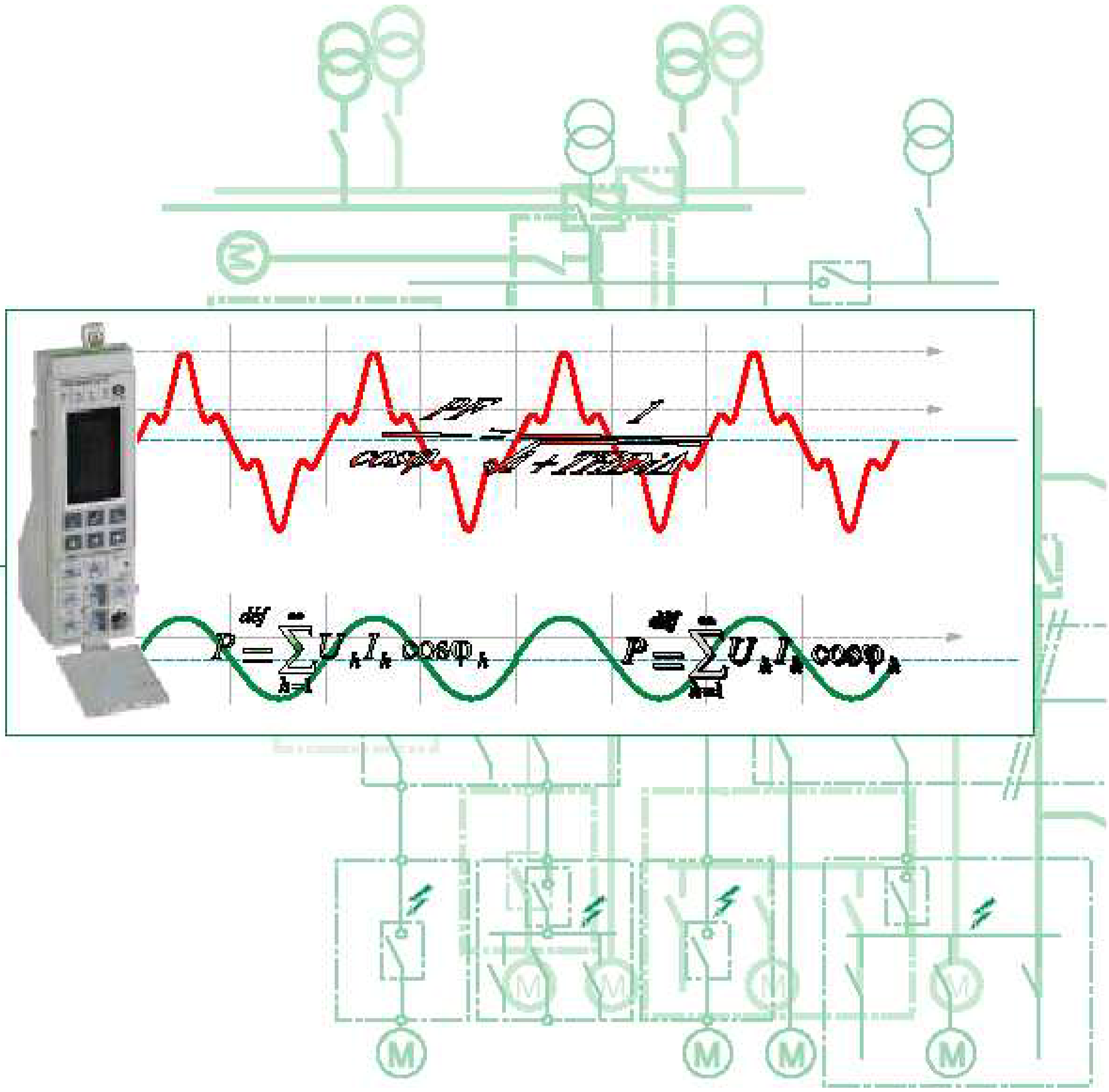
N° 4

Low-voltage expert guides

Harmonic *detection* and filt*ering*



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General

1.1 Definition of harmonics and their origin

In short

Harmonics distort current and/or voltage waves, disturbing the electrical distribution system and degrading power quality.

1.1.1 Distortion of a sinusoidal signal

The Fourier theorem states that all non-sinusoidal periodic functions can be represented as the sum of terms (i.e. a series) made up of:
- a sinusoidal term at the fundamental frequency,
- sinusoidal terms (harmonics) whose frequencies are whole multiples of the fundamental frequency,
- a DC component, where applicable.

The ***nth order harmonic*** (commonly referred to as simply the nth harmonic) in a signal is the sinusoidal component with a frequency that is n times the fundamental frequency.

The equation for the harmonic expansion of a periodic function is presented below:

$$y(t) = Yo + \sum_{n=1}^{n=\infty} Y_n \sqrt{2} \sin(n\omega t - \varphi_n)$$

where:
- Yo: value of the DC component, generally zero and considered as such hereinafter,
- Yn: rms value of the nth harmonic,
- ω: angular frequency of the fundamental frequency,
- φ_n: displacement of the harmonic component at t = 0.

Example of signals (current and voltage waves) on the French electrical distribution system:
- the value of the fundamental frequency (or first order harmonic) is 50 Hertz (Hz),
- the second (order) harmonic has a frequency of 100 Hz,
- the third harmonic has a frequency of 150 Hz,
- the fourth harmonic has a frequency of 200 Hz,
- etc.

A distorted signal is the sum of a number of superimposed harmonics.

Figure 1 shows an example of a current wave affected by harmonic distortion.

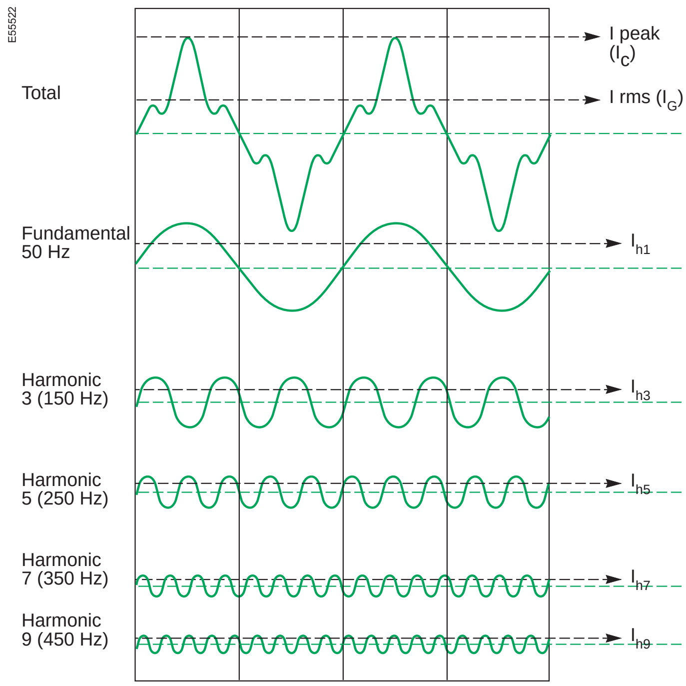

Figure 1 *- example of a current containing harmonics and expansion of the overall current into its harmonic orders 1 (fundamental), 3, 5, 7 and 9*

Representation of harmonics: the frequency spectrum

The frequency spectrum is a practical graphical means of representing the harmonics contained in a periodic signal.

The graph indicates the amplitude of each harmonic order.

This type of representation is also referred to as spectral analysis.

The frequency spectrum indicates which harmonics are present and their relative importance.

Figure 2 shows the frequency spectrum of the signal presented in figure 1.

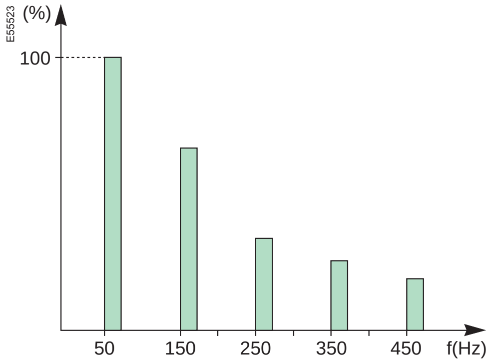

Figure 2 *- spectrum of a signal comprising a 50 Hz fundamental and harmonic orders 3 (150 Hz), 5 (250 Hz), 7 (350 Hz) and 9 (450 Hz)*

1.1.2 Origin of harmonics

Devices causing harmonics are present in all industrial, commercial and residential installations. Harmonics are caused by ***non-linear loads***.

Definition of non-linear loads

A load is said to be **non-linear** when the current it draws does not have the same wave form as the supply voltage.

Examples of non-linear loads

Devices comprising **power electronics** circuits are typical non-linear loads.

Such loads are increasingly frequent and their percentage in overall electrical consumption is growing steadily.

Examples include:
- industrial equipment (welding machines, arc furnaces, induction furnaces, rectifiers),
- variable-speed drives for asynchronous and DC motors,
- office equipment (PCs, photocopy machines, fax machines, etc.),
- household appliances (television sets, microwave ovens, fluorescent lighting, etc.),
- UPSs.

Saturation of equipment (essentially transformers) may also cause non-linear currents.

In short

Harmonic currents are caused by non-linear loads connected to the distribution system. The flow of harmonic currents through system impedances in turn creates voltage harmonics, which distort the supply voltage.

Disturbances caused by non-linear loads, i.e. current and voltage harmonics

The supply of power to non-linear loads causes the flow of harmonic currents in the distribution system.

Voltage harmonics are caused by the flow of harmonic currents through the impedances of the supply circuits (e.g. transformer and distribution system a whole in figure 3).

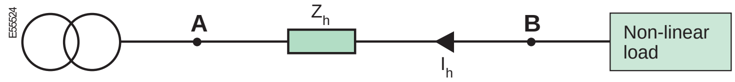

Figure 3 *- single-line diagram showing the impedance of the supply circuit for h-order harmonic*

Note that the impedance of a conductor increases as a function of the frequency of the current flowing through it. For each h-order harmonic current, there is therefore an impedance Z_h in the supply circuit.

The h-order harmonic current creates via impedance Z_h a harmonic voltage U_h, where $U_h = Z_h \times I_h$, i.e. a simple application of Ohm's law. The voltage at B is therefore distorted and all devices supplied downstream of point B will receive a distorted voltage.

Distortion increases in step with the level of the impedances in the distribution system, for a given harmonic current.

Flow of harmonics in distribution systems

To better understand harmonic currents, it may be useful to imagine that the non-linear loads reinject harmonic currents upstream into the distribution system, in the direction of the source.

Figures 4a and 4b show an installation confronted with harmonic disturbances. Figure 4a shows the flow of the fundamental 50 Hz current, whereas in 4b, the h-order harmonic current is presented.

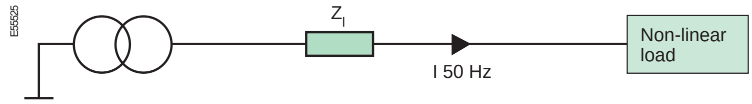

Figure 4a *- diagram of an installation supplying a non-linear load, showing only the fundamental 50 Hz current*

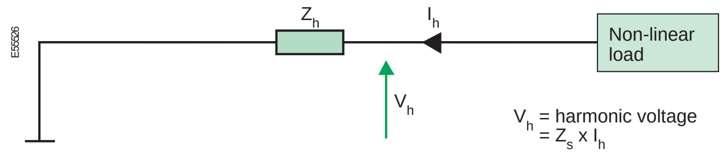

Figure 4b *- diagram of the same installation, showing only the phenomena related to the h-order harmonic*

Supply of this non-linear load causes the flow in the distribution system of current I_{50Hz} (shown in figure 4a) to which is added each of the harmonic currents I_h (shown in figure 4b) corresponding to each harmonic (order h).

General

Using once again the model of non-linear loads reinjecting harmonic currents into the distribution system, it is possible to graphically represent this phenomena (figure 5).

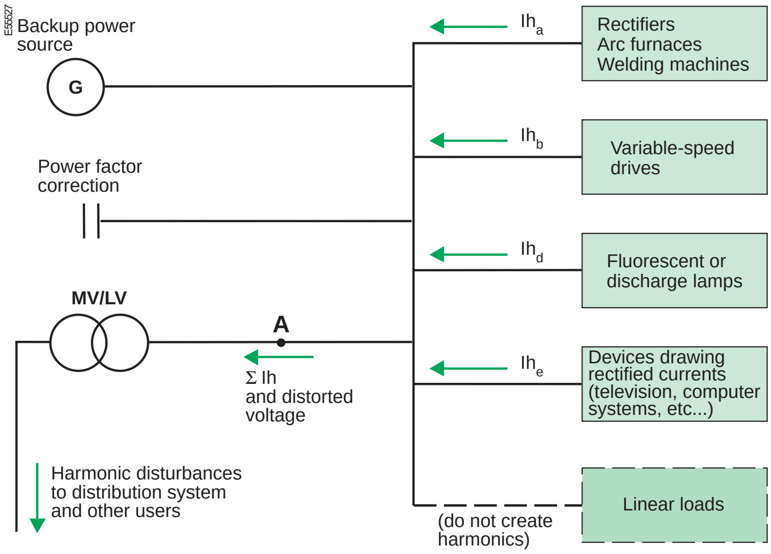

***Figure 5** - flow of harmonic currents in a distribution system*

Note in this figure that certain loads cause harmonic currents in the distribution system and other loads are disturbed by them.

1.2 Why harmonics need to be detected and suppressed?

1.2.1 Disturbances caused by harmonics

In distribution systems, the flow of harmonics reduces power quality and consequently causes a number of problems:
■ overloads on distribution systems due to the increase in the rms current,
■ overloads on neutral conductors due to the summing of third-order harmonics created by single-phase loads,
■ overloads, vibrations and premature ageing of generators, transformers, motors, etc., transformer hum,
■ overloading and premature ageing of capacitors in power factor correction equipment,
■ distortion of the supply voltage, capable of disturbing sensitive loads,
■ disturbances on communications networks and telephone lines.

1.2.2 The economic impact of disturbances

Harmonics have a significant economic impact, in that:
■ premature ageing of equipment means that it must be replaced earlier, unless it was oversized to begin with,
■ overloads on the distribution system mean the level of subscribed power must be increased, with additional losses, unless the installation can be upgraded,
■ distortion of the current provokes nuisance tripping and shutdown of production equipment.

These **extra costs in terms of equipment, energy** and **productivity** all contribute to reducing the competitiveness of companies.

