitor Voltage 480 V - 14 % Detuned Reactor					
Effective Power at 400 V (kVAr)	Power Capacitor at 480 V (KVAr)	Alpican Capacitor Cat. No	Detuned Reactor Cat. No 135 Hz (p = 4 %)	Contactor ref . to be completed with the coil voltage code	HRC Fuse, gG type
10	12,5	4 151 90	SAH8.10-15.7A	4 161 0x	25 A
20	25	4 151 93	SAH4.05-31.4A	4 161 2x	50 A
40	50	2 x 4 151 93	SAH2.02-62.8A	4 161 6x / 4 161 7x	80 A
60	75	3 x 4 151 93	SAH1.35-94.2A	4 162 2x / 4 162 3x	125 A
80	100	4 x 4 151 93	SAH1.00-125.6A	4 162 6y / 4 162 7y	160 A

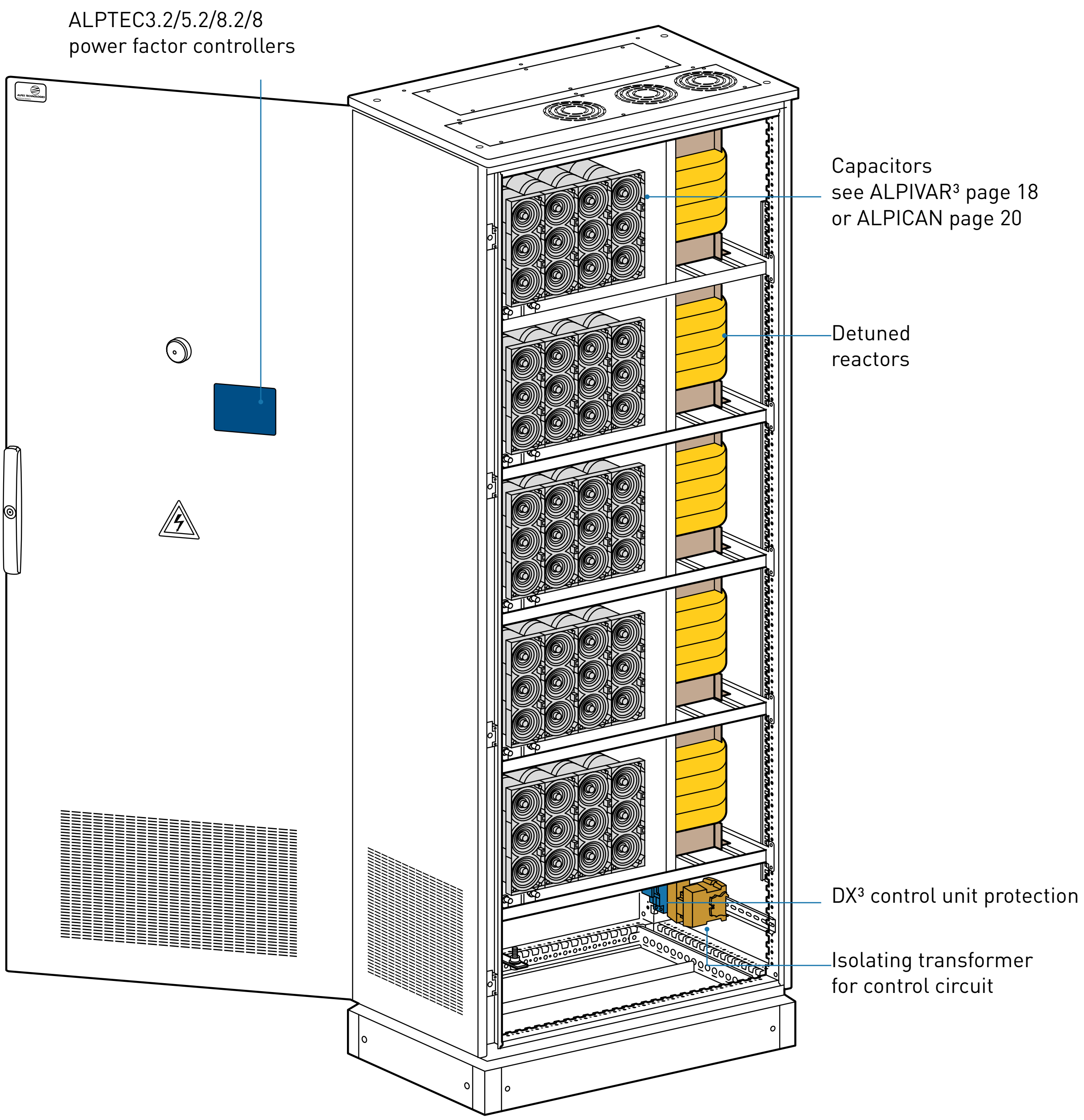
Coil voltage code			
Control Voltage	x	Control Voltage	y
24V AC	0	24V AC	0
24V DC	1	24V DC	1
48V AC	2	48V AC	2
48V DC	3	48V DC	3
110V AC	4	100-240V AC / 100-220V AC	6
230V AC	6		
380V AC	8	400-440V AC	9
415V AC	9		

ALPES TECHNOLOGIES

DESIGNING THE CAPACITOR BANK ENCLOSURE

This section describes the recommended design rules in order to maximise the capacitor bank's performance and service life, and ensure the safety of your installation.




ALPTEC3.2/5.2/8.2/8
power factor controllers
Capacitors
see ALPIVAR³ page 18
or ALPICAN page 20
Detuned
reactors
DX³ control unit protection
Isolating transformer
for control circuit

Protection and control

The design of the automatic capacitor banks requires special precautions for this application, in particular improved ventilation for components which dissipate a lot of energy in the form of heat (capacitors, reactors).

It is therefore necessary to follow certain mounting and wiring recommendations in order to optimise capacitor bank enclosure operation and service life, and also to minimise the chance of damage to the equipment caused by overheating for example.

THERMAL PROTECTION OF THE BANK AND THE CAPACITORS

In addition to electrical protection of the bank, it also needs to be protected against excessive temperature rises.

• Built-in thermal protection device in the controller

Legrand controllers include built-in protection against excessive temperature rises. This temperature-controllable protection device can be used to disconnect all the steps if the programmed threshold is exceeded, based on a temperature measurement taken by a sensor inside the controller, to prevent damage to the equipment in the capacitor bank.

This protection device protects against average temperature rises in the capacitor bank, and therefore takes no account of hot spots and natural temperature differences at the various heights in the enclosure. It is used at minimum to protect the controller against excessive temperature rises so that it works properly.

• Protection using temperature sensors

To improve thermal protection, it is possible to use sensors or thermostats placed at different locations in the enclosure:

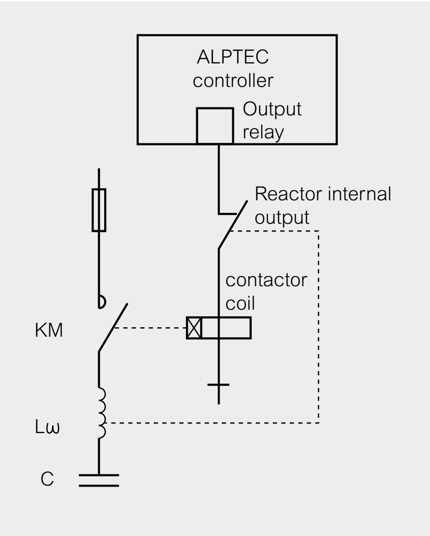
To protect the enclosure average temperature, a sensor placed at approximately 2/3 of the enclosure height (equivalent to controller built-in protection), set to 45°C.

To protect the enclosure maximum temperature, a sensor placed in the top of the enclosure, between the top step and the roof, set to 55°C.

These sensors must always be used to disconnect the capacitor bank in the event of excessive temperature rise, by connecting an NC contact in series with the controller power supply, or by energising a trip coil on the capacitor bank supply end protection.

• Protection against temperature rise in the reactors

The reactors (Lω) used in the capacitor bank should include an internal sensor in the coils. This sensor should be connected in series with the contactor coil power supply (KM), so the step can be disconnected in the event of excessive temperature rise.



• **Safety kits**

Installation conditions in rooms with high temperature, failure to take account of the enclosure operating conditions in their environment (power rating, nature of the loads, presence and level of harmonics, etc), and/or inadequate maintenance of the capacitor banks can result in a shorter capacitor bank service life, leading to an increased risk of accidents.

Thus, to enable enhanced capacitor bank monitoring, the Legrand Group recommends installation of a smoke detection control system for each capacitor bank cubicle and in the event of failure:

- Disconnection of the capacitor step power supply.
- Switching off the fans for enclosures equipped with forced ventilation.

We have developed safety kits ready to use with these functions which are suitable for any type of capacitor bank with surface and flush mounting versions in the form of Racks.

To ensure smoke is monitored in each capacitor bank cubicle, a safety kit must be installed in each cubicle. And to reduce equipment costs we have developed Master safety kits which can be used to:

- Disconnect the step power supply via the power factor controller generator (GE) load-shedding contact, to make it easier to install these safety kits in existing enclosures (retrofit).
- Local signalling using an audible signal via an integrated 80 dB buzzer.
- Remote signalling by making available a contact on terminals which MUST be used by the customer in order to activate: a technical alarm and/or trip the circuit breaker upstream of the capacitor bank using a trip coil.

Slave safety kits for monitoring 2 to 3 additional cubicles with synchronisation of the contacts on the Master kit.

Cat. Nos.	Description	Product
KSSVM	IP20 Master surface mounted safety kit with forced ventilation	 (*)
KSSVS	IP20 Slave surface mounted safety kit with forced ventilation	
KSSNM	IP30 Master surface mounted safety kit with natural ventilation	 (*)
KSSNS	IP30 Slave surface mounted safety kit with natural ventilation	
KSRNM	IP2X Master rack mounted safety kit with natural ventilation	 (*)
KSRNS	IP2X Slave rack mounted safety kit with natural ventilation	

(*): photos of Master safety kits

ALPES TECHNOLOGIES

Protection and control (continued)

BUILT-IN ELECTRICAL PROTECTION IN THE CONTROLLER

Power factor controllers, in addition to their function of controlling the target power factor level with connection and disconnection of the steps, should allow continuous monitoring of the quality of the installation electrical energy and in particular should allow capacitor bank disconnection if the maximum levels of harmonics (THDi and THDU) the capacitor banks have been sized to withstand are exceeded, in versions with or without detuned reactors, etc. (See "Determining the type of step" section on page 18).

Our Alptec controllers have several parameters and protection devices for the electrical and temperature measurements, and an algorithm for switching sophisticated steps.

A WIDE RANGE OF ELECTRICAL MEASUREMENTS

- Voltage
- Current
- Harmonic THD (current and voltage)
- Harmonic orders (up to no. 15)
- Active and Apparent Power
- Weekly average Cos φ
- Temperature
- Max. values

Type of voltage/current measurement: TRMS

Measurements available in all four quadrants

	ALPTEC 3.2/5.2/8.2	ALPTEC 8
Number of steps	**ALPTEC 3.2** (up to 6 with EXT2GR/ EXT3GR) **ALPTEC 5.2** (up to 8 with EXT2GR/ EXT3GR) **ALPTEC 8.2** (up to 14 with EXT2GR/ EXT3GR)	**ALPTEC 8** (8 to 18 with EXT2GR/ EXT3GR/EXT4GRS)
MEASUREMENT		
Rated measurement voltage	600 VAC max	600 VAC max
Voltage measurement range	50-720 VAC	50-720 VAC
Instantaneous cos ø (displacement factor)	•	•
Power factor - instantaneous and average weekly	•	•
Voltage and current	•	•
Reactive power to achieve the setpoint and total	•	•
Capacitor overload	•	•
Control panel temperature	•	•
Maximum voltage and current value	•	•
Maximum capacitor overload value	•	•
Maximum control panel temperature value	•	•
Active apparent power		•
Analysis of current and voltage harmonics	• up to 15th order	• up to 31st order
Measured value of each step, in VAr	•	•
Number of switching operations per step	•	•
PROTECTION		
Voltage too high and too low	•	•
Current too high and too low	•	•
Over-compensation (all capacitors disconnected and cos ø higher than the setpoint)	•	•
Under-compensation (all capacitors disconnected and cos ø lower than the setpoint)	•	•
Capacitor overload	•	•
Capacitor overload on all 3 phases		•
Overheating	•	•
Micro-power cuts	•	•
Failure of a capacitor bank	•	•
Maximum current harmonic distortion overshoot level	•	•
Programming alarm properties (activation, delay on tripping, relay excitation, etc.)		•
DIMENSIONS	Alpec3.2/5.2 : 96x96 Alpec8.2 : 144x144	144x144

! The controller parameters must be entered with care and adapted to the operating conditions (harmonic pollution, temperature, etc). Any inappropriate setting carries the risk of premature wear or even destruction of the equipment, involving risks to its environment and people, leading to unavailability of the installation, and the user is wholly responsible for any such action. The Legrand Group accepts no liability and the warranty is rendered null and void in the event of failure to comply with these recommendations.

Protection and control (continued)

SELECTING CONTACTORS

A • Transition states: Connection and disconnection

Connection and disconnection of a capacitor is accompanied by transient phenomena (voltage and current). Transient currents can be as much as ten times the nominal current for a capacitor on its own; the phenomenon is amplified if the capacitor is a step in a capacitor bank and other steps are already operating, which discharge briefly via the newly connected step.

Implementing certain practical measures can protect the system against these major disturbances: damping resistors, reactors and solid state contactors.

1 - Capacitor on its own

The inrush current when a capacitor on its own is connected is calculated as follows:

$$\hat{I}_S \simeq I_N \cdot \sqrt{2S/Q}$$

$$f_S \simeq f_N \cdot \sqrt{S/Q}$$

$\hat{I}_s$: peak inrush current when capacitor is connected
I_n: capacitor nominal current
S: short-circuit power
Q: capacitor reactive power
f_s: inrush current frequency
f_n: rated frequency

Example:

In a 1000 kVA installation at 400 V with an estimated short-circuit current of 25 kA (in other words with short-circuit power of approximately 17 MVA), compensated by a 250 kVAr capacitor bank, we get:

$$\frac{\hat{I}_S}{I_N} \simeq \sqrt{\frac{2x17x10^6}{250x10^3}} = 11.6$$

$$f_S \simeq 50x\sqrt{\frac{2x17x10^6}{250x10^3}} = 412\text{ Hz}$$

It is clear that the inrush current is very high, almost 12 times the nominal capacitor current, and at a high frequency above 400 Hz. With a nominal current of 72 A corresponding to a 50 kVAr capacitor, we get an inrush current of 835 A. It is therefore necessary to protect against it.

In practice the actual current is limited by the resistance of the cables (amongst other things), and can therefore be less than the theoretical maximum value. However this calculation is only valid with a single capacitor, if other capacitors are present in parallel these values may be higher.