1.2.3 Increasingly serious consequences

As recently as ten years ago, harmonics were not considered a major problem, because their effects on distribution systems were, generally speaking, relatively slight. However, the massive increase in the use of loads employing power electronics has significantly worsened the situation in all fields of activity.

Harmonics are all the more difficult to reduce in that they are often caused by equipment that is vital to the operation of companies.

1.2.4 Practically speaking, which harmonics must be measured and reduced ?

The harmonics most frequently encountered (and consequently the most troublesome) on three-phase distribution systems are the odd-order harmonics (3rd, 5th, 7th, etc.).

Beyond the 50th order, harmonic currents are negligible and measurements are not required.

Sufficient accuracy of measurements is obtained by taking into account harmonics up to the 30th order.

Utilities monitor harmonic orders 3, 5, 7, 11 and 13.

It follows that conditioning of harmonics is imperative up to order 13 and ideally should include harmonics up to order 25.

In short

A number of indicators exist that may be used to quantify and assess the harmonic distortion of current and voltage waves.

These indicators are:
- the power factor,
- the crest factor,
- the distortion power,
- the frequency spectrum,
- harmonic distortion.

These indicators are indispensable in determining any corrective action required.

The essential indicators of harmonic distortion and measurement principles

2.1 Power factor

The power factor will be noted “PF” in this document

2.1.1 Definition

The power factor is the ratio between the active power P and the apparent power S.

$$PF = \frac{P}{S}$$

In electrical jargon, the power factor is often confused with cosine phi (cos φ), which may be defined by the equation:

$$\cos\varphi = \frac{P_1}{S_1}$$

P1 = active power of the fundamental,
S1 = apparent power of the fundamental.

As the above equation makes clear, cos φ applies only to the fundamental frequency. When harmonics are present, its value is different than that of the power factor.

2.1.2 Interpreting the value of the power factor

An initial indication that significant harmonic distortion exists is provided when the measured power factor is not equal to cos φ (i.e. the power factor is less than cos φ).

2.2 Crest factor

2.2.1 Definition

The crest factor is the ratio between the value of the peak current or voltage (I_m or U_m) and the corresponding rms value.

$$k = \frac{I_m}{I_{rms}} \quad \text{or} \quad k = \frac{U_m}{U_{rms}}$$

For a sinusoidal signal, the crest factor is therefore equal to r.
For non-sinusoidal signals, the crest factor can be greater than or less than $\sqrt{2}$.

This factor is particularly useful in drawing attention to exceptional peak values with respect to the rms value.

2.2.2 Interpreting the value of the crest factor

A typical crest factor for the current drawn by non-linear loads is much greater than $\sqrt{2}$. Its value can range from 1.5 to 2 or even up to 5 in critical situations.

A very high crest factor indicates that high overcurrents occur from time to time. These overcurrents, detected by the protection devices, may cause nuisance tripping.

2.3 Power and harmonics

2.3.1 Active power

The active power P of a signal distorted by harmonics is the sum of the active powers corresponding to the voltages and currents in the same frequency order. The expansion of the voltage and current into their harmonic components may be written as:

$$P = \sum_{h=1}^{\infty} U_h I_h \cos\varphi_h$$

where φ_h is the displacement between voltage and current of harmonic order h.

Note:
- it is assumed that the signal does not contain a DC component, i.e. $U_0 = I_0 = 0$,
- when the signal is not distorted by harmonics, the equation $P = U_1 I_1 \cos\varphi_1$ again applies, indicating the power of a sinusoidal signal, where $\cos\varphi_1$ is equal to "$\cos\varphi$".

2.3.2 Reactive power

Reactive power applies exclusively to the fundamental and is defined by the equation:

$$Q = U_1.I_1.\sin\varphi_1$$

2.3.3 Distortion power

Consider the apparent power S.

$$S = U_{rms}.I_{rms}$$

In the presence of harmonics, the equation becomes:

$$S^2 = \left(\sum_{n=4}^{\infty} U_h^2\right).\left(\sum_{n=1}^{\infty} I_h^2\right)$$

Consequently, in the presence of harmonics, the equation $S^2=P^2+Q^2$ is no longer valid. The distortion power D is defined as $S^2=P^2+Q^2+D^2$, i.e.:

$$D = \sqrt{S^2 - P^2 - Q^2}$$

The essential indicators of harmonic distortion and measurement principles

2.4 Frequency spectrum and harmonic content

2.4.1 Principle

Each device causing harmonics has its own harmonic-current "fingerprint", with different amplitudes and displacements.

These values, notably the amplitude of each harmonic order, are essential elements for analysis of harmonic distortion.

2.4.2 Individual harmonic distortion (or harmonic distortion of order h)

Individual harmonic distortion is defined as the level of distortion, in percent, of order h, with respect to the fundamental:

$$u_h(\%) = 100\frac{U_h}{U_1} \quad \text{or} \quad i_h(\%) = 100\frac{I_h}{I_1}$$

2.4.3 Frequency spectrum

By plotting the amplitude of each harmonic order on a graph, we obtain a graphical representation of the frequency spectrum. This technique is referred to as spectral analysis.

Figure 6 shows the spectral analysis of a square-wave signal.

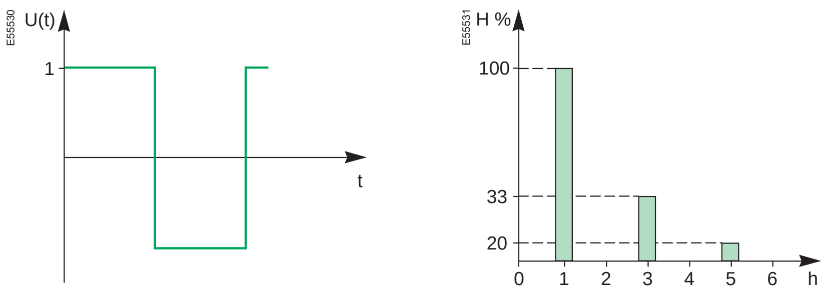

Figure 6 *- spectral analysis of a square-wave signal, for voltage* $U(t)$

2.4.4 RMS value

The rms value of a current or voltage is calculated on the basis of the rms values of the various harmonic orders.

$$I_{rms} = \sqrt{\sum_{h=1}^{\infty} I_h^2}$$

$$U_{rms} = \sqrt{\sum_{h=1}^{\infty} U_h^2}$$

In short

THD stands for Total Harmonic Distortion.

The level of harmonic distortion is often used to define the degree of harmonic content in an alternating signal.

2.5 Total harmonic distortion (THD)

2.5.1 Definition of total harmonic distortion

For a signal y, the total harmonic distortion (THD) is defined by the equation:

$$THD = \frac{\sqrt{\sum_{h=2}^{\infty} y_h^2}}{y_1}$$

This definition complies with that of standard IEC 61000-2-2.

Note that the resulting value may exceed one.

According to the standard, h can generally be limited to 50. This equation produces a single value indicating the distortion of a voltage or a current flowing at a given point in a distribution system.

Harmonic distortion is generally expressed as a percentage.

2.5.2 Current and voltage THD

When dealing with current harmonics, the equation becomes:

$$THD_I = \frac{\sqrt{\sum_{h=2}^{\infty} I_h^2}}{I_1}$$

The above equation is equivalent to the one below, which is more direct and easier to use when the total rms value is known:

$$THD_I = \sqrt{\left(\frac{I_{rms}}{I_1}\right)^2 - 1}$$

When dealing with voltage harmonics, the equation becomes:

$$THD_u = \frac{\sqrt{\sum_{h=2}^{\infty} u_h{}^2}}{U_1}$$

2.5.3 Total harmonic factor (THF)

In certain countries with different work habits, a different equation is used to determine harmonic distortion. In this equation, the value of the fundamental voltage U_1 or the fundamental current I_1 is replaced by the rms values U_{rms} and I_{rms} respectively.

To distinguish between the two equations, we will call the second the total harmonic factor (THF).

Example of a voltage THF:

$$THF_u = \frac{\sqrt{\sum_{h=2}^{\infty} U_h^2}}{U_{rms}}$$

The total harmonic factor, whether for voltage or current, is always less than 100%. It makes analogue measurements of signals easier but is used less and less because the result is very close to the THD defined above when a signal is not significantly distorted. What is more, it not well suited to highly distorted signals because it cannot exceed the value of 100%, contrary to the THD defined at the beginning of this section.

The essential indicators of harmonic distortion and measurement principles

2.5.4 Relation between power factor and THD

When the voltage is sinusoidal or virtually sinusoidal, it may be said that:

$$P \# P_1 = U_1.I_1.\cos\varphi_1$$

Consequently: $PF = \frac{P}{S} \# \frac{U_1.I_1.\cos\varphi_1}{U_1.I_{rms}}$

or : $\frac{I_1}{I_{rms}} = \frac{1}{\sqrt{1+THD_I^2}}$

hence: $PF \# \frac{\cos\varphi_1}{\sqrt{1+THD_I^2}}$

Figure 7 shows a graph of PF / cos φ as a function of THDi.
PF / cos φ = f (THDi)

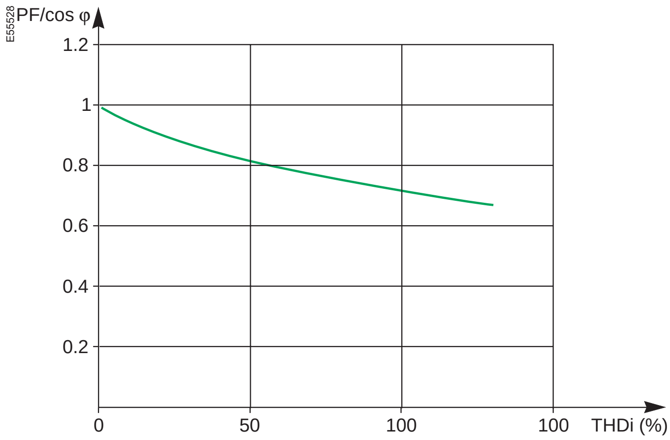

Figure 7 *- variation of PF / cos φ as a function of THDi, where THDu = 0*

In short

The primary indicator is the THD, a single value that reflects the level of distortion in voltage and current waves.

The harmonic spectrum provides a "fingerprint" of the distorted signal.

2.6 Usefulness of the various indicators

■ **The voltage THD** indicates the distortion of the voltage wave.

The measured THDu can provide information on phenomena observed in the installation. A THDu value of less than 5% is considered normal and there is virtually no risk of equipment malfunctions.

A THDu value between 5% and 8% indicates significant harmonic distortion. Some equipment malfunctions may occur.

A THDu value higher than 8% indicates high harmonic distortion. Equipment malfunctions are probable. In-depth analysis is required and an attenuation system must be installed.

■ **The current THD** indicates the distortion of the current wave.

To identify the load causing the disturbance, the current THD must be measured on the incomer and the outgoers of the different circuits.

The measured THDi can provide information on phenomena observed in the installation. A THDi value of less than 10% is considered normal and there is virtually no risk of equipment malfunctions.

A THDi value between 10% and 50% indicates significant harmonic distortion. Temperature rise may occur, which means cables and sources must be oversized.

A THDi value higher than 50% indicates high harmonic distortion. Equipment malfunctions are probable. In-depth analysis is required and an attenuation system must be installed.

■ **The power factor** PF indicates the extent to which the source of the installation must be oversized.

■ **The crest factor** is used to determine the capacity of a generator (UPS or generator) to provide high instantaneous currents. For example, computers draw highly distorted current with crest factors that may reach 3 or even 5.

■ **The spectrum** (signal broken down into frequency) provides a different view of electrical signals and may be used to assess distortion.

Measuring the values of the indicators

3.1 Measurement devices

3.1.1 Selection of a measurement device

Only **digital analysers**, based on recent technology, provide sufficiently accurate measurements for the indicators presented above.

Other measurement devices were used in the past.

■ **oscilloscopes** for observation purposes
A general indication of the distortion of a signal may be obtained by viewing the current or the voltage on an oscilloscope.
When the wave form is not sinusoidal, the signal is distorted by harmonics. The voltage and current peaks can be displayed.
Note that using an oscilloscope, it is not possible to precisely quantify the harmonic components.

■ **analogue spectral analysers**
Implementing old technology, these devices are made up of a passband filter combined with an rms voltmeter.
These devices, now outdated, produce mediocre results and do not provide any information on displacement.

3.1.2 Functions of digital analysers

The microprocessors used in digital analysers:

■ calculate the values of the harmonic indicators (**power factor, crest factor, distortion power, THD**),

■ offer a number of additional functions (correction, statistical detection, management of measurements, display, communication, etc.),

■ when they are multi-channel devices, provide simultaneously and nearly in real time the **spectral breakdown** of voltage and current.

3.1.3 Operating principle of digital analysers and data-processing techniques

Analogue signals are converted into a series of digital values.

On the basis of the digital values, an algorithm implementing the Fast Fourier Transform (FFT) calculates the amplitude and the phases of the harmonics over a large number of observation time windows.

Most digital analysers measure harmonics up to the 20th or 25th order for calculation of the THD.

Processing of the various values calculated using the FFT algorithm (smoothing, classification, statistics) can be carried out by the measurement device or by external software.

3.2 Procedure for harmonic analysis of a distribution system

Measurements are carried out on industrial and commercial sites as a:
- preventive measure:
  - to obtain an **overall assessment of the extent of the problem** (map of the distribution system),
- remedial measure:
  - to **determine the origin of a disturbance** and devise solutions to correct the problem,
  - to **check that the solutions implemented actually produced the desired effect**.

Operating mode

Voltage and current measurements must be carried out:
- at the power source,
- on the incoming busbars of the main distribution switchboard,
- on each of the outgoers leaving the main distribution switchboard.

When the measurements are carried out, it is necessary to have precise information on the conditions, in particular the status of capacitor banks (ON or OFF, number of stages connected).

On the basis of analysis results, it may be necessary to:
- derate any future equipment installed,

or
- quantify the protection and harmonic-filtering solutions that must be installed,
- compare the values measured to the reference values of the utility (harmonic-distortion limits, acceptable values, reference values).

Use of measurement devices

The devices show both the instantaneous effects and the long-term effects of harmonics.
Correct analysis requires integrated values over time spans ranging from a few seconds to a few minutes, for observation periods of a few days.

The required values are:
- the amplitude of voltage and current harmonics,
- the individual harmonic distortion of each order, for both current and voltage,
- total harmonic distortion for both current and voltage,
- where applicable, the displacement between voltage and current harmonics of the same order and the phase of the harmonics with respect to a common reference (the fundamental voltage, for example).