2 - Capacitors in parallel

If several capacitors are connected in parallel, the inrush current is increased by discharging all the capacitors already supplied with power into the newly-connected capacitor. It is calculated as follows:

$$\hat{I}_S = I_N\sqrt{2} \cdot \frac{U}{\sqrt{Q\omega L}} \cdot \frac{n}{n+1}$$

U: voltage between phase and earth
C: capacitance per phase corresponding to X_c
L: inductance per phase corresponding to X_L
n: number of capacitors in parallel, with the same capacitance

Example:

With a capacitor bank with 10 steps of 25 kVAr mounted in parallel at 400 V, wired with conductors whose loops between two steps give an inductance of 1 µH, we can calculate:

$$\frac{\hat{I}_S}{I_N} \simeq \sqrt{2}\,x\,\frac{400}{\sqrt{25 \cdot 10^3 x 314 x 1 \cdot 10^{-6}}}\,x\,\frac{9}{10} = 181.7$$

With a 25 kVAr capacitor with nominal current of 36 A, we get a theoretical maximum inrush current of 6541 A peak! The actual current is very likely to be less than this value, but obviously it is necessary to minimise these inrush currents in order to protect the contactors, capacitors and other components of the capacitor bank enclosure.

B • Solutions

There are several practical measures that protect the system against these major disturbances: damping resistors, reactors and solid state contactors.

1 - Capacitor switching units (damping resistors) are resistive auxiliary contacts, mounted in parallel on the electromechanical contactors for connecting the capacitors These contacts close for a few milliseconds before the main contactor contacts and thus dissipate some of the inrush current, to prevent this current flowing fully through the main contacts, with the risk of damaging them.

Operation sequence

Capacitor unit: OFF
Contactor: OFF

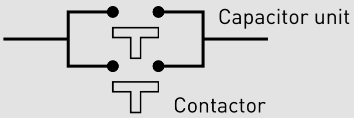


Fig.1

Capacitor unit: ON
Contactor: OFF

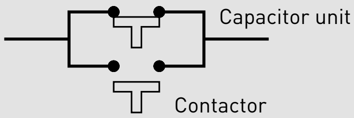


Fig.2

Capacitor unit: OFF
Contactor: ON

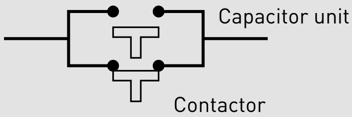


Fig.3

Note - Closing sequence: Fig. 1 => Fig.2 => Fig.3
Opening sequence: Fig.3 => Fig.1

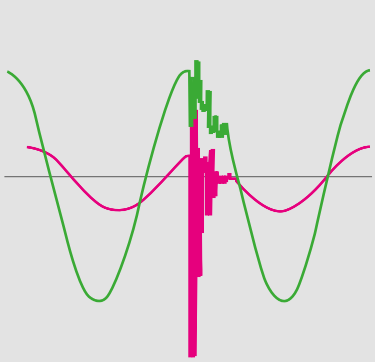
2 - Reactors are usually installed to protect the capacitors against harmonic resonances. In this example the coils are mounted in series with the capacitors, which limits the inrush current, by increasing the inductance L of the conductor loops (see the equation page 38).

Protection and control (continued)

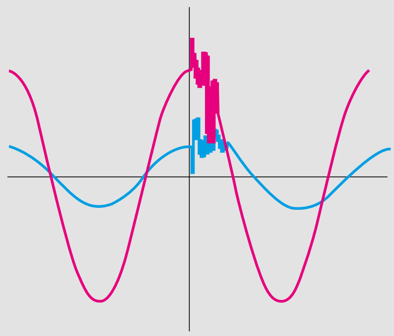
3 - Static contactors (thyristor modules)

. Finally, solid state contactors are based on the power electronics (thyristors) and can switch very quickly (a few milliseconds). In this way it is possible to switch them at the time the voltage passes through zero, and thus almost cancel out the inrush currents (as we then have U = 0 V).

Conventional switching using electromechanical contactors

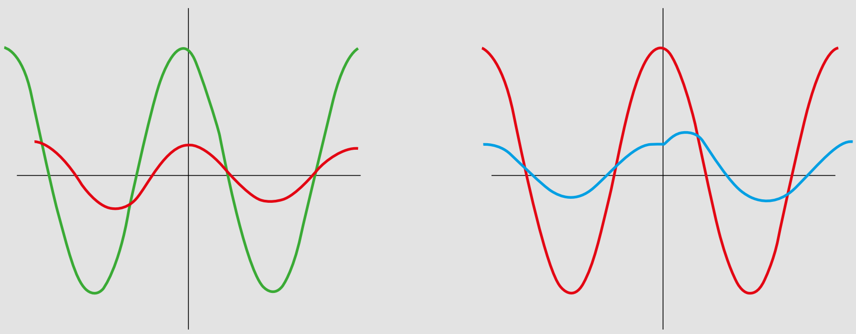


Coupling a step



Uncoupling a step

Soft switching using Alpistatic static contactors



- Soft switching using Alpistatic static contactors does not cause disturbance on the mains supply.
- Its reaction speed (40 milliseconds) provides instant control of the reactive power.

C • The CTX³ offer

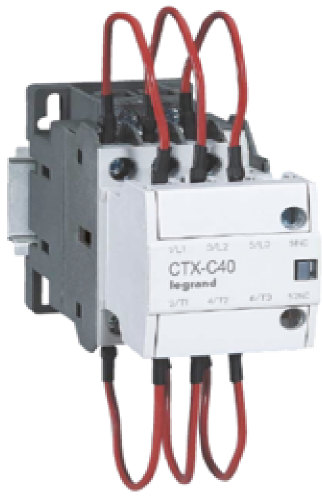
Thanks to a wide range of accessories, CTX³ contactors can be used in a variety of applications:

- switching capacitor banks
- supply inverter
- forward/reverse switch
- time-delayed starter
- switch mechanism on machine, etc

Auxiliary contact blocks for switching the capacitors are installed directly on 3-pole CTX³ contactors, from 9 to 100 A. Thanks to their discharge resistors, they reduce current peaks during capacitor bank switching.

Characteristics of the discharge resistor module:

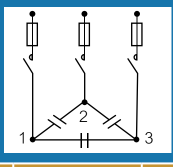
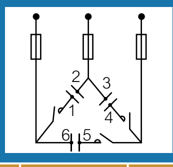
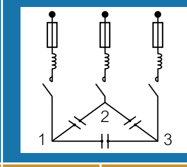
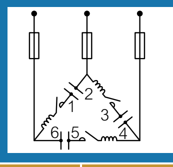
- Discharge resistors can limit the inrush current to 60 x In by closing before the main contactor contacts
- No heat loss via the series resistor
- Eliminate switching voltage surges
- Improve the capacitor system performance



	With Capacitor Switching Units CTX-C									
Frame 3P	Capacitor switching units CTX-C Screw Cage terminals	Ith	kVAr	A	kVAr	A	kVAr	A	kVAr	A
			220-240V		400-440V		500-550V		600-690V	
CTX³ 9A	4 168 74 / NA	21,6	5	13	9,7	14	14	16	16	15,4
CTX³ 12A	4 168 74 / NA	28,4	6,7	18	12,5	18	18	21	18	17,3
CTX³ 18A	4 168 74 / NA	37,8	8,5	22	16,7	24	24	28	26	25,0
CTX³ 22A	4 168 74 / NA	40,5	10	26	18	26	26	30	30	28,9
CTX³ 32A	4 168 74 / NA	56,1	15	39	25	36	36	42	40	38,5
CTX³ 40A	4 168 74 / NA	74,8	20	39	33,3	48	48	55	53	51,0
CTX³ 50A	4 168 75 / 4 168 76	90,4	20	52	40	58	58	67	65	62,5
CTX³ 65A	4 168 75 / 4 168 76	102,9	25	66	45,7	66	66	76	73	70,2
CTX³ 75A	4 168 77 / 4 168 76	121,6	29,7	78	54	78	78	90	85	81,8
CTX³ 85A	4 168 77 / 4 168 76	143,4	35	92	60	87	92	106	100	96,2
CTX³ 100A	4 168 77 / 4 168 76	146,5	37	97	62	89	94	109	105	101,0

Protection and control (continued)

Selection Table for CTX^3 contactors for capacitor banks 400 V - 50 Hz

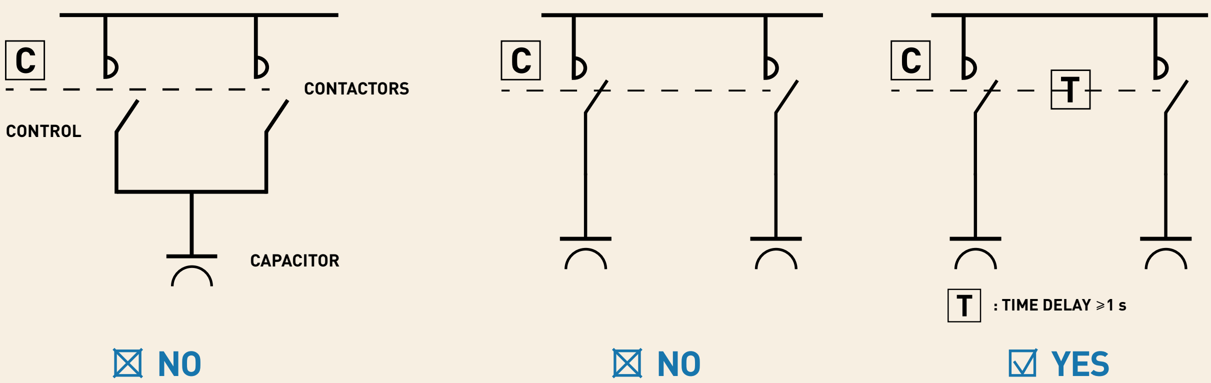
Step Power at 400 V up to	Terminals	Steps without detuned reactors						Steps with detuned reactors			
		Three-phase capacitors Alpivar^3 & Alpican 			3 Single-phase capacitors Alpivar^3 (wiring inside Δ) 			Three-phase capacitors Alpivar^3 & Alpican 		3 Single-phase capacitors Alpivar^3 (wiring inside Δ) 	
		Contactors	+ capacitor switching units CTX-C	Max. operating current AC 3	Contactors	+ capacitor switching units CTX-C	Max. operating current AC 3	Contactors	Max. operating current AC 3	Contactors	Max. operating current AC 3
7,5 Kvar	Screw terminals	4 160 8x	4 168 74	9A	4 160 8x	4 168 74	9A	4 160 9x	12A	4 160 8x	9A
12,5 Kvar	Screw terminals	4 160 9x	4 168 74	12A	4 160 8x	4 168 74	9A	4 161 0x	18A	4 160 9x	12A
20 Kvar	Screw terminals	4 161 2x	4 168 74	32A	4 161 1x	4 168 74	22A	4 161 2x	32A	4 161 1x	22A
25 Kvar	Screw terminals	4 161 2x	4 168 74	32A	4 161 2x	4 168 74	32A	4 161 3x	40A	4 161 2x	32A
30 Kvar	Screw terminals	4 161 3x	4 168 74	40A	4 161 2x	4 168 74	32A	4 161 4x	50A	4 161 2x	32A
40 Kvar	Screw terminals	4 161 4x	4 168 75	50A	4 161 3x	4 168 74	40A	4 161 6x	65A	4 161 4x	50A
	Cage terminals	4 161 5x	4 168 76	50A	4 161 5x	4 168 76	50A	4 161 7x	65A	4 161 5x	50A
50 Kvar	Screw terminals	4 161 8x	4 168 77	75A	4 161 4x	4 168 75	50A	4 161 8x	75A	4 161 4x	50A
	Cage terminals	4 161 9x	4 168 76	75A	4 161 5x	4 168 76	50A	4 161 9x	75A	4 161 5x	50A
60 Kvar	Screw terminals	4 162 2x	4 168 77	100A	4 161 8x	4 168 77	75A	4 162 2x	100A	4 161 8x	75A
	Cage terminals	4 162 3x	4 168 76	100A	4 161 9x	4 168 76	75A	4 162 3x	100A	4 161 9x	75A
75 Kvar	Screw terminals	NA		NA	4 161 8x	4 168 77	75A	4 162 4y	130A	4 162 2x	100A
	Cage terminals	NA		NA	4 161 9x	4 168 76	75A	4 162 5y	130A	4 162 3x	100A
80 Kvar	Screw terminals	NA		NA	4 162 2x	4 168 77	100A	4 162 6y	150A	4 162 4y	130A
	Cage terminals	NA		NA	4 162 3x	4 168 76	100A	4 162 7y	150A	4 162 5y	130A

Control Voltage	x	Control Voltage	y
24V AC	0	24V AC	0
24V DC	1	24V DC	1
48V AC	2	48V AC	2
48V DC	3	48V DC	3
110V AC	4	100-240V AC / 100-220V AC	6
230V AC	6		
380V AC	8	400-440V AC	9
415V AC	9		

STEP DESIGN FOR BIG POWER

Do not supply power to a single capacitor with two contactors in parallel because there is a risk of the whole inrush current flowing through a single contactor, which would damage it beyond repair.
The solution to be used if there is a need to build steps with power > maximum is to connect two steps with a lower power rating in parallel (half the required total power). Certain limitations must then be respected:

- Phase shift the contactor connection using a time delay (1 second for example) in order to minimise the inrush currents and the bounce phenomenon between the two capacitors.
- Use just one contactor per capacitor.
- Use just one protection device for both capacitors.



Protection and control (continued)

SIZING PROTECTION DEVICES AND CONDUCTORS

The capacitor and bank protection device must be able to withstand the overload stated in the relevant standards (30 %) and the capacitance manufacturing tolerance (max. 10 %). The overload protection device should therefore be approximately times the capacitor or bank nominal current. For practical reasons the value can be used as a reference.

The conductors should also be sized according to the capacitance of their protection devices. Conductors with current carrying capacity at 90°C higher than 1.5 In should therefore be used.

The tightening torques to be complied with are as follows:

- Capacitor terminals: 12 N.m
- CTX³ contactor terminals: 4 or 5 N.m depending on the power rating
- DPX³ 160 circuit breaker terminals:
  - Powered by conductors: 8 N.m
  - Powered by busbars: 7 N.m
- DPX³ 250 circuit breaker terminals: 10 N.m

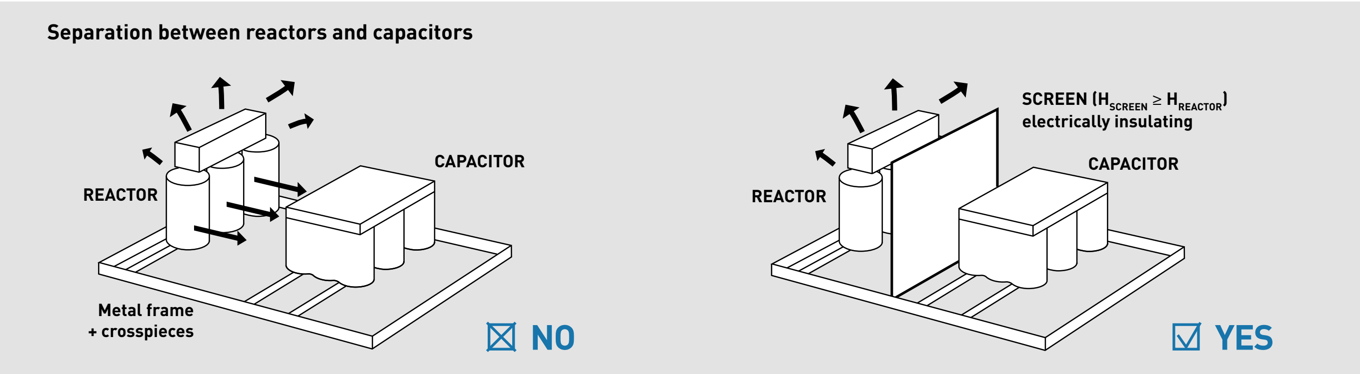
Table: sizing circuit breakers and conductors for capacitors and banks up to 1000 kVAr