Measuring the values of the indicators

3.3 Anticipating harmonic conditioning needs

The harmonic indicators can be measured:
■ by permanently installed devices,
■ by an expert present at least a half-day on the site (for a view limited in time).

3.3.1 The advantages of permanently installed devices

For a number of reasons, it is preferable to use devices installed permanently in the distribution system.

■ a visit by an expert is necessarily limited in time, whereas measurements at different points in the installation over a sufficiently long period (one week to one month) **provide an overall view** of system operation and cover all the situations that may arise following:
□ fluctuation of the power source,
□ variations in system operation,
□ installation of new equipment.

■ measurement devices installed in the distribution system **prepare and facilitate troubleshooting** by experts, thus reducing the number and duration of their visits.

■ permanently installed measurement devices **detect any new disturbances** caused by the installation of new equipment, by new operating modes or by fluctuations on the distribution system.

3.3.2 The advantages of integrated measurement and detection devices

Measurement and detection devices that are built into the electrical distribution equipment offer a number of advantages.

■ **for an overall assessment of the distribution system (preventive measure),** they avoid:
□ renting the measurement devices,
□ hiring the services of experts,
□ having to connect and disconnect all the measurement devices.

In an overall assessment of the distribution system, an analysis at the main low-voltage switchboard level can commonly be carried out by the incoming device and/or the measurement devices built into each outgoing device.

■ **for an assessment in view of remedial action, they:**
□ indicate the operating conditions when the incident occurred,
□ provide a "map" of the installation and indications on the selected solution.

A full diagnosis will often also require additional information provided by specific equipment suited to the problem at hand.

The main effects of harmonics in installations

In short

Harmonics have a major economic impact on installations in that they cause:
- higher energy bills,
- premature ageing of equipment,
- drops in productivity.

4.1 Resonance

The use of both capacitive and inductive devices in distribution systems leads to resonance phenomena, resulting in extremely high or low impedance values. These variations in impedance modify the current and voltage in the distribution system.

Here we will discuss only parallel-resonance phenomena, which are the most frequent.

Consider the simplified diagram below, showing an installation made up of:
- a transformer supplying power,
- linear loads,
- non-linear loads causing harmonic currents,
- power factor correction capacitors.

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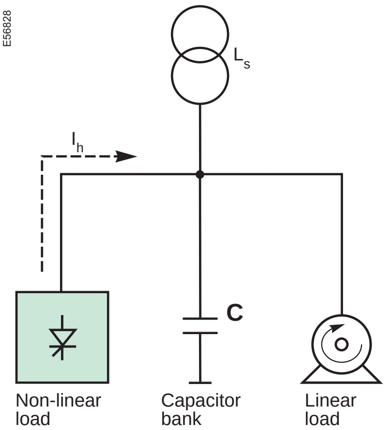

For harmonic-analysis purposes, the equivalent diagram is shown below:

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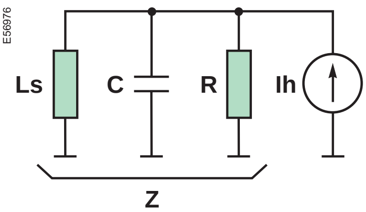

Ls: supply inductance (distribution system + transformer + line)
C: power factor correction capacitance
R: resistance of the linear loads
Ih: harmonic current

$$Z = \frac{jL_s\omega}{1 - L_sC\omega^2}$$ when R is neglected

Resonance occurs when the denominator $1\text{-}L_sC\omega^2$ approaches zero. The corresponding frequency is called the resonant frequency of the circuit. At this frequency, the impedance is at its maximum value, resulting in considerable voltage harmonics and consequently major voltage distortion. This voltage distortion is accompanied by the circulation of harmonic currents in the Ls + C circuit which are greater than the injected harmonic currents.

The distribution system and the power factor correction capacitors are subjected to considerable harmonic currents, resulting in the risk of overloads.

The main effects of harmonics in installations

4.2 Increased losses

4.2.1 Losses in conductors

The active power transmitted to a load depends on the fundamental current. When the current drawn by the load contains harmonics, the rms value of the current (I_{rms}) is greater than the fundamental I_1.

With THD defined as:

$$THD = \sqrt{\left(\frac{I_{rms}}{I_1}\right)^2 - 1}$$

it may be deduced that:

$$I_{rms} = I_1 \sqrt{1 + THD^2}$$

Figure 8 below shows, as a function of the harmonic distortion:

- the increase in the rms current (I_{rms}) for a load drawing a given fundamental current,
- the increase in the Joule losses (PJoules), without taking into account the skin effect.

(The reference point for I_{rms} and PJoules with no harmonics is set to 1 on the graph).

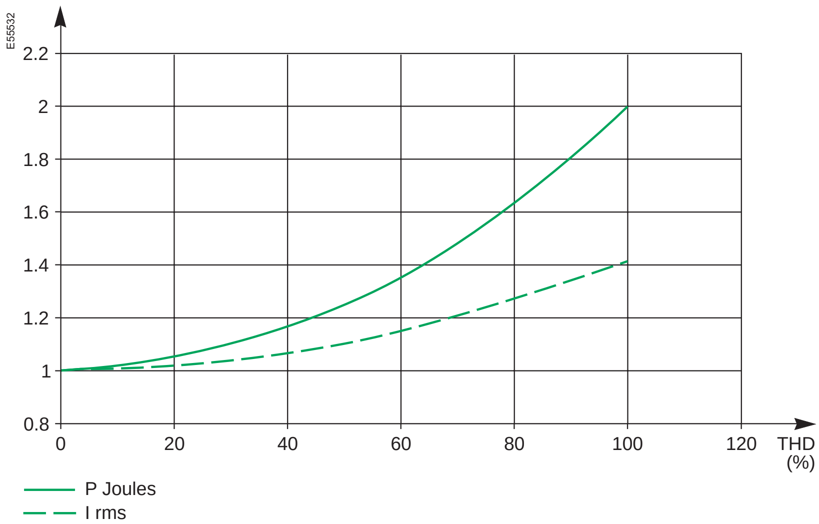

Figure 8 *- increase in rms current and Joule losses as a function of THD*

Current harmonics provoke an increase in Joule losses in all the conductors through which they flow and additional temperature rise in the transformers, circuit breakers, cables, etc.

4.2.2 Losses in asynchronous machines

Voltage harmonics, when applied to asynchronous machines, provoke the flow of currents with frequencies higher than 50 Hz in the rotor. These currents cause additional losses that are proportional to U_h^2/h.

■ Estimating the losses:
□ a virtually square-wave supply voltage provokes a **20% increase in losses**,
□ a supply voltage with the following levels of individual harmonic distortion (u_h): where U_1 is the fundamental voltage:
- u_5: 8% of U_1,
- u_7: 5% of U_1,
- u_{11}: 3% of U_1,
- u_{13}: 1% of U_1,

(i.e. a voltage THD of 10%) results in additional losses of 6%.

4.2.3 Losses in transformers

Harmonic currents flowing in transformers provoke increased losses in the windings through the Joule effect and increased iron losses due to eddy currents.

What is more, voltage harmonics cause iron losses due to hysterisis.

Roughly speaking, it may be said that the losses in the windings increase as the square of the current THD, and losses in the core increase linearly with the voltage THD.

■ Estimating the losses:
□ the **increase in losses represents 10% to 15%** for public-distribution transformers, where distortion levels relatively low.

4.2.4 Losses in capacitors

Harmonic voltage, when applied to capacitors, provokes the flow of currents that are proportional to the frequency of the harmonics. These currents cause additional losses.

■ Example:
Consider a supply voltage with the following levels of individual harmonic distortion (u_h): where U_1 is the fundamental voltage:
- u_5: 8% of U_1,
- u_7: 5% of U_1,
- u_{11}: 3% of U_1,
- u_{13}: 1% of U_1,

(i.e. a voltage THD of 10%).

$$I_1 = U_1.C.\omega$$

$$I_5 = U_5.C.5.\omega = u_5.5.I_1$$

$$I_7 = U_7.C.7.\omega = u_7.7.I_1$$

$$I_{11} = U_{11}.C.11.\omega = u_{11}.11.I_1$$

$$I_{13} = U_{13}.C.13.\omega = u_{13}.13.I_1$$

$$I_{rms} = \sqrt{\sum I_h^2}$$

$$\frac{I_{rms}}{I_1} = \sqrt{1 + (u_5.5)^2 + (u_7.7)^2 + (u_{11}.11)^2 + (u_{13}.13)^2} = 1.19$$

In this example, **Joule losses are multiplied by 1.19^2 = 1.4**.

The main effects of harmonics in installations

4.3 Overloads on installation equipment

4.3.1 Generators

Generators supplying non-linear loads must be derated due to the additional losses caused by the harmonic currents. The **derating coefficient is approximately 10%** for a generator supplying a set of loads in which 30% are non-linear loads. As a result, the generator must be oversized.

4.3.2 UPSs

The current drawn by computer equipment has a high crest factor. A UPS sized taking into account only the rms current value may not be capable of supplying the required peak current and thus be overloaded.

4.3.3 Transformers

■ The curve in figure 9 below shows typical derating values for a transformer supplying electronic (i.e. non-linear) loads.

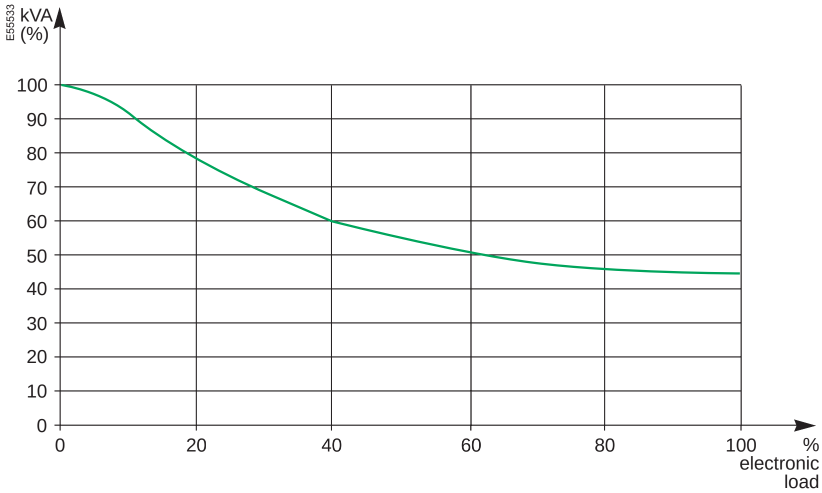

Figure 9 *- derating values for a transformer supplying electronic loads*

Example: a **transformer supplying loads that are 40%** electronic must be derated 40 %.

■ Standard UTE C15-112 indicates a derating factor for transformers calculated as a function of the harmonic currents:

$$k = \frac{1}{\sqrt{1+0,1.\left(\sum_{h=2}^{40} h^{1,6}.T_h^2\right)}}$$

$$T_h = \frac{I_h}{I_1}$$

Typical values:
□ "square-wave" current (spectrum inversely proportional to h **(*)**): k = 0.86,
□ current drawn by a frequency converter (THD ≈ 50%): k = 0.80.
(*) in fact, the current wave form is approximately that of a square wave form. This is the case for all current rectifiers (three-phase rectifiers, induction furnaces, etc.).

■ "K factor":
Standard ANSI C57.110 defines a derating method based on the "K factor", with the equation below.

$$K = \frac{\sum_{h=1}^{\infty} I_h^2.h^2}{\sum_{h=1}^{\infty} I_h^2} = \sum_{h=1}^{\infty}\left(\frac{I_h}{I_{rms}}\right)^2.h^2$$

The K factor produces more severe derating and is widely used in North America.

In the example presented below, the resulting "K factor" is 13.

Order h	I_h (%)
5	30
7	20
11	14
13	11
17	8
19	7
23	5
25	4

The increase in cost for a transformer sized using the "K factor" varies from 30% to 60% depending on the rating, in a range from 15 to 500 kVA.

4.3.4 Asynchronous machines

Standard IEC 60892 defines a weighted harmonic voltage factor (*HVF*) for which the equation and the maximum permissible value are presented below:

$$HVF = \sqrt{\sum_{h=2}^{13} \frac{U_h\Delta}{h^2}} \leq 0.02$$

■ Example:
Consider a supply voltage with the following levels of individual harmonic distortion (u_h): where U_1 is the fundamental voltage:
- u_3 : 2 % de U_1,
- u_5 : 3 % de U_1,
- u_7 : 1 % de U_1,
(i.e. a voltage THD of 3.7% and a HVF of 0.018).

In this example, the harmonic voltage factor is very close to the maximum value at which the machine must be derated.
Practically speaking, an asynchronous machine must not be supplied with power having a THDu greater than 10%.

The main effects of harmonics in installations

4.3.5 Capacitors

According to standards, the rms current flowing in capacitors must not exceed 1.3 times the rated current.

■ Example (already presented above):
Consider a supply voltage with the following levels of individual harmonic distortion (u_h): where U_1 is the fundamental voltage:
- u_5 : 8 % de U_1,
- u_7 : 5 % de U_1,
- u_{11} : 3 % de U_1,
- u_{13} : 1 % de U_1,
(i.e. a voltage THD of 10%).

as a result $\frac{I_{rms}}{I_1} = 1.19$, at the rated voltage.

At a voltage level equal to 1.1 times the rated voltage, $\frac{I_{rms}}{I_1} = 1.3$ the maximum current level is overrun and the capacitors must be resized.

4.3.6 Neutral conductors

Consider a system made up of a balanced three-phase source and three identical single-phase loads connected phase-to-neutral.