Power rating 400 V (kVAr)	Nominal current (A)	Current to be protected (A)	Supply end protection	Rating (A)	Regulation (A)	Cu cross-section (mm^2)
2.5	4	6	DX^3	6	6	2.5
5	7	11	DX^3	10	10	2.5
6.3	9	14	DPX^3 160	16	12.8	2.5
7.5	11	16	DPX^3 160	16	16	2.5
10	14	21	DPX^3 160	25	20	4
15	22	31	DPX^3 160	40	32	6
20	29	42	DPX^3 160	40	40	10
25	36	52	DPX^3 160	63	50	16
30	43	62	DPX^3 160	63	63	16
35	51	73	DPX^3 160	80	80	25
40	58	83	DPX^3 160	80	80	25
47.5	69	99	DPX^3 160	100	100	35
50	72	104	DPX^3 160	100	100	35
60	87	124	DPX^3 160	125	125	50
67.5	97	140	DPX^3 160	160	128	50
75	108	155	DPX^3 160	160	160	70
80	115	166	DPX^3 160	160	160	70
90	130	186	DPX^3 250	200	180	95
100	144	207	DPX^3 250	200	200	95
125	180	259	DPX^3 250	250	250	150
150	217	310	DPX^3 630	400	300	185
175	253	362	DPX^3 630	400	350	240
200	289	413	DPX^3 630	400	400	300
225	325	465	DPX^3 630	630	450	400
250	361	517	DPX^3 630	630	500	400
275	397	568	DPX^3 630	630	550	500
300	433	620	DPX^3 630	630	600	630
325	469	671	DPX^3 630	630	630	630
350	505	723	DPX^3 1600	800	700	2x400
375		775	DPX^3 1600	800	750	2x400
400	541	826	DPX^3 1600	800	800	2x400
450	577	929	DPX^3 1600	1000	900	2x500
500	650	1033	DPX^3 1600	1000	1000	2x630
550	722	1136	DPX^3 1600	1250	1100	2x630
600	866	1239	DPX^3 1600	1250	1200	3x500
650	938	1342	DPX^3 1600	1250	1250	3x500
700	1010	1445	DPX^3 1600	1600	1400	3x630
750	1083	1549	DPX^3 1600	1600	1500	4x500
800	1155	1652	DPX^3 1600	1600	1600	4x630
850	1227	1755	DMX^3	2000	1700	4x630
900	1299	1858	DMX^3	2000	1800	4x630
950	1371	1961	DMX^3	2000	1900	5x630
1000	1443	2065	DMX^3	2000	2000	5x630

Mounting recommendation

In order to optimise the enclosure ventilation (see how to select a ventilation system in the next section), it is important to comply with the following instructions:

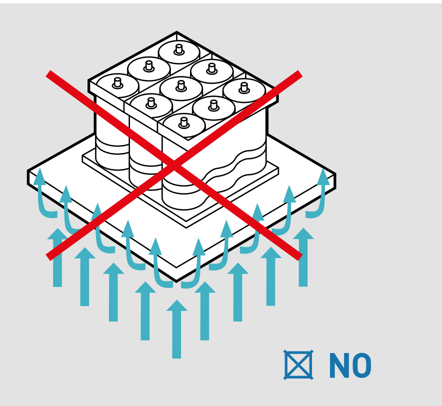
• Allow space around the enclosure so that air is able to enter and exit correctly. The minimum distance to be maintained between the enclosure and the walls of the room is 200 mm, and the same between the top of the enclosure and the ceiling.



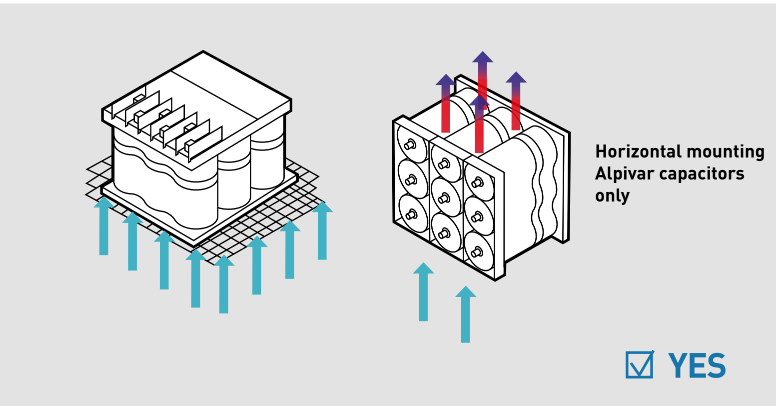
• Separate the reactors from the other components with a physical barrier to limit component overheating due to radiation, as the reactors can reach temperatures of more than 100°C.

The components must be positioned in a certain way to ensure correct operation:

The Alpivar capacitors[3] must be in a vertical or horizontal position. If they are vertical, pressure monitoring devices must be placed underneath for protection. If they are horizontal, this must be achieved by positioning the modules of which they consist vertically.



Solid plate

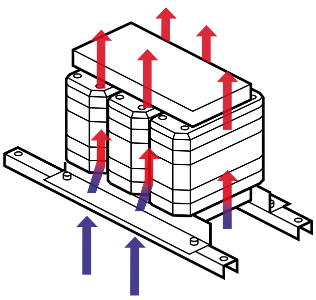


Tray or crosspiece

Alpican capacitors must always be positioned vertically.

The contactors must be positioned vertically or horizontally, but never lying down or the wrong way round, to prevent bounce phenomena.

The reactors must always be positioned vertically:

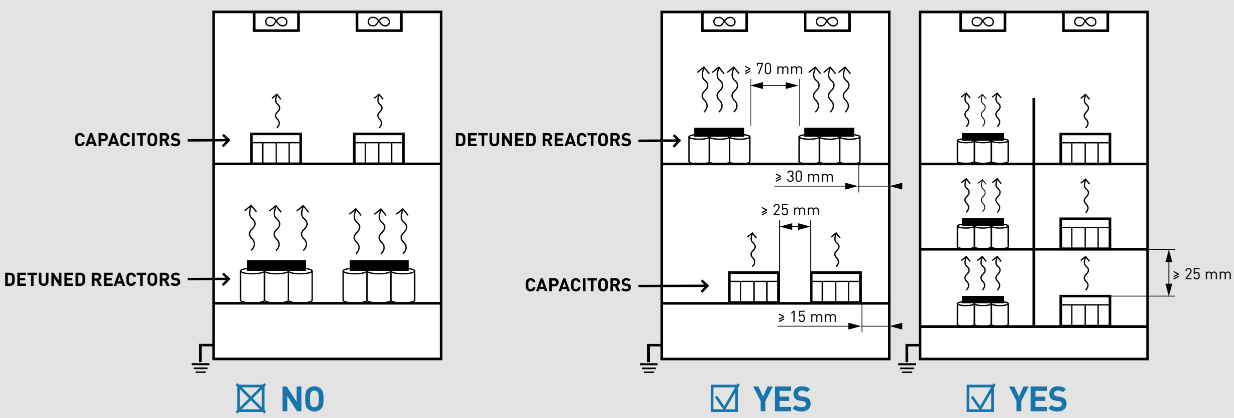


Ideally the fans should be positioned above the capacitors and above the reactors to maximise the air flow over them.

Certain distances must also be maintained between the components:

- 25 mm between the capacitors and above them
- 15 mm between each capacitor and any metal structure
- 30 mm between the reactor coils and the cabinet structure
- 70 mm between two reactors.

Position of the reactors and capacitors



Thermal study of the assembly

Capacitor banks are assemblies consisting of products with significant heat dissipation, mostly capacitors and detuned reactors. It is therefore important to size the enclosure ventilation correctly in order to prevent overheating, which can seriously damage devices in the enclosure.

The following rules are applicable for standard operating conditions. The calculation formulas used are theoretical.

STANDARD OPERATING CONDITIONS

- Maximum temperature in the room: 40°C.
- Maximum average temperature over 24 hrs in the room: 35°C.
- Minimum temperature in the room: -5°C.
- Maximum altitude: 2000 m.a.s.l.
- Max. humidity 80 %
- No dust or corrosive products

! A minimum space of 200 mm must be allowed around the ventilation louvres (wall, ceiling, other elements).

VENTILATION RULES

The enclosure must be supplied with an air intake at the bottom and air extraction (natural or forced) at the top.

A roof elevation of 15 mm is strongly recommended in the case of natural ventilation.

The air intakes and outlets must never be blocked, neither inside the enclosure nor outside during installation.

POWER ANALYSIS

Firstly we need to determine the power dissipated in the product thermal losses inside the enclosure. There are two methods of doing this:

1- If using racks, their global losses are estimated:

- Racks without reactor (capacitor + contactor + cables + fuses + busbars): 2 W/kVAr.
- Racks with reactor (capacitor + reactor + contactor + cables + fuses + busbars): 8 W/kVAr.
- For example, for a rack Cat. No. PH7540 the estimated dissipated power will be: 75 [kVAr] x 2 [W/kVAr] = 150 W

2 - If using individual products, add up the maximum load losses, as declared by the manufacturer. For Legrand products, this information is supplied in the product technical data sheets.

For example, the losses for Alpivar[3] capacitors represent 0.3 W/kVAr maximum. A 50 kVAr capacitor will therefore dissipate 50 x 0.3 = 15 W.

We are trying to calculate the average temperature rise ΔT in the enclosure compared to the temperature in the room. To do this we will use the following data:

- P (in W): power dissipated by the products inside the enclosure, this is the sum of the power dissipated by all the devices.
- S_e (in m²): enclosure equivalent dissipation surface area. For this, take the sum of the surface areas on each side of the enclosure, applying a coefficient as a function of the surface area being considered.

CALCULATING THE EQUIVALENT DISSIPATION SURFACE AREA

Coefficients to be applied to the actual surfaces for calculating the equivalent dissipation surface area S_e as a function of the enclosure IP rating		
Surface	**IP ⩽ 30**	**IP > 30**
S1: free top horizontal surface	1	1
S2: insulated top horizontal surface	0.7	0.5
S3: free rear vertical surface	0.9	0.8
S4: insulated rear vertical surface	0.4	0.3
S5: free side surface	0.9	0.8
S6: insulated side surface	0.4	0.3
S7: free horizontal bottom surface	0.6	0.6
S8: insulated horizontal bottom surface	0.3	0.2
S9: front surface with faceplates or door	0.9	0.8
S10: front surface with faceplates and door	0.6	0.6

For example, for a 1900 x 800 x 500 mm enclosure without faceplates, with door, floor mounted, free on the sides and on top, and with an IP ⩽ 30:

$$S_e = \underbrace{0.8 \times 0.5}_{S1} \times 1 + \underbrace{1.9 \times 0.8}_{S3} \times 0.9 + 2 \times \underbrace{1.9 \times 0.5}_{S5} \times 0.9 + \underbrace{0.8 \times 0.5}_{S8} \times 0.3 + \underbrace{1.9 \times 0.8}_{S9} \times 0.9 = 4966\ m^2$$

Here is a table summarising the equivalent surface areas for the most common Legrand enclosures in the same conditions as the previous calculation:

Model	Height (mm)	Width (mm)	Depth (mm)	Equivalent dissipation surface area (m^2)
Altis	2100	600	500	4.58
Altis	2100	600	600	5.04
Altis	2100	800	500	5.47
Altis	2100	800	600	5.96
XL^3 4000	2135	725	475	5.09
XL^3 4000	2135	725	725	6.31
XL^3 4000	2135	725	975	7.52
XL^3 4000	2135	975	475	6.22
XL^3 4000	2135	975	725	7.52
XL^3 4000	2135	975	975	8.82

Thermal study of the assembly (continued)

CALCULATING THE T° RISE

The formula for calculating the average temperature rise (expressed in Kelvin) inside the enclosure, without ventilation, is as follows:

$$\Delta T = 5.5 \times \frac{P}{S_e}$$

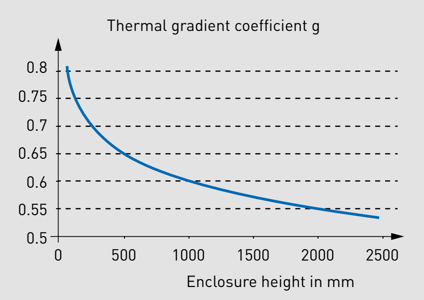
In order to obtain the average temperature inside the enclosure in °C, simply add this value to the ambient temperature outside the enclosure:

$$\Delta T_{av} = T_{amb} + \Delta T$$

To calculate the maximum enclosure temperature, usually in the top of it, a coefficient g can be applied to the average temperature rise.

This then gives:

$$\Delta T_{max} = \frac{\Delta T_{av}}{g}$$



For example, take the 1900 x 800 x 500 mm enclosure for which we previously calculated the equivalent dissipation surface area. We want to dissipate 400 W of power in this enclosure.

The average temperature rise is $\Delta T_{av} = 400/(5.5 \times 4.966) \simeq 14.6$ K and the ambient temperature around the enclosure is $T_{amb} = 30°$, so the average temperature inside the enclosure will be $T_{av} = 30 + 26.3 = 56.3°C$, at the top of the enclosure.

We can therefore see that temperatures can be very high, even with only a few Watts to be dissipated, if enclosures are not ventilated. We will see below some potential solutions to this problem.

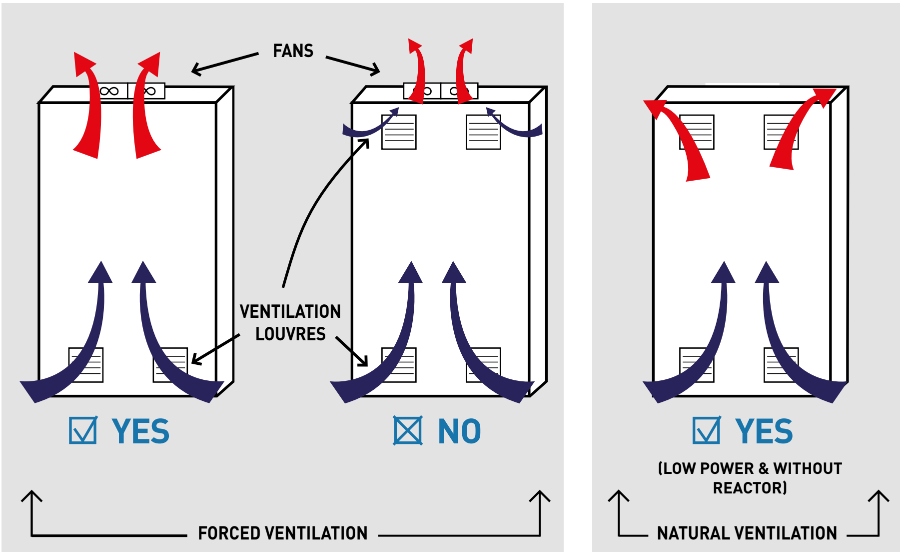
DISSIPATION SOLUTION

The simplest way of reducing the temperature inside the enclosure is to add ventilation. This creates an air flow which evacuates the heat to the outside. "Cold" air is introduced at the bottom, this air absorbs the heat dissipated by the components and the "hot" air exits via the top of the enclosure, evacuating a certain amount of power in the form of heat.