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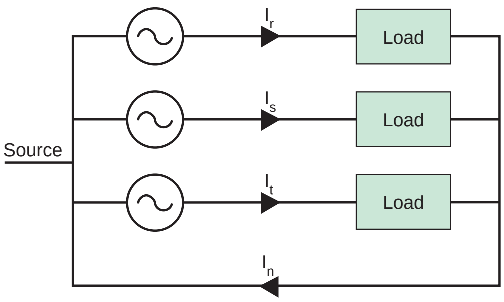
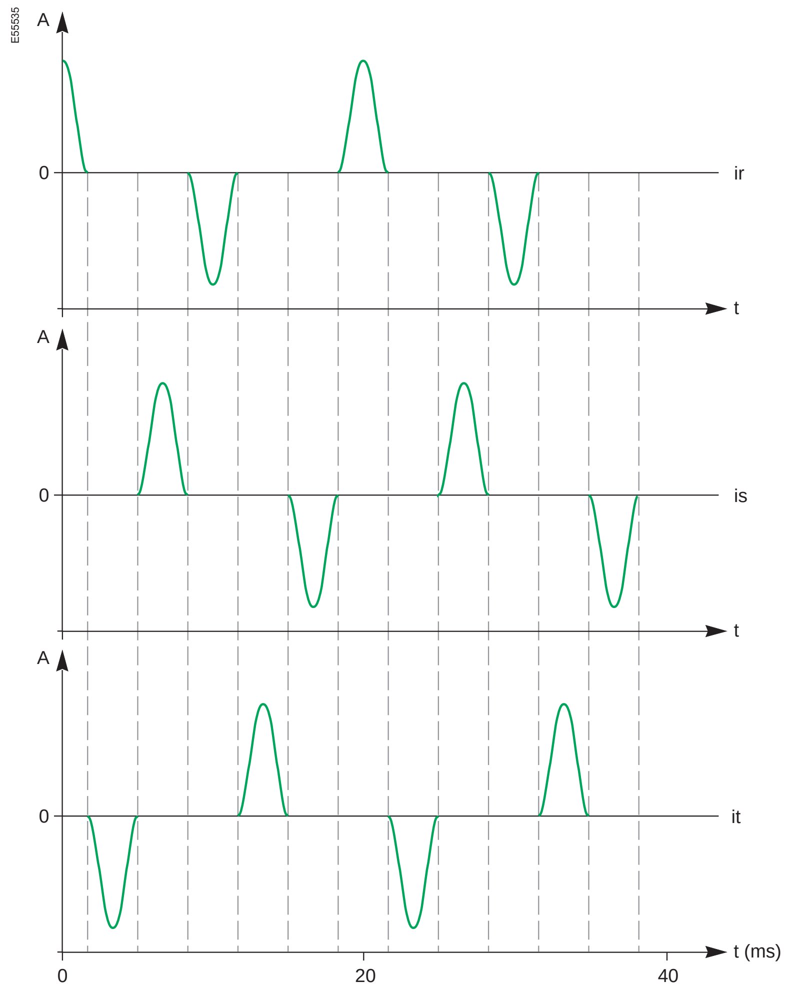


Figure 10 *- flow of currents in the various conductors connected to a three-phase source*

The graphs in figure 11 below show an example of the currents flowing in the three phases and the resulting current in the neutral conductor.



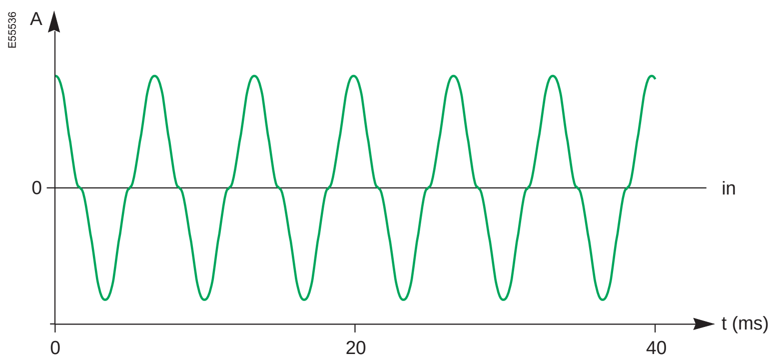


Figure 11 *- example of currents flowing in the various conductors connected to a three-phase load, where In =* $i_r + i_s + i_t$

In this example, the rms value of the current in the neutral conductor is $\sqrt{3}$ times greater than that of the current in a phase. The neutral conductor must therefore be resized accordingly.

The main effects of harmonics in installations

4.4 Disturbances to sensitive loads

4.4.1 Effects of supply-voltage distortion

■ Distortion of the supply voltage may disturb operation of sensitive loads, including:
□ regulation systems (temperature, etc.),
□ computer equipment,
□ control and monitoring systems (protection relays).

4.4.2 Disturbances on telephone lines

■ Harmonics can induce disturbances in circuits conducting low currents. The degree of disturbance depends on the distance over which the power and signal lines run in parallel, the distance between the lines and the frequency of the harmonics.

4.5 Economic consequences

4.5.1 Power losses

The Joule effect, induced by harmonic currents in the conductors and equipment, causes additional power losses.

4.5.2 Additional subscribed power costs

The presence of harmonic currents makes it necessary to increase the subscribed power level and, consequently, the cost of the subscription.

What is more, utilities will be increasingly inclined in the future to transfer costs to the producers of harmonic disturbances.

4.5.3 Oversizing of equipment

■ Derating of power sources (generators, transformers and UPSs) means they must be oversized.

■ Conductors must be sized taking into account the flow of harmonic currents. Because the frequencies of the harmonics are higher than that of the fundamental, the impedances encountered by these currents are higher. To avoid excessive losses due to the Joule effect, the conductors must be oversized.

■ The circulation of harmonic currents in the neutral conductor means the conductor must be oversized.

4.5.4 Reduction in the service life of equipment

(Data obtained from the Canadian Electrical Association).

When distortion of the supply voltage is in the 10% range, equipment service life is significantly reduced. Depending on the type of device, the reduction in service life may be estimated at:
- 32.5% for single-phase machines,
- 18% for three-phase machines,
- 5% for transformers.

To maintain the service life observed with a normal supply voltage, devices must be oversized.

4.5.5 Nuisance tripping and installation shutdown

Installation circuit breakers are subjected to current peaks caused by harmonics.

These current peaks cause nuisance tripping and result in production losses as well as costs corresponding to the time required to put the installation back into running order.

4.5.6 A few examples

For the installations in the examples below, the significant economic consequences made necessary the use of harmonic filters.

- Computer centre of an insurance company:
In this computer centre, nuisance tripping of a circuit breaker caused a loss estimated at 100 000 euros per hour of down time.

- Pharmaceutical laboratory:
Harmonics provoked the failure of an engine generator set and interruption of a very lengthy test phase on a new product. The estimated loss amounted to 17 million euros.

- Metallurgy factory:
Induction furnaces provoked overloads causing irreversible damage to three transformers ranging from 1500 to 2500 kVA in one year, and production losses estimated at 20 000 euros per hour.

- Garden-furniture factory:
Failure of variable-speed drives provoked production losses estimated at 10 000 euros per hour.

Standards and the regulatory environment

In short

Harmonic levels are governed by a series of standards and regulations:
■ compatibility standards for distribution systems.
■ standards setting limit values for devices causing harmonics.
■ recommendations issued by utilities and applicable to installations.

In order to rapidly reduce the effects of harmonic disturbances, a three-part system of standards and regulations is now in force. This system is presented below.

5.1 Compatibility standards between distribution systems and products

These standards stipulate a number of criteria concerning compatibility between distribution systems and products, such that:
■ the harmonic disturbances caused by a device in the system must not exceed the set limits,
■ each device must be capable of operating normally in the presence of disturbances at least equal to the set limits.

■ IEC 1000-2-2 for low-voltage public distribution systems,
■ IEC 1000-2-4 for low-voltage and medium-voltage industrial installations.

5.2 Distribution-system quality standards

■ Standard EN 50160 stipulates the characteristics of the voltage supplied by low-voltage public distribution systems,
■ Standard IEEE 519 (Recommended practices for harmonic control in electrical power systems) is a joint approach between utilities and their customers to limit the impact of non-linear loads.
What is more, utilities encourage preventive action to limit the impact on the quality of electricity, temperature rise and reductions in the power factor. They are also considering applying financial penalties to those customers producing disturbances.

5.3 Standards on devices

■ IEC 61000-3-2 or EN 61000-3-2 for low-voltage devices drawing less than 16 A,
■ IEC 61000-3-4 or EN 61000-3-4 for low-voltage devices drawing more than 16 A.

5.4 Maximum permissible harmonic values

On the basis of data drawn from a number of international studies, it was possible to estimate the typical harmonic values encountered in distribution systems.

Formulated on the basis of work carried out by the CIGRE organisation, the table below reflects the opinion of a large number of utilities concerning harmonic limits that should not be exceeded.

Odd harmonics, non-multiples of 3				**Odd harmonics, multiples of 3**				**Even harmonics**			
Order h	LV	MV	VHV	Order h	LV	MV	VHV	Order h	LV	MV	VHV
5	6	6	2	3	5	2.5	1.5	2	2	1.5	1.5
7	5	5	2	9	1.5	1.5	1	4	1	1	1
11	3.5	3.5	1.5	15	0.3	0.3	0.3	6	0.5	0.5	0.5
13	3	3	1.5	21	0.2	0.2	0.2	8	0.5	0.2	0.2
17	2	2	1	>21	0.2	0.2	0.2	10	0.5	0.2	0.2
19	1.5	1.5	1					12	0.2	0.2	0.2
23	1.5	1	0.7					>12	0.2	0.2	0.2
25	1.5	1	0.7								
>25	0.2+25h	0.2+25h	0.1+25h								

Solutions to attenuate harmonics

In short

There are three different types of solutions that may be used to attenuate the effects of harmonics:
- modifications to the installation,
- use of special devices in the power supply system (inductors, special transformers),
- filters.

6.1 General solutions

To limit the propagation of harmonics in the distribution system, a number of measures may be taken, particularly when designing a new installation.

6.1.1 Positioning the disturbing loads upstream in the system

The overall level of harmonic disturbance increases as the short-circuit power decreases.

Economic considerations aside, it is therefore preferable to connect the disturbing loads as far upstream as possible (see figure 13a).

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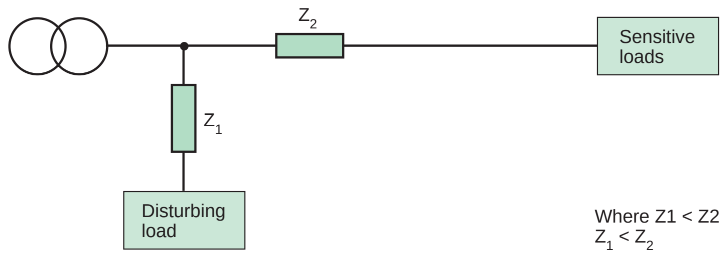

Figure 13a *- supply of non-linear loads as far upstream as possible (recommended diagram)*

6.1.2 Grouping the disturbing loads

When preparing the single-line diagram, separate where possible the disturbing equipment from the other loads (see figure 13b). Practically speaking, the different types of loads should be supplied by different busbars.

By grouping the disturbing loads, the possibilities of angular recomposition are increased. The reason is that the vector sum of the harmonic currents is lower than their algebraic sum.

An effort should also be made to avoid the flow of harmonic currents in the cables, thus limiting voltage drops and temperature rise in the cables.

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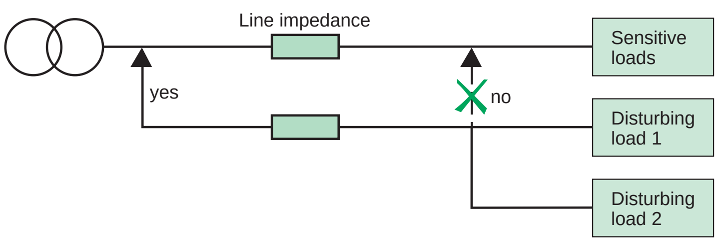

Figure 13b *- grouping of non-linear loads and supply as far upstream as possible (recommended diagram)*

6.1.3 Separating the sources

In efforts to attenuate harmonics, an additional improvement may be obtained by supplying the different loads via different transformers, as indicated in the simplified diagram below (figure 14).

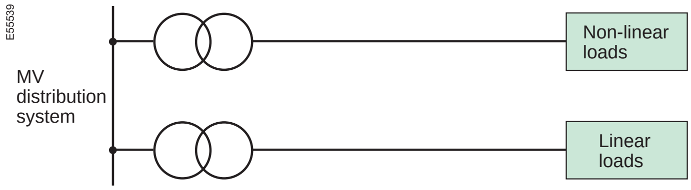

Figure 14 *- supply of the disturbing loads via a separate transformer*

This disadvantage of this solution is the increase in the cost of the installation.

6.1.4 Using transformers with special connections

Special types of connection may be used in transformers to eliminate certain harmonic orders.

The harmonic orders eliminated depend on the type of connection implemented:
■ a delta-star-delta connection eliminates harmonic orders 5 and 7 (see figure 15),
■ a delta-star connection eliminates harmonic order 3 (the harmonics flow in each of the phases and loop back via the transformer neutral),
■ a delta-zigzag$_5$ connection eliminates harmonic order 5 (loop back via the magnetic circuit).

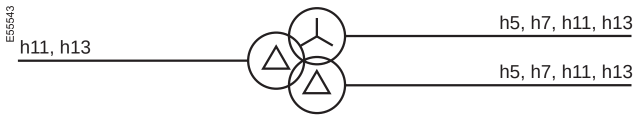

Figure 15 *- a delta-star-delta transformer prevents propagation of harmonic orders 5 and 7 upstream in the distribution system*

6.1.5 Installing inductors

In installations comprising variable-speed drives, the current can be smoothed by installing **line inductors**. By increasing the impedance of the supply circuit, the harmonic current is limited.

Use of **harmonic inductors** on capacitor banks is a means of increasing the impedance of the inductor and capacitor assembly, for harmonics with high frequencies.

Solutions to attenuate harmonics

6.1.6 Selection of a suitable system earthing arrangement

■ TNC system.

In TNC systems, a single conductor, the PEN, ensures protection in the event of an earth fault and carries imbalance currents.

Under steady-state conditions, the harmonic currents flow through the PEN. However, the PEN has a certain impedance, resulting in slight voltage differences (a few volts) between devices which may lead to malfunctions of electronic equipment.

The TNC system must therefore be used only for the supply of power circuits on the upstream end of installations **and must never be used for the supply of sensitive loads**.

■ TNS system.

This system is recommended when harmonics are present.

The neutral conductor and the protection conductor PE are completely separate, thus ensuring a much more stable voltage on the distribution system.

In short

In cases where the preventive measures presented above are not sufficient, the installation must be equipped with filters.

There are three types of filters:
■ passive filters,
■ active filters,
■ hybrid filters.

6.2 Solutions when limit values are exceeded

6.2.1 Passive filters

■ Typical applications:
□ industrial installations comprising a set of devices causing harmonics with a total power rating greater than approximately 200 kVA (variable-speed drives, UPSs, rectifiers, etc.),
□ installations where power factor correction is required,
□ situations where voltage distortion must be reduced to avoid disturbing sensitive loads,
□ situations where current distortion must be reduced to avoid overloads.

■ Operating principle:
An LC circuit, tuned to each of the harmonic frequencies requiring filtering, is installed in parallel with the device causing the harmonic distortion (see figure 16). This bypass circuit draws the harmonics, thus avoiding the flow of harmonics to the power source.

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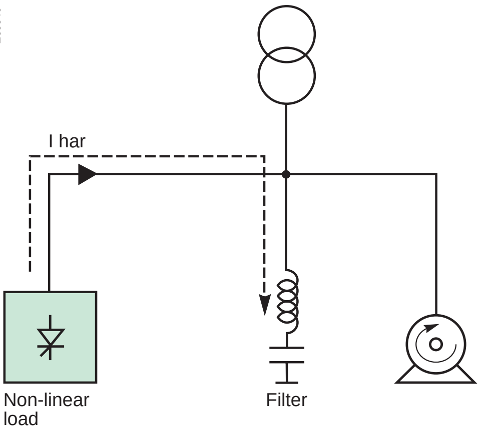


Figure 16 *- operating principle of a passive filter*

Generally speaking, the passive filter is tuned to a harmonic order near the one to be eliminated. A number of parallel-connected filters may be used when a significant reduction in distortion over a range of orders is required.

6.2.2 Active filters (active harmonic conditioners)

■ Typical applications:
□ commercial installations comprising a set of devices causing harmonics with a total power rating less than 200 kVA (variable-speed drives, UPSs, office equipment, etc.),
□ situations where current distortion must be reduced to avoid overloads.

■ Operating principle:
Active filters are systems employing power electronics, installed in series or in parallel with the non-linear load, to provide the harmonic currents required by non-linear loads and thereby avoid distortion on the power system.

Solutions to attenuate harmonics

Figure 17 shows an example of an active filter compensating the harmonic current ($I_{har} = -I_{act}$).

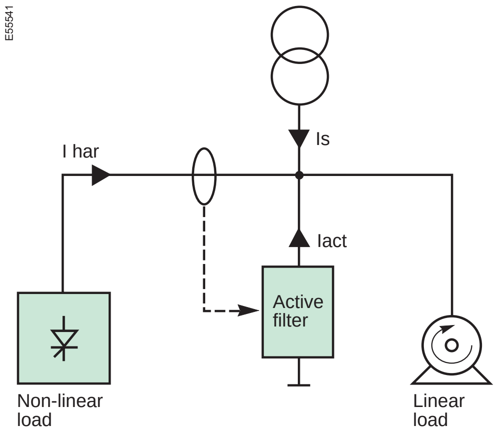


Figure 17 *- operating principle of an active filter*

The active filter injects, in opposite phase, the harmonics drawn by the load, such that the line current Is remains sinusoidal.

6.2.3 Hybrid filters

■ Typical applications:
□ industrial installations comprising a set of devices causing harmonics with a total power rating greater than 200 kVA approximately (variable-speed drives, UPSs, rectifiers, etc.),
□ installations where power factor correction is required,
□ situations where voltage distortion must be reduced to avoid disturbing sensitive loads,
□ situations where current distortion must be reduced to avoid overloads,
□ situations where conformity with strict harmonic-emission limits is required.

■ Operating principle:
The two types of filters presented above can be combined in a single device, thus constituting a hybrid filter (see figure 18). This new filtering solution combines the advantages of the existing systems and provides a high-performance solution covering a wide power range.

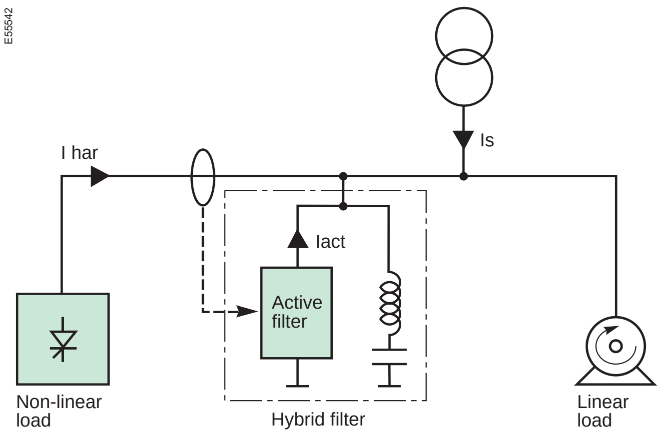


Figure 18 *- operating principle of a hybrid filter*

6.2.4 Selection criteria

■ **Passive filters** offer both:
□ power factor correction,
□ large capacity for current filtering.

Installations where passive filters are installed must be sufficiently stable, i.e. a low level of load fluctuations.

If a high level of reactive power is supplied, it is advised to de-energise the passive filter when load levels are low.

Preliminary studies for a filter must take into account any capacitor banks and may lead to their elimination.

■ **Active harmonic** conditioners compensate harmonics over a wide range of frequencies. They can adapt to any load, however, their conditioning capacity is limited.

■ **Hybrid filters** combine the strong points of both passive filters and active harmonic conditioners.

Harmonic-detection devices from Schneider Electric

In short

Schneider Electric offers a complete range of harmonic-distortion detection devices:
- Digipact,
- Powerlogic (Power Meter and Circuit Monitor),
- Micrologic.

7.1 Detection

Management of harmonic disturbances is based above all on measurement functions. Depending on the type of each installation, different types of equipment from Schneider Electric provide the solution.

7.1.1 Power meters

Digipact

Digipact

Digipact is designed for simple applications in the field of low-voltage electrical-distribution management, including indication and remote-control functions, alarms, etc.

The PM digital power meters of the Digipact range combine a number of traditionally separate functions in a single unit, including ammeter, voltmeter, wattmeter, watthour meter and harmonic measurements.

To provide information on power quality in low-voltage distribution systems, Digipact indicates the:
- voltage THD,
- current THD,
- power factor (depending on the model in the range),

locally and/or remotely via a communications system and supervision software.

Digipact devices are easy to wire and use. They detect power-quality problems and can be used to monitor the installation over time.

On the basis of the power-quality information provided by Digipact, the operator can launch a more in-depth analysis of the installation before critical disturbance levels are reached.

Digipact is part of the overall management of an electrical distribution system.

Power Meter and Circuit Monitor of PowerLogic System

Power Meter

Powerlogic products are high-performance analysis tools for medium- and low-voltage distribution systems. They are digital power meters designed to measure power quality.

The Powerlogic range is made up of Power Meters (PM) and Circuit Monitors (CM). This highly modular range provides solutions for very simple needs, covered by the PMs, up to the most complex, covered by the CMs. These products are used in new or existing installations where a high level of power quality is mandatory. They may be operated both locally and remotely.

Depending on their position in the installation, Power Meters offer an initial estimation of power quality. The main measurements carried out by PMs are the:
- current and voltage THD,
- power factor.

Depending on the model in the range, these functions may be combined with time stamping and alarms.

Circuit Monitor

Circuit Monitors provide in-depth analysis of power quality and system disturbances. The main CM functions are:
- measurement of over 100 electrical parameters,
- storage in memory and time stamping of the minimum and maximum values for each electrical parameter,
- alarm tripping by electrical parameters,
- event logging,
- recording of current and voltage disturbances,
- harmonic analysis,
- recording of wave forms (waveform capture).

056404

Micrologic H control unit integrated into the new NW and NT power circuit breaker

054503

Digivision supervision software

Micrologic : a power meter built into circuit breakers

For new installations, the Micrologic H control unit, built into the circuit breaker, is a particularly useful solution for measurements on the upstream side of the installation or on large outgoing circuits.

The Micrologic H control unit provides in-depth analysis of power quality and detailed diagnostics of events. The data provided by Micrologic H is intended for use on a switchboard display unit or a supervisor.

It provides:
- measurement of currents, voltages, active and reactive power,
- measurement of the current and voltage THD and THF,
- display of the current and voltage harmonic components (amplitude and phase up to the 50th order),
- recording of wave forms (waveform capture).

The functions offered by Micrologic H control units are equivalent to those provided by Circuit Monitor devices.

7.1.2 Using power-meter data

Remote management and analysis software

In the wider framework of an entire distribution system that must be monitored, Schneider Electric offers the communications systems required to interconnect all the various devices via a network, thus making it possible to centralise information and obtain an overall view of disturbances over the entire distribution system.

Depending on the devices and software used, it is possible to carry out measurements in real time, calculate averages, record wave forms, anticipate on alarms, etc.

The power meters transmit all the accessible data via either ModBus or the Digipact bus.

The primary purpose of these systems is to assist in identifying and planning maintenance work. They can significantly reduce servicing times and installation costs for temporary devices used for on-site measurements or for sizing of equipment (filters).

Schneider Electric offers two supervision-software products.

Digivision

The Digivision supervision software, installed on a standard PC, can be used to manage all the measurement and protection data supplied by the low-voltage devices. It represents the first level of supervision software for electrical installations.
Via the PC, the operator can:
- view the information provided by the PM power meters and Micrologic H control units,
- set alarm thresholds,
- communicate with the various connected protection and control devices to view their status and settings, as well as remotely control opening and closing.

SMS

SMS is a very complete software system for analysis of distribution systems, used in conjunction with Powerlogic products.
Installed on a standard PC, it can be used to:
- view measurements on a real time basis,
- view histories, over a set period,
- select the manner in which data is displayed (tables, various curves),
- process statistical data (display of histograms).

Harmonic-detection devices from Schneider Electric

7.2 Selection guide

The table below presents the most suitable applications of the various devices for harmonic measurements:

Goal of detection	PM100/300	PM650	Micrologic H	CM2000/2450
Overall evaluation of distribution-system status	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■
Precise diagnostics	■	■ ■	■ ■ ■	■ ■ ■
Analysis	■	■ ■	■ ■	■ ■ ■
Advantages	Basic measurements, easy to use, inexpensive, small size and high accuracy	Complete measurement device with built-in alarms and non-volatile memory	Built-into the circuit breaker, monitors incomers or large outgoing circuits without additional wiring or current transformers	Very complete, highly accurate measurement device, large data-storage capacity, programmable, fast measurements

Key:
■ ■ ■ *: perfectly suited*
■ ■ *: satisfactory*
■ *: indicates a disturbance, other functions require other devices*

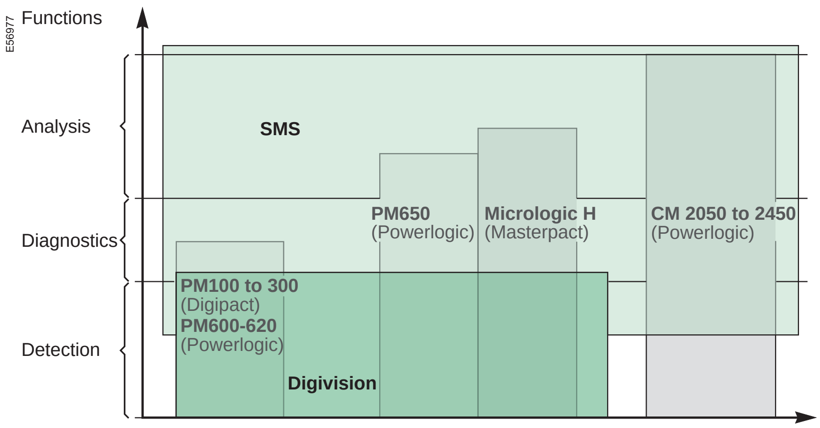


Figure 19 *- relative positions of the various detection products*

Selection table

	PM100	PM150	PM300	PM600	PM620	PM650	Micrologic H	CM2150	CM2250	CM2350	CM2450
communications											
no communication	■										
communication via Digipact bus		■									
communication via RS-485 / Modbus			■	■	■	■	■	■	■	■	■
metering and monitoring											
current, voltage, frequency	■	■	■	■	■	■	■	■	■	■	■
power, energy, power factor	■	■	■	■	■	■	■	■	■	■	■
true rms metering through 31st harmonic	■	■	■	■	■	■	■	■	■	■	■
THD for voltage and current, per phase	■	■	■		■	■	■	■	■	■	■
relay output (programmable)	■	■	■	■	■	■	■	■	■	■	■
low-voltage applications	■	■	■	■	■	■	■	■	■	■	■
medium-voltage applications (via PTs)				■	■	■		■	■	■	■
current/voltage accuracy class	0.5 %	0.5 %	0.5 %	0.2 %	0.2 %	1 % for I (1) 1.5 % for U	0.2 %	0.2 %	0.2 %	0.2 %	0.2 %
demand current per phase, present and maximum					■	■	■	■	■	■	■
demand power per phase, present and maximum			■		■	■	■	■	■	■	■
time/date stamping					■	■	■	■	■	■	■
user-configurable alarms					■	■	■	■	■	■	■
predicted demand power					■	■	■	■	■	■	■
synchronised demand via comm.					■	■	■	■	■	■	■
min/max recording					■	■	■	■	■	■	■
on-board memory for data and event logs					■	■	■	■	■	■	■
advanced monitoring and analysis											
time/data stamping of min/max values							■	■	■	■	■
optional input/output module							■	■	■	■	■
front optical comm. port								■	■	■	■
extended memory **(2)**								■	■	■	■
field-upgradeable firmware								■	■	■	■
waveform capture for harmonic analysis							■		■	■	■
voltage disturbance monitoring (dips, spikes)										■	■
programmable for special applications							■				■

(1) *Including the sensors.*

(2) *User-accessible memory of100 k standard on all CM devices, 512 k and 1 M optional.*

Harmonic-management solutions from Schneider Electric

In short

Schneider Electric offers a complete range of harmonic-management services:
- expert analysis,
- measurement and surveillance devices,
- filters.

8.1 Analysis and diagnostics from Schneider Electric

Selection of the best solution, from both the technical and economic point of view, requires an in-depth study of the installation.

MV and LV diagnostics

When an expert from a Schneider Electric CEAT unit is called in, the user is guaranteed that the proposed solution will be effective (e.g. a guaranteed maximum THDu level).

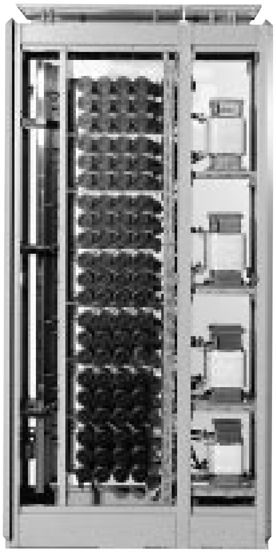
The harmonic analysis and diagnostics are carried out by an engineer specialised in the field of disturbances in electrical distribution systems and equipped with powerful analysis and simulation equipment.