The maximum air flow rate D (in m³/h) needed to cool the capacitor bank sufficiently is calculated as follows:

$$D = 3.1 \times \left(\frac{P}{45 - T_{amb}} - 5.5 \cdot S_e\right)$$

P : power dissipated by the components
S_e : equivalent dissipation surface area of the enclosure
T_{amb} : maximum ambient temperature in the room



VENTILATION SOLUTIONS FOR CAPACITOR BANKS WITHOUT REACTORS (AMBIENT T° 30°C)

Capacitor bank power (kVAr)	Dissipated power (W) Estimated at 2 W/kVAr	Maximum flow rate required (m³/h)	Ventilation solutions[b] (example of product)
100	200	7	Sufficient natural ventilation
150	300	28	Sufficient natural ventilation
200	400	49	Sufficient natural ventilation
300	600	90	1 fan 120 m³/h (034851)
400	800	131	1 fan 240 m³/h (034852)
450	900	151	1 fan 240 m³/h (034852)

VENTILATION SOLUTIONS FOR CAPACITOR BANKS WITH REACTORS (AMBIENT T° 30°C)

Capacitor bank power (kVAr)	Dissipated power (W) Estimated at 8 W/kVAr	Maximum flow rate required (m³/h)	Ventilation solutions[b] (example of product)
100	800	80	1 fan 120 m³/h (034851)
200	1600	245	1 fan 240 m³/h (034852)
300	2400	411	1 fan 400 m³/h (034853)
400	3200	576	1 fan 600 m³/h (034807)
500	4000	741	1 fan 1000 m³/h (034808)
600	4800	907	1 fan 1000 m³/h (034808)

[a] Please note that it is impossible to reach a temperature higher than the ambient temperature using this method. If the ambient temperature is too high, a cooling system should be used such as an air conditioning unit, for example.

[b] The proposed solutions are not exhaustive. Specific operating conditions for each installation also need to be taken into account, as well as the size of the enclosures used. The precise calculation taking into account the enclosure equivalent dissipation surface area can optimise the ventilation required.

Fan operation can be made dependent on reaching an average temperature of 35°C, by means of a thermostat or a controller.

Ventilation louvres should be provided at the bottom of the enclosure, on all 4 sides, over a minimum surface area of 1000 cm² per enclosure column.

TESTS TO BE CONDUCTED

Tests and checks must be conducted in conformity with standards IEC 61921 and IEC 61439-2.

For more details of these checks, refer to the corresponding articles in the standards mentioned.

Design check: to be conducted on the product design, with tests on a typical sample if necessary.

A) CONSTRUCTION

- Strength of materials and parts
- Degree of protection provided by enclosures
- Clearances and creepage distances
- Electric shock protection and integrity of protection circuits
- Integration of connection devices and components
- Internal electrical circuits and connections
- Terminals for external conductors

B) PERFORMANCE

- Dielectric properties
- Temperature rise check
- Short-circuit withstand
- Electromagnetic compatibility
- Mechanical operation

When using XL^3 enclosures and Legrand products, compliance with IEC 61439-2 can be confirmed with certificates corresponding to the factory tests on reference configurations.

These certificates can be provided on request by Legrand.

Characteristics to be checked	Original manufacturer (Legrand)
Strength of materials and parts	LOVAG 10.2 certificate
Degree of protection (IP)	LOVAG 10.3 certificate
Clearance	LOVAG 10.4 certificate
Creepage distance	LOVAG 10.4 certificate
Electric shock protection and integrity of protection circuits	LOVAG 10.5 certificate
Integration of connection devices and components	Checked on tested configurations Legrand 10.6
Internal electrical circuits and connections	Checked on tested configurations Legrand 10.7
Terminals for external conductors	Checked on tested configurations Legrand 10.8
Dielectric properties	LOVAG 10.9 certiwficate (time 5 s)
Temperature rise	LOVAG 10.10 certificate
Short-circuit withstand	LOVAG 10.11 certificate
Electromagnetic compatibility	LOVAG 10.12 certificate
Mechanical operation	LOVAG 10.13 certificate

Individual checks: to be performed systematically on each enclosure

A) CONSTRUCTION

- Degree of protection provided by enclosures > examples: integrity of the enclosure, louvres, fans
- Clearances and creepage distances > measurement of distances between live conductors, and between them and the exposed conductive parts
- Electric shock protection and integrity of protection circuits > measurement of continuity of the exposed conductive parts
- Integration of built-in components > check compliance with the manufacturer's mounting instructions
- Internal electrical circuits and connections > examples: cable and busbar cross-sections, tightening
- Terminals for external conductors > installation, permissible control terminal cross-sections (examples: CTs, status feedback)
- Mechanical operation > examples: doors, faceplates

B) PERFORMANCE

- Dielectric properties > capacitors disconnected, application of a high voltage at 50 Hz (usually 1890 V AC)
- Wiring, electrical operation and function:
  - Conformity with specifications
  - Measurement of individual capacitor capacitance (to be carried over to the final test report)
  - Controller operation (if present)
  - Overall capacitor bank operation (example: contactor control, smoke detector, ventilation)

The individual checks should be recorded in a test report with the results of the corresponding measurements.

XL³ workshop specifications include the mounting instructions and provide additional information on selecting and installing equipment, accessories and distribution systems.

MAINTENANCE PROCEDURE

During use, your automatic capacitor bank will be exposed to different factors such as harmonics, high temperatures, voltage surges, an installation upgrade, environmental pollution (dust, vapours), and wear and tear (contactor, capacitor).

These factors risk causing faults which may reduce the service life of the automatic capacitor banks.

Monitoring the state of the equipment in its operating environment will help prevent breakdowns or damage.

By carrying out the various maintenance operations at the recommended intervals, you will ensure that the capacitor bank operates in optimum conditions and will maximise its service life.

PRELIMINARY ACTION

Before undertaking maintenance operations, make sure you have checked that your installation has not changed since the initial size of the capacitor bank was determined:

Check if any of the non-linear loads (eg: motor) and devices generating harmonics (eg: variable speed drive, LED lighting) have changed.

Measure the ambient temperature and the voltage and harmonic fluctuations on the electricity supply with operational loads over a significant time period.

! If any change is recorded in either of the above points, it may be necessary to resize the capacitor bank.

GENERAL

Automatic capacitor banks must be installed in accordance with the installation instructions. Incorrect installation and use may lead to the risk of electric shock or fire. Read the manual and consider exactly where the product is to be fitted before carrying out installation. Any unauthorised modification or repair voids all liability, replacement rights and warranties. Only use Legrand Group accessories.

• Installation, use and maintenance of an automatic capacitor bank must only be undertaken by qualified staff who have undergone appropriate safety training, in accordance with the regulations in force specific to each country.

• Capacitor banks must be used in normal conditions, in other words they must not be subjected to any other Voltage/Current/Frequency/Harmonic distortion/Temperature values than those specified in the corresponding documentation.

If they have suffered any external knocks or blows, do not connect or use the capacitors or capacitor banks.

• Comply with the Legrand Group's recommendations as well as the maintenance instructions in order to maximise capacitor bank performance and service life.