The service provided by Schneider Electric is divided into steps:
- measurement of disturbances, in current and in phase-to-neutral and phase-to-phase voltages, on the disturbing loads, on the disturbed outgoing circuits and the power sources,
- a computer model of the measured phenomena is created, providing a precise explanation of their causes and optimised selection of the possible solutions,
- a complete report is drawn up, indicating:
  - the measured levels of disturbance,
  - the maximum permissible levels of disturbance (IEC 61000, IEC 34, etc.),
- the performance of the selected solutions is guaranteed,
- the final solution is implemented, using the selected equipment and systems.

The entire service is certified ISO 9002.

8.2 Specific Schneider Electric products

8.2.1 Passive filters



Passive filter

Passive filters are made up of inductors and capacitors set up as resonant circuits tuned to the frequency of the harmonic order to be eliminated. A system may comprise a number of filters to eliminate several harmonic orders.

General characteristics	
Voltage	400 V three phase
Power rating	up to 265 kvar / 470 A for the 5th order filter up to 145 kvar / 225 A for the 7th order filter up to 105 kvar / 145 A for the 11th order filter
Enclosure	Prisma

8.2.2 Active filters of MGE UPS SYSTEMS

Active filter of MGE UPS SYSTEMS

General characteristics	
Voltage	400 V
Conditioning capacity per phase (A rms)	20 to 120 A rms
Conditioned harmonic currents	orders 2 to 25, complete spectrum or selected orders
Harmonic attenuation	Load THDi / Upstream THDi greater than 10 at rated load on conditioner
Functions	displacement power-factor correction, 7-language alphanumeric display, diagnostics and maintenance system, parallel connection, remote control, communications interface JBus/RS485

8.2.3 Hybrid filters

Hybrid filter

Hybrid filters combine the advantages of a passive filter and a SineWave active harmonic conditioner in a single unit.

General characteristics	
Passive filter	5th order harmonics
Active harmonic conditioner	20 to 180 A
Voltage	400 V three phase
Reactive energy compensation	up to 265 kvar
Harmonic orders conditioned	2 to 25
Total harmonic current	up to 440 A
Enclosure	Prisma

Harmonic-management solutions from Schneider Electric

8.2.4 Selection guide

Type of application	Rectiphase passive filter	SineWave MGE UPS SYSTEMS harmonic conditioner	Rectiphase hybrid filter
Commercial buildings (computer systems, air-conditioning, lighting, lifts)	■	■ ■ ■	■ ■
Paper, cardboard, plastics industry (conveyers, winding/unwinding equipment)	■ ■ ■	■	■ ■
Water-treatment (pumps, mixers)	■ ■	■ ■ ■	■ ■ ■
Handling (cranes, ski lifts)	■ ■	■	■ ■ ■

Key:
■ ■ ■ *: perfectly suited*
■ ■ *: perfectly suited technically, but costly*
■ *: satisfactory*

Batteries de compensation automatique d'énergie réactive
Rectimat 2

choisissez la
sérénité

Merlin Gerin
Modicon
Square D
Telemecanique

Schneider Electric
Qui fait autant avancer l'électricité ?

Rectimat 2
une nouvelle génération de batterie automatique

Avec la nouvelle génération Rectimat 2, vous bénéficiez du savoir-faire de Rectiphase dans la compensation d'énergie réactive. Rectimat 2 renouvelle l'offre Rectimat et Secomat avec une gamme de 30 à 900 kvar et rend la compensation plus simple et plus sûre.

■ **Simplicité**
L'espace de raccordement des câbles de puissance est amélioré; l'auto-transformateur pour l'alimentation des auxiliaires est intégré.

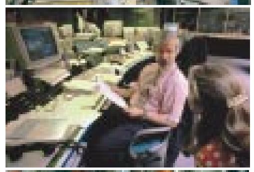
■ **Sécurité**
Rectimat 2 est protégée contre les contacts directs; cet équipement est testé à 100 % en usine.

■ **Disponibilité**
La mise à disposition de Rectimat 2 est deux fois plus rapide.

Pour répondre à tous les besoins de compensation

Coffret ou armoire

Les batteries Rectimat 2 se présentent sous forme de coffret pour les petites puissances, ou d'armoire pour les moyennes et fortes puissances.



Fonctions étendues

A différents types de réseaux conviennent différents types de batteries :

- réseaux peu pollués = batteries Rectimat type standard
- réseaux pollués = batteries Rectimat type H (renforcés).
- réseaux fortement pollués = batteries type SAH (protégé par selfs).

TESTÉ 100% EN USINE

100% testé en usine

Les séquences d'essai se déroulent en automatique dans l'ordre suivant :

1 : mesure de la continuité des masses
2 : essai diélectrique circuit de commande
3 : essai diélectrique circuit de puissance
4 : mesure des capacités individuelles
5 : test alimentation régulateur
6 : fonctionnement du régulateur

Pourquoi compenser l'énergie réactive ?

De nombreux récepteurs consomment de l'énergie réactive. Compenser l'énergie réactive, c'est fournir cette énergie en lieu et place du réseau de distribution, par l'installation d'équipements de compensation. Les avantages qui en résultent se traduisent par :

- une économie sur les équipements électriques liée à une diminution de la puissance appelée
- une augmentation de la puissance disponible au secondaire des transformateurs
- une diminution de tension et de pertes Joule dans les câbles
- **une économie sur les factures d'électricité.**

EDF facture l'énergie réactive pour les abonnés dont la puissance souscrite est supérieure à 250 kVA.
La gamme de condensateurs et de batteries Rectimat permet d'apporter la solution immédiate pour une baisse des factures d'électricité.
L'installation est rapide et les économies réalisées permettent de rentabiliser en quelques mois l'investissement.

Comment compenser ?

Le choix d'un équipement de compensation s'effectue en fonction des critères suivants :

- puissance réactive à installer
- mode de compensation fixe ou automatique.

Selon la puissance on peut choisir entre compensation fixe ou automatique.
Rectiphase propose deux solutions pour la compensation :

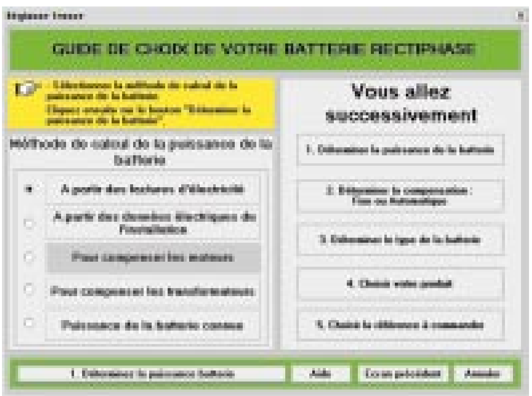
- batterie fixe Rectibloc
- batterie automatique Rectimat 2.

Deux solutions pour compenser

Compensation automatique : batteries Rectimat 2
Avec la nouvelle batterie Rectimat 2, Rectiphase propose une réponse performante à vos besoins d'optimisation. Plus facile à mettre en oeuvre et d'un niveau de sécurité accru, Rectimat 2 s'adapte à tous les environnements, avec ou sans courants harmoniques.

Compensation fixe : batterie Rectibloc
En coffret ou structure avec un disjoncteur intégré, cet ensemble de condensateurs existe en :
- type standard, pour réseaux peu pollués
- type H, pour réseaux pollués.
- type SAH pour réseaux fortement pollués.

Rectiphase facilite le choix

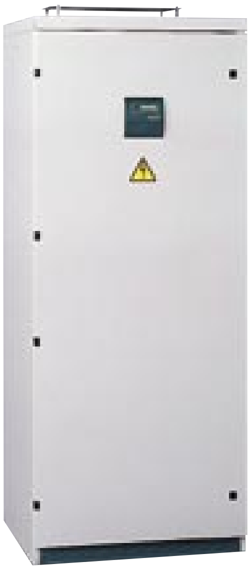


Pour vous aider à choisir facilement votre solution de compensation, Rectiphase met à votre disposition un nouvel outil : le logiciel Reglavar. Reglavar permet de déterminer rapidement le choix d'une batterie Rectiphase, en calculant sa nature à partir du bilan de la puissance ou des factures d'électricité, et d'en choisir le type : standard, H ou SAH.

Compensation automatique : gamme de batteries Rectimat 2


coffret


armoire


armoire


armoire double

Les batteries Rectimat 2 sont des équipements de compensation automatique qui se présentent sous la forme de coffret ou d'armoire selon la puissance.

Caractéristiques :

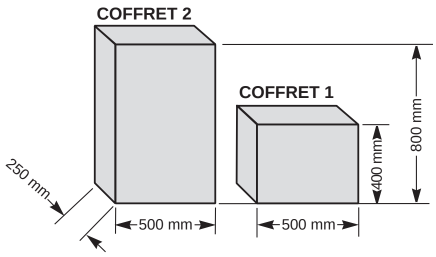
- ■ tension assignée : 400 V, triphasée 50 Hz,
- ■ classe d'isolement : 0,66 kV,
- ■ catégorie de température (400 V) :
- □ température maximale : 40°C,
- □ température moyenne sur 24 h : 35°C,
- □ température moyenne annuelle : 25°C,
- □ température minimale : -5°C.
- ■ degré de protection : IP31
- ■ auto-transformateur 400/230 V intégré,
- ■ protection contre les contacts directs (porte ouverte)
- ■ couleur :
- □ tôle : RAL 9002,
- □ bandeau : RAL 7021,
- ■ normes : CEI 439-1, EN 60439.

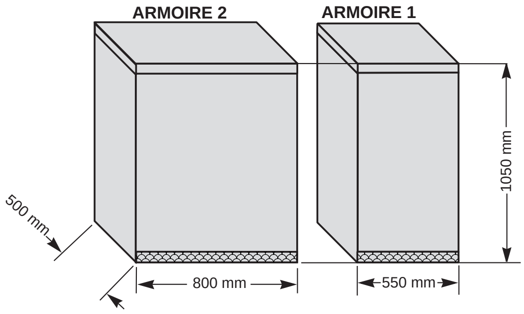
Installation :

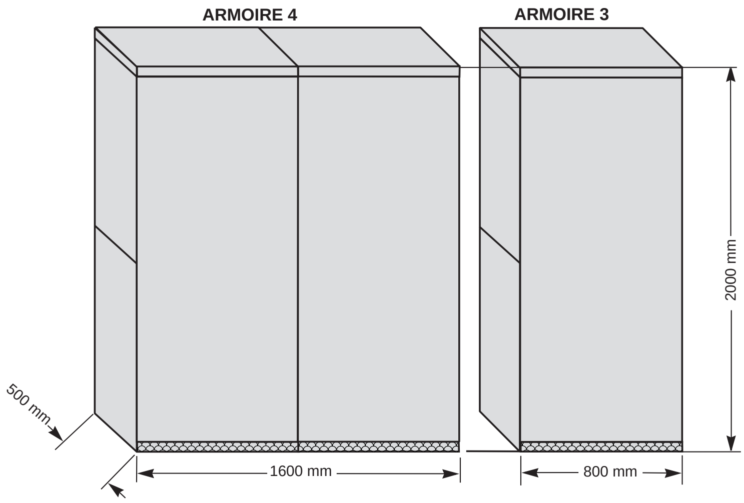
- ■ fixation :
- □ coffret : fixation murale ou au sol sur socle (accessoire)
- □ armoire : fixation au sol ou sur réhausse (accessoire)
- ■ raccordement des câbles de puissance par le bas sur plages
- ■ le TI (5 VA, sec 5 A), non fourni, est à placer en amont de la batterie et des récepteurs
- ■ il n'est pas nécessaire de prévoir une alimentation 230 V/50 Hz pour alimenter les bobines des contacteurs.

Options :

- ■ disjoncteur de tête
- ■ talon de compensation fixe
- ■ delestage (EJP, normal-secours)
- ■ raccordement par le haut
- ■ autres options sur demande.

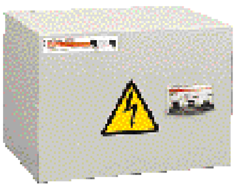






	dimensions			fixations		
	H(mm)	L(mm)	P(mm)	H(mm)	L(mm)	P(mm)
coffret 1	400	500	250	350	460	-
coffret 2	800	500	250	750	460	-
armoire 1	1050	550	500	-	520	400
armoire 2	1050	800	500	-	770	400
armoire 3	2000	800	500	-	770	400
armoire 4	2000	1600	500	-	2x770	400

Compensation fixe : gamme de batteries Rectibloc



coffret

structure

Type Standard et type H

Ensemble constitué de condensateurs Varplus M en coffret ou montés dos à dos sur une structure en tôle peinte et protégé par un disjoncteur intégré. Il existe en deux types en fonction du niveau de pollution harmonique :

- type standard, pour réseaux peu pollués Gh/Sn ≤ 15%.
- type H, pour réseaux pollués 15% < Gh/Sn ≤ 25%.

Caractéristiques Standard et H :

- tension assignée : 400 V, triphasée 50 Hz,
- classe d'isolement : 0,66 kV,
- catégorie de température (400 V) :
  - température maximale : 40°C,
  - température moyenne sur 24 h : 35°C,
  - température moyenne annuelle : 25°C,
  - température minimale : -5°C,
- degré de protection : IP31 ;
- couleur :
  - coffret : RAL 7032,
  - structure : RAL 7032.
- normes : CEI 439-1, EN 60439.

Installation :

- au sol avec raccordement des câbles de puissance par le bas.

Type SAH

Ensemble constitué de condensateurs Varplus M associés à une self antiharmoniques et protégé par un disjoncteur intégré. Il s'installe sur un réseau fortement pollué 25% < Gh/Sn ≤ 60%.

Caractéristiques SAH :

- tension assignée : 400 V, triphasée 50 Hz
- classe d'isolement : 0,66 kV,
- catégorie de température (400 V) :
  - température maximale : 40°C,
  - température moyenne sur 24 h : 35°C,
  - température moyenne annuelle : 25°C,
  - température minimale : -5°C,
- degré de protection : IP31 ;
- couleur :
  - type SAH :
    - tôle : RAL 9002,
    - bandeau : RAL 7021,
- normes : CEI 439-1, EN 60439.

Installation :

- au sol avec raccordement des câbles de puissance par le bas.

Type Standard, 400 V

puissance (kvar)	disjoncteur	réalisation	**réf.**
10	NC100L	coffret	**51270**
15	NC100L	coffret	**51271**
20	NC100L	coffret	**51272**
25	NS100	structure	**52480**
30	NS100	structure	**52481**
40	NS100	structure	**52482**
50	NS100	structure	**52483**
60	NS160	structure	**52484**
70	NS160	structure	**52485**
80	NS160	structure	**52486**
100	NS250	structure	**52487**
120	NS250	structure	**52488**

Type H, 400 V, 470 V

puissance (kvar) **(1)** 400 V	**(2)** 470V	disjoncteur	réalisation	**réf.**
7,5	10	NC100L	coffret	**52004**
10	14	NC100L	coffret	**52135**
15	20	NC100L	coffret	**52005**
20	24	NS100	structure	**52499**
22,5	30,5	NS100	structure	**52500**
30	42	NS100	structure	**52501**
35	48	NS100	structure	**52502**
40	57,5	NS160	structure	**52503**
45	60	NS160	structure	**52504**
52,5	72	NS160	structure	**52505**
60	76	NS250	structure	**52506**
70	96	NS250	structure	**52507**
80	115	NS250	structure	**52508**
90	120	NS250	structure	**52509**
105	144	NS250	structure	**52510**

(1) puissance utile (kvar)
(2) puissance dimensionnement (kvar)

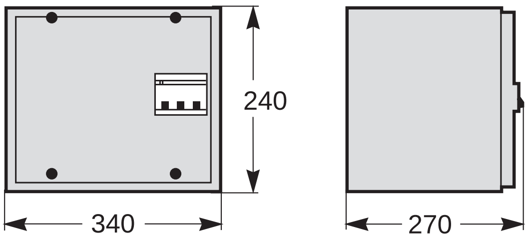
Type SAH, 400 V

puissance (kvar)	disjoncteur	réalisation	**réf.**
25	NS100	armoire	**52585**
37,5	NS100	armoire	**52586**
50	NS100	armoire	**52587**
75	NS160	armoire	**52588**
100	NS250	armoire	**52589**
125	NS250	armoire	**52590**
150	NS400	armoire	**52591**

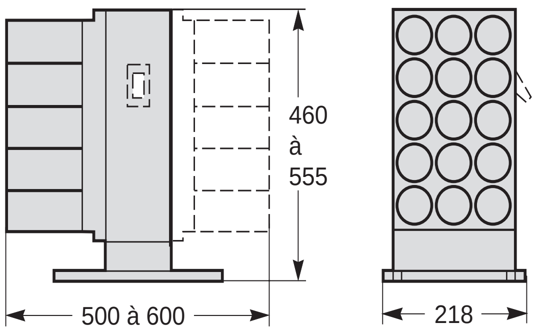
Caractéristiques des disjoncteurs

type du disjoncteur	**Icu (kA eff.)**
NS100/NC 100L	**25**
NS160	**36**
NS250	**36**
NS400	**45**

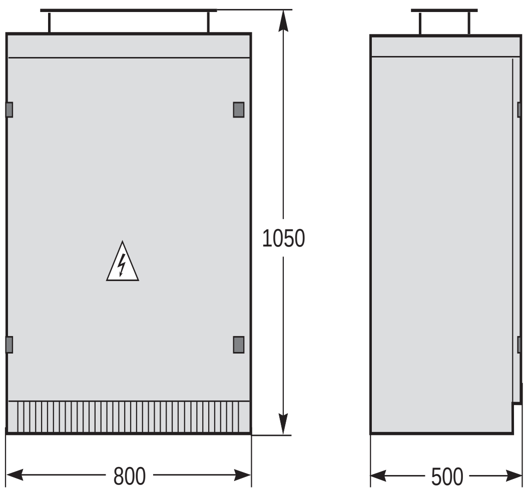
Type Standard et type H



Type Standard et type H



Type SAH



Guide de choix et références*

solutions préconisées

puissance transfo kVA	puissance totale prévue kvar (2)	puissance des générateurs d'harmoniques (3) inférieure à kVA	comprise entre kVA	comprise entre kVA
160		24	24 et 40	40 et 96
	<25	Rectibloc std	Rectibloc H	Rectibloc SAH
	>25	Rectimat std	Rectimat H	Rectimat SAH
250		37	37 et 63	63 et 150
	<40	Rectibloc std	Rectibloc H	Rectibloc SAH
	>40	Rectimat std	Rectimat H	Rectimat SAH
400		60	60 et 100	100 et 240
	<60	Rectibloc std	Rectibloc H	Rectibloc SAH
	>60	Rectimat std	Rectimat H	Rectimat SAH
630		94	94 et 157	157 et 378
	<100	Rectibloc std	Rectibloc H	Rectibloc SAH
	>100	Rectimat std	Rectimat H	Rectimat SAH
800		120	120 et 200	200 et 480
	<120	Rectibloc std	Rectibloc H	Rectibloc SAH
	>120	Rectimat std	Rectimat H	Rectimat SAH
1000		150	150 et 250	250 et 600
	>120 (1)	Rectimat std	Rectimat H	Rectimat SAH
1250		187	187 et 312	312 et 750
	>120	Rectimat std	Rectimat H	Rectimat SAH
1600		240	240 et 400	400 et 960
	>120	Rectimat std	Rectimat H	Rectimat SAH
2000		300	300 et 500	500 et 1200
	>120	Rectimat std	Rectimat H	Rectimat SAH

* références
Rectibloc : page 9
Rectimat 2 : page 11

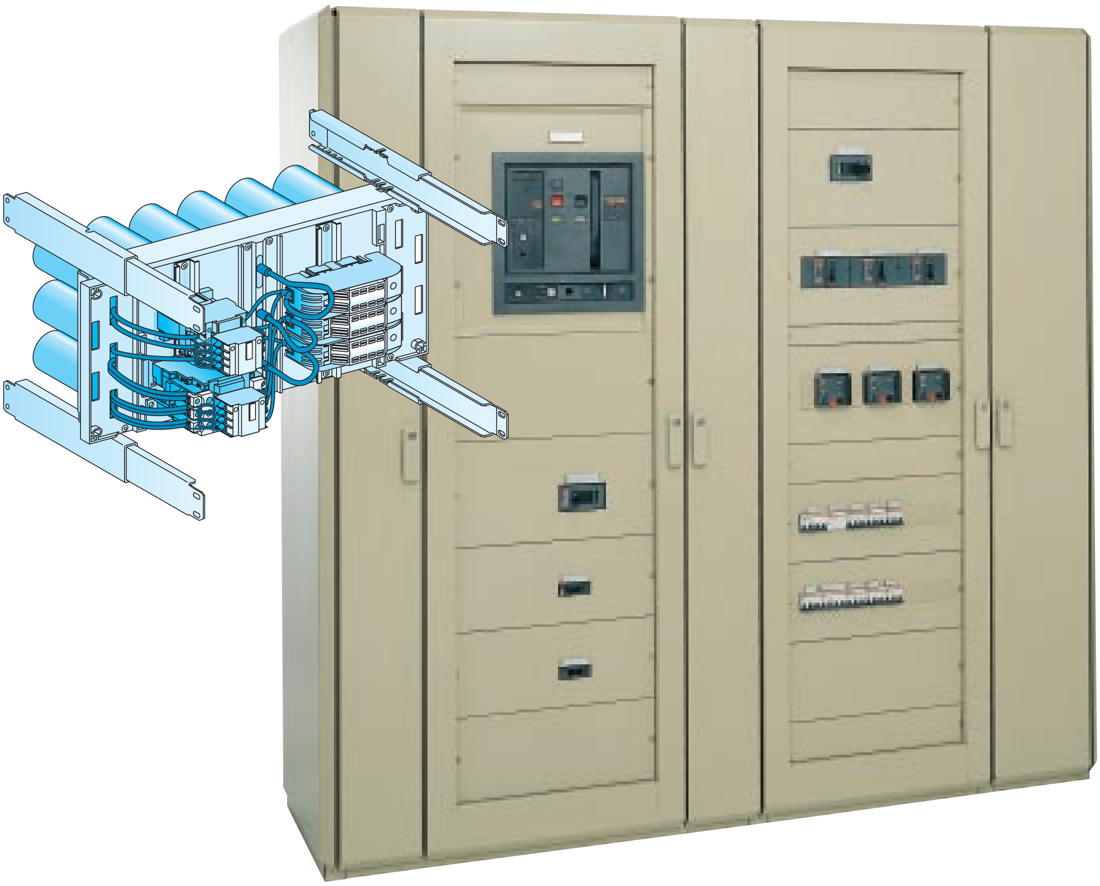
(1) à partir d'une puissance de transformateur de 1 000 kVA il est conseillé de toujours utiliser un système automatique
(2) tenir compte de la puissance des batteries existantes éventuelles augmentée de la puissance à rajouter
(3) générateurs harmoniques = moteurs à vitesse variable,convertisseurs statiques, électronique de puissance, onduleurs, …

	Réf	produit	puissance/régulation	présentation		disjoncteur recommandé
standard	52609	Rectimat 2 400V STD	30 kvar 4*7,5	coffret	1	NS100
	52610	Rectimat 2 400V STD	45 kvar 3*15	coffret	1	NS100
	52611	Rectimat 2 400V STD	60 kvar 4*15	coffret	2	NS160
	52612	Rectimat 2 400V STD	75 kvar 5*15	coffret	2	NS160
	52613	Rectimat 2 400V STD	90 kvar 3*30	armoire	1	NS250
	52614	Rectimat 2 400V STD	105 kvar 7*15	armoire	1	NS250
	52615	Rectimat 2 400V STD	120 kvar 8*15	armoire	2	NS250
	52616	Rectimat 2 400V STD	150 kvar 5*30	armoire	1	NS400
	52617	Rectimat 2 400V STD	180 kvar 6*30	armoire	1	NS400
	52618	Rectimat 2 400V STD	210 kvar 7*30	armoire	2	NS630
	52619	Rectimat 2 400V STD	240 kvar 8*30	armoire	2	NS630
	52620	Rectimat 2 400V STD	270 kvar 9*30	armoire	2	NS630
	52621	Rectimat 2 400V STD	315 kvar 7*45	armoire	3	NS630
	52622	Rectimat 2 400V STD	360 kvar 8*45	armoire	3	C801
	52623	Rectimat 2 400V STD	405 kvar 9*45	armoire	3	C801
	52624	Rectimat 2 400V STD	450 kvar 5*90	armoire	3	C1001
	52625	Rectimat 2 400V STD	495 kvar 11*45	armoire	4	C1001
	52626	Rectimat 2 400V STD	540 kvar 6*90	armoire	4	C1251
	52627	Rectimat 2 400V STD	585 kvar 13*45	armoire	4	C1251
	52628	Rectimat 2 400V STD	630 kvar 7*90	armoire	4	C1251
	52629	Rectimat 2 400V STD	675 kvar 15*45	armoire	4	CM1600
	52630	Rectimat 2 400V STD	720 kvar 8*90	armoire	4	CM1600
	52631	Rectimat 2 400V STD	765 kvar 17*45	armoire	4	CM1600
	52632	Rectimat 2 400V STD	810 kvar 9*90	armoire	4	CM1600
	52633	Rectimat 2 400V STD	855 kvar 19*45	armoire	4	CM2000
	52634	Rectimat 2 400V STD	900 kvar 10*90	armoire	4	CM2000
H	52635	Rectimat 2 400V H	30 kvar 4*7,5	coffret	2	NS100
Renforcé	52636	Rectimat 2 400V H	45 kvar 6*7,5	coffret	2	NS100
	52637	Rectimat 2 400V H	50 kvar 5*10	coffret	2	NS160
	52638	Rectimat 2 400V H	80 kvar 8*10	armoire	2	NS250
	52639	Rectimat 2 400V H	100 kvar 5*20	armoire	1	NS250
	52640	Rectimat 2 400V H	120 kvar 6*20	armoire	1	NS400
	52641	Rectimat 2 400V H	160 kvar 8*20	armoire	2	NS400
	52642	Rectimat 2 400V H	180 kvar 9*20	armoire	2	NS400
	52643	Rectimat 2 400V H	210 kvar 6*35	armoire	2	NS630
	52644	Rectimat 2 400V H	245 kvar 7*35	armoire	3	NS630
	52645	Rectimat 2 400V H	280 kvar 8*35	armoire	3	NS630
	52646	Rectimat 2 400V H	315 kvar 9*35	armoire	3	C801
	52647	Rectimat 2 400V H	350 kvar 10*35	armoire	3	C801
	52648	Rectimat 2 400V H	420 kvar 6*70	armoire	4	C1001
	52649	Rectimat 2 400V H	455 kvar 13*35	armoire	4	C1001
	52650	Rectimat 2 400V H	525 kvar 15*35	armoire	4	C1251
	52651	Rectimat 2 400V H	560 kvar 8*70	armoire	4	C1251
	52652	Rectimat 2 400V H	630 kvar 9*70	armoire	4	CM1600
	52653	Rectimat 2 400V H	700 kvar 10*70	armoire	4	CM1600
SAH	52654	Rectimat 2 400V SAH	25 kvar 2*12,5	armoire	2	NS100
protégé	52655	Rectimat 2 400V SAH	37,5 kvar 3*12,5	armoire	2	NS100
par selfs	52656	Rectimat 2 400V SAH	50 kvar 4*12,5	armoire	2	NS100
	52657	Rectimat 2 400V SAH	62,5 kvar 5*12,5	armoire	2	NS160
	52658	Rectimat 2 400V SAH	75 kvar 3*25	armoire	2	NS160
	52659	Rectimat 2 400V SAH	100 kvar 4*25	armoire	2	NS250
	52660	Rectimat 2 400V SAH	125 kvar 5*25	armoire	3	NS250
	52661	Rectimat 2 400V SAH	150 kvar 6*25	armoire	3	NS400
	52662	Rectimat 2 400V SAH	150 kvar 3*50	armoire	3	NS400
	52663	Rectimat 2 400V SAH	175 kvar 7*25	armoire	3	NS400
	52664	Rectimat 2 400V SAH	200 kvar 4*50	armoire	3	NS400
	52665	Rectimat 2 400V SAH	250 kvar 5*50	armoire	4	NS630
	52666	Rectimat 2 400V SAH	300 kvar 6*50	armoire	4	NS630
	52667	Rectimat 2 400V SAH	350 kvar 7*50	armoire	4	C801
	52668	Rectimat 2 400V SAH	400 kvar 8*50	armoire	4	C801
	52669	Rectimat 2 400V SAH	450 kvar 9*50	armoire	4	C1001
	52670	Rectimat 2 400V SAH	500 kvar 10*50	armoire	4	C1001
accessoires	52671	socle Rectimat 2 fixation au sol coffret	STD et H			
	52672	socle Rectimat 2 H 250 pour armoire L 500	STD et H			
	52673	socle Rectimat 2 H 250 pour armoire L 800	STD et H			
	52674	socle Rectimat 2 H 250 pour armoire L 800	SAH			

Reactive power factor correction

P400 power factor correction modules

Integrate power factor correction modules in standard electrical distribution switchboards



Merlin Gerin
Modicon
Square D
Telemecanique

Schneider Electric
No one in the world does more with electricity!