MAINTENANCE SCHEDULE

Operations	Frequency	Power on	Power off
1/4 - Electrical connection check			
Check the tightening torque of the power cables	2 months after commissioning/Annually		X
Check the tightening torque of the electrical components Tightening torques as per manufacturer data			X
2/4 - Visual inspection and cleaning			
External cleanliness, atmosphere, environment	Annual		X
Enclosure internal cleanliness	Annual		X
Cleanliness of smoke detectors	Annual		X
Enclosure integrity	Annual		X
Integrity and cleanliness of fans/ extractors/air conditioning units	Annual		X
Integrity and cleanliness of intake and outlet ventilation louvres	Annual		X
Integrity and cleanliness of air intake and outlet filters Versions with filters	Annual		X
Integrity of detuned reactors	Annual		X
Integrity of switching and protection devices	Annual		X
Integrity of earthing kits	Annual		X
Protection devices (circuit breakers) not tripped	Annual		X

MAINTENANCE SCHEDULE (CONTINUED)

Operations	Frequency	Power on	Power off
3/4 - Functional check and measurements			
Temperature sensor check (version with detuned reactors)	Annual	X	
Controller check and parameter reading	Annual	X	
Automation device check (cos φ setpoints)	Annual	X	
Alarm message reading and analysis Alarm acknowledgement	Annual	X	
Temperature readings (eg: thermal camera)	Annual	X	
Step activation test	Annual	X	
Smoke detector test With Spray test	Annual	X	
Capacitance measurements for each step* If not possible: assessment by current/ voltage measurement for each phase	Annual		X
Current measurements for each step	Annual	X	
Voltage measurements and harmonic levels	Annual	X	
Protection devices (circuit breakers) not tripped	Annual	X	
4/4 - Replacement of wear parts and components (according to installation status and operating conditions)			
Air intake and outlet filters	Every 2 years		X
Fans	Every 5 years		X
Contactors	Every 5 years		X
Smoke detectors	Every 5 years		X
Capacitors	Alpican: Every 7 years Alpivar: Every 10 years		X
Reactors	Every 15 years		X

* The capacitance measurements must be compared to the previous measurements (after commissioning). If the capacitance is < 5 % the previous measurement, or if there is an imbalance in the capacitance, the capacitors should be replaced.

We strongly recommend that you keep a service log for each capacitor bank with a record of the checks and maintenance operations performed.

PRELIMINARY ACTION

In the event of a problem when using or commissioning the capacitor bank, refer to the table below.
If the problem persists or is not resolved with the table below, please contact Legrand Energy Solutions.

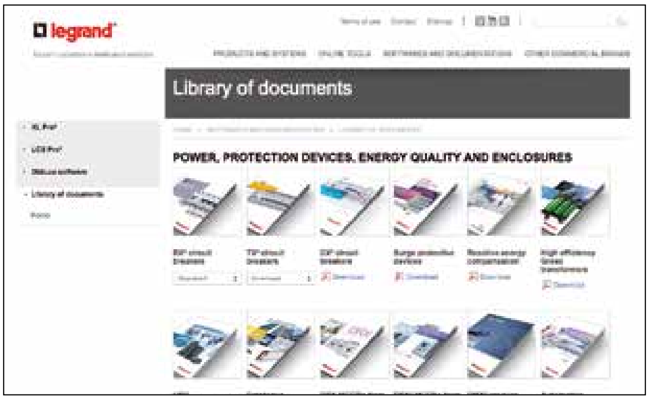
Failure	Possible cause	Actions
Under-compensation	The CT is in the wrong position or is incorrectly configured	Check the CT position (see manual) and the controller configuration
	Incorrect setting of setpoint cos φ	Check the setpoint value configured in the controller
	If setting OK, the capacitor bank is too small, or has insufficient power	Check the required compensation value by selecting the menu "Δ kvar"
Overcompensation	The CT is in the wrong position or is incorrectly configured	Check the CT position (see manual) and the controller configuration
	Incorrect setting of setpoint cos φ	Check the setting value configured in the controller
	If setting OK, the installation's inductive load is too low	Check the cos φ without compensation (steps disconnected)
Enclosure overheating	Poor ventilation	- Check the ventilation conditions (see "Maintenance Schedule" table) - Check the temperature sensor (reactor version)
Smoke detector alarms (X1/X2 status feedback)	Smoke detection	Switch off the capacitor bank upstream power supply before carrying out work
	Loss of smoke detector circuit power supply	Check the control and switching circuit power supply
Controller alarms	A12: maintenance required (see alarm acknowledgement section) Other alarms: see manual	
Loss of controller display	Loss of power supply	Check the control and switching circuit power supply
	Controller not working	Change the controller
Noise coming from the reactors	Reactors out of sync	Check the capacitor bank values: if there is no capacitance, disconnect the step concerned immediately by switching off its protection device (fuse or circuit breaker depending on the model). Replace the capacitors before powering the step up again
	Saturated reactors	Check your installation's harmonic distortion (see the maximum threshold for your model in the manual or catalogue)

ALPES TECHNOLOGIES

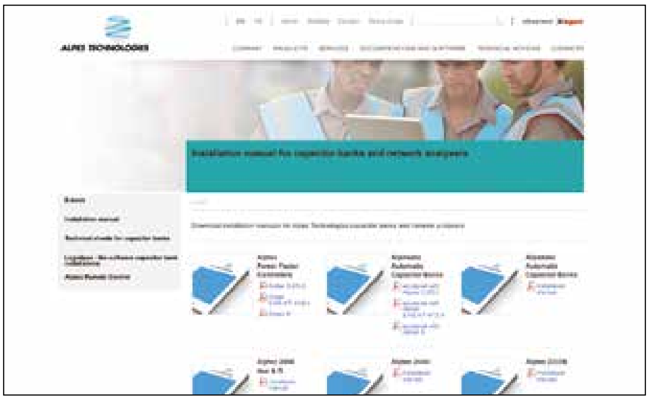
LIBRARY OF DOCUMENTS

All technical data of the products inside this workshop specifications book are available on :
www.export.legrand.com/EN and www.alpes-technologies.com

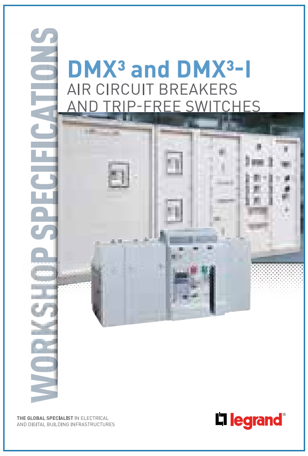
www.export.legrand.com/EN
Click on: DOWNLOAD DOCUMENTS

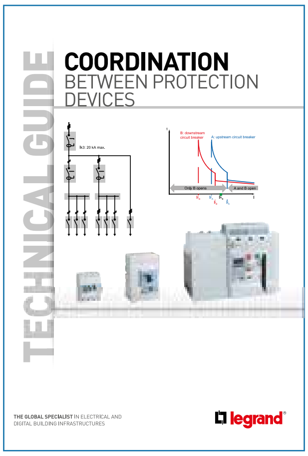


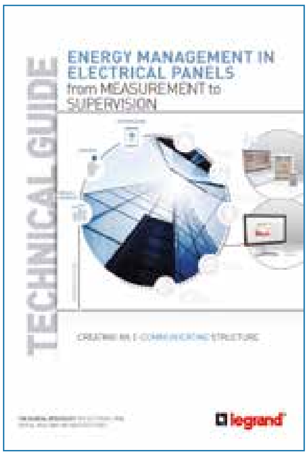
www.alpes-technologies.com
Click on: DOCUMENTATION AND SOFTWARE



Workshop specifications and technical guides







FOLLOW US ON

www.legrand.com
youtube.com/user/legrand
twitter.com/legrand_news
pinterest.com/legrandgroup

legrand

Head office
and International Department
87045 Limoges Cedex - France
Tel: + 33 (0) 5 55 06 87 87
Fax: + 33 (0) 5 55 06 74 55

EXB17031 - October 2017