Contents

The reactive power solution !

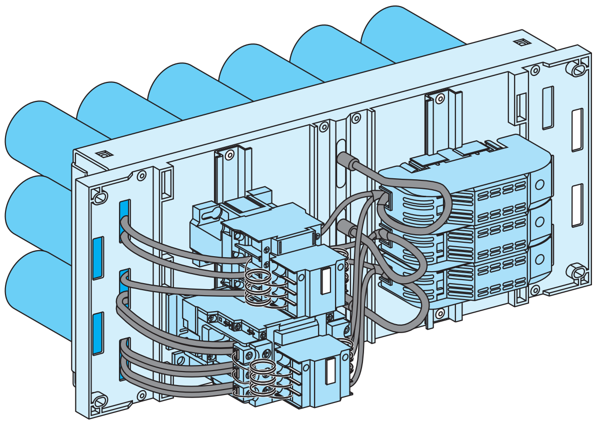
Simplified installation

*The P400 power factor correction module allows for optimal use of your cubicles, **including those that are only 400 mm deep.***

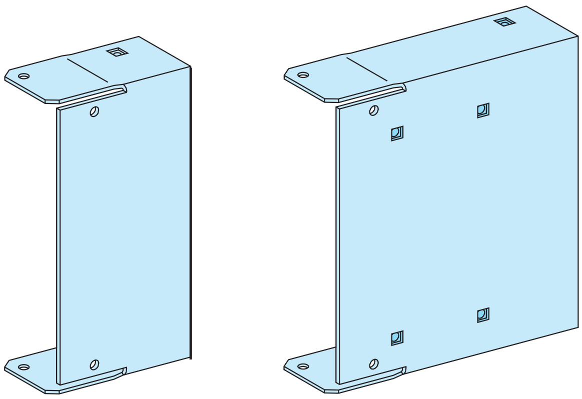
The P400 power factor correction module ensures you benefit from Rectiphase's proven expertise in the area of reactive power correction.
You benefit from a simple solution that is easy to install and that allows you to optimise the assembly of a complete system.

The P400 power factor correction module is a unique solution, compatible with all enclosures

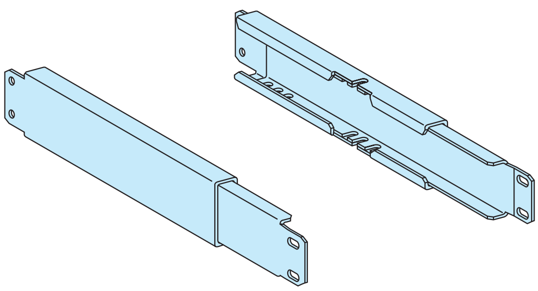
■ The physical size for all reactive power ratings.
■ Adjustable fasteners, adaptable to the dimensions of all enclosures (width, depth).
■ Connection accessories.



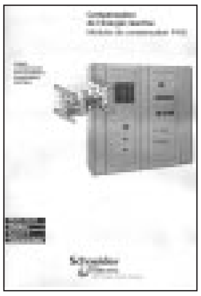
Power factor correction module for cubicle W = 600



Extension pieces for cubicles W = 700 and W = 800



Fastening cross-members adjustable in depth (D = 400 or 500)



Detailed guide

Increased simplicity

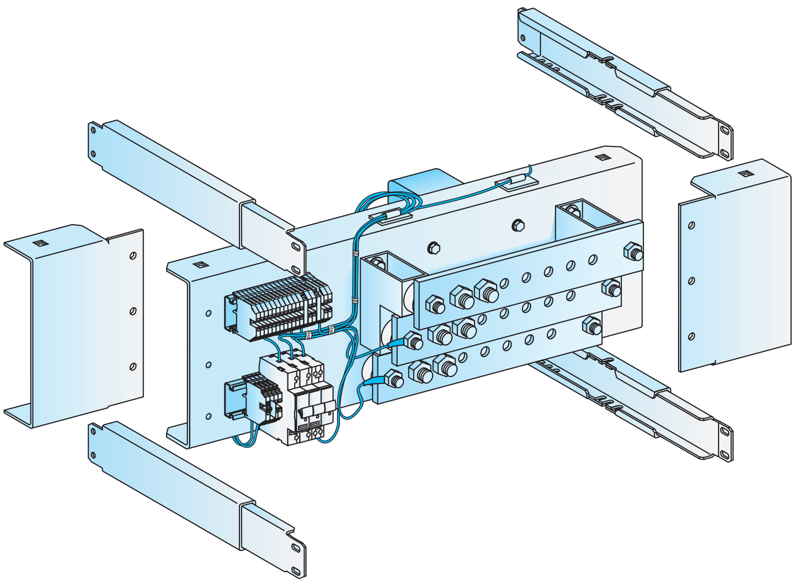
■ Design and ordering of the correction components simplified by a detailed guide.
■ Reduced assembly time :
□ pre-cabled components
□ fastening kits adaptable to any enclosure
□ detailed assembly and connection manual, supplied with each module.

Increased safety

■ Materials and design backed by extensive testing provide proven reliability, longevity and safety unsurpassed in the industry.
■ Detailed instructions guide you through all of the critical aspects of assembling a complete system.
■ The front face of the module is manufactured with IP 20 accessories, guaranteeing "protection against direct contact".

Increased peace of mind

■ Module design is backed by Rectiphase's proven design expertise.
■ Rigorous testing of the module design ensures reliable operation.
■ Each module is completely tested prior to dispatch.



Connection module

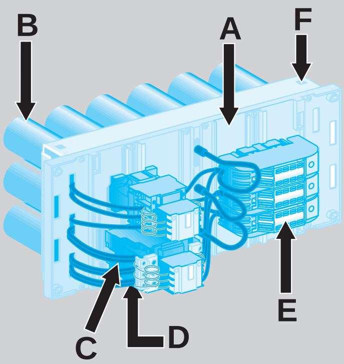
A Rating plate
B Capacitors
C Contactors with preinsertion resistor
D Contactor coil connection terminal block
E Fuses with high breaking capacity (HBC)
F Fixing points (4 M6 captive nuts)

The fuses are not mounted in the delivered module, so as to allow the connection of power cables.

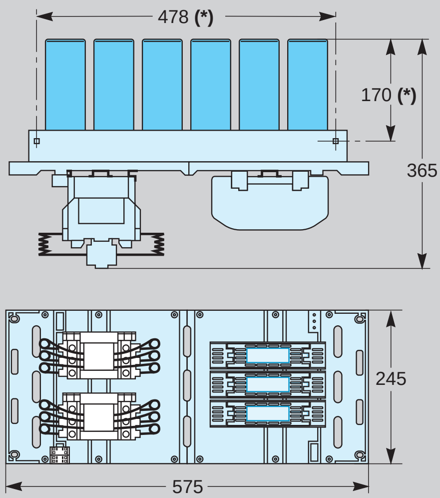
The precabled power factor correction module is a factory-tested subassembly, containing:
- capacitors protected by an overpressure device, associated with a HBC fuse (HQ system).
- 1 or 2 contactors adapted to capacitive breaking, with pre-insertion resistor
- 1 set of 3 HBC fuses, size 0 or 00 (see p. 17).

The power factor correction module can be incorporated into cubicles 600, 700 or 800 mm wide and 400 or 500 mm deep.
The centre distance of the correction module is ideally suited to installation in a 600 mm wide cubicle.
For easy installation in a 700 or 800 mm wide cubicle, it is necessary to increase the width of the power factor correction module by adding a 700 or 800 mm extension piece (ordered separately).
In the case of a cubicle deeper than 500 mm, provide two intermediate vertical uprights.

- Single module:
1 physical step, with a single contactor
- Double module:
2 physical steps, with two contactors.

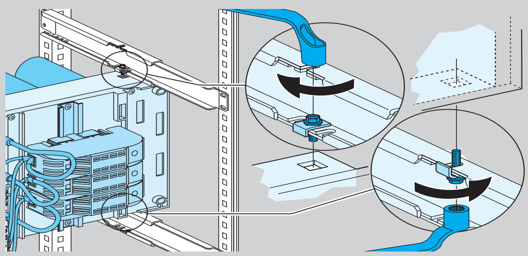


P400 module



(*) entraxe de fixation
fixing point

P400 dimensions, with depth 400 mm



Mounting the module on the P45 cross-members

Type of power factor correction module

Depending upon the degree of harmonic pollution, Rectiphase provides 3 types of correction modules:
- standard
- H
- DR (on quotation).

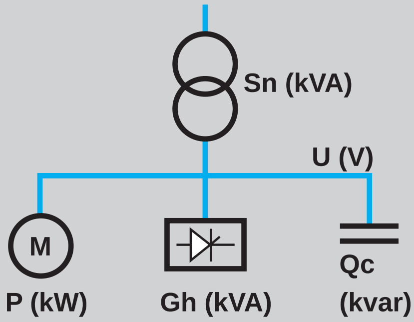
Main harmonic generators:
- variable speed drives
- rectifiers
- electronic starters
- welding machines
- UPS
- arc furnaces, etc.

The Gh/Sn ratio allows you to determine the appropriate type of equipment.

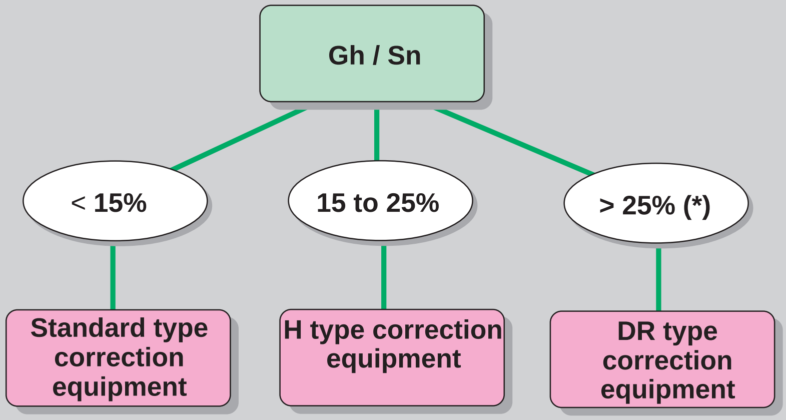
Example 1
U = 400 V
Sn = 800 kVA
P = 450 kW
Gh = 50 kVA
$\frac{Gh}{Sn}$ = 6,2 % → Standard equipment

Example 2
U = 400 V
Sn = 800 kVA
P = 300 kW
Gh = 150 kVA
$\frac{Gh}{Sn}$ = 18,75 % → H type equipment

Example 3
U = 400 V
Sn = 800 kVA
P = 100 kW
Gh = 400 kVA
$\frac{Gh}{Sn}$ = 50 % → DR type equipment



***Sn**: transformer apparent power*
***Gh**: apparent power of harmonic-generating loads (variable speed drives, static switches, power electronics, etc.)*
***Qc**: correction equipment power*
***U**: network voltage.*



(*) Beyond 60 %, a harmonic filtering study is recommended by Rectiphase

Selecting the correct reactive power module

In the event of a customer specification detailing the size and number of steps, refer to page 17 to selection of the relevant modules.
The modules must be chosen according to the control sequences of the power factor controller.

The 6 and 12 step Varlogic power factor controllers allow the following control sequences to be selected:
1-1-1-1-1-1 etc.
1-1-2-2-2-2 etc.
1-2-2-2-2-2 etc.
1-2-3-3-3-3 etc.
1-2-3-4-4-4 etc.
1-2-4-4-4-4 etc.
1-1-2-3-3-3 etc.
1-2-2-3-3-3 etc.

If there are no specifications, we recommend that you use the optimisation tables defined by Rectiphase (see p. 6 and 7).

Example:

Assume a power factor bank 150 kvar, 400 V, 3 phases, 50 Hz, made up of:
1 module + 1 module
15 + 45 kvar 30 + 60 kvar
Step size is: 10 x 15 kvar
and the programming sequence: 1-2-3-4

Optimisation table

Standard type, 400/415 V, 50 Hz

reactive power (kvar)	step size (kvar)	power factor correction modules: physical composition	nbr of modules	controller: R6	R12	sequence	progr.
45	3 x 15	15+30	1	•		1.2.	CB
62.5	5 x 12.5	12.5+25 + 25	2	•		1.2.2	CB
75	5 x 15	15+30 + 30	2	•		1.2.2	CB
90	6 x 15	15+30 + 45	2	•		1.2.3	n
105	7 x 15	15+30 + 60	2	•		1.2.4	n
120	8 x 15	15+30 + 15+ 30 + 30	3	•		1.1.2.2.2	n
125	5 x 25	25+50 + 50	2	•		1.2.2	CB
150	10 x 15	15+45 + 30+60	2	•		1.2.3.4	n
	5 x 30	30+60 + 60	2	•		1.2.2	CB
180	6 x 30	30+60 + 90	2	•		1.2.3.	n
200	8 x 25	25+50 + 50 + 75	3	•		1.2.2.3	n
210	7 x 30	30+30 + 60 + 90	3	•		1.1.2.3.	n
240	8 x 30	30+60 + 60 + 90	3	•		1.2.2.3	n
250	10 x 25	25+25 + 50 + 75 + 75	4	•		1.1.2.3.3	n
270	9 x 30	30+60 + 90 + 90	3	•		1.2.3.3	n
300	10 x 30	30+30 + 60 + 90 + 90	4	•		1.1.2.3.3	n
330	11 x 30	30+60 + 60 + 90 + 90	4	•		1.2.2.3.3	n
360	12 x 30	30+60 + 90 + 90 + 90	4	•		1.2.3.3.3	n
405	9 x 45	45 + 90 + 90 + 90 + 90	5	•		1.2.2.2.2	CB
450	10 x 45	45+45 + 90 + 90 + 90 + 90	5	•		1.1.2.2.2.2	n
495	11 x 45	45 + 90 + 90 + 90 + 90 + 90	6	•		1.2.2.2.2.2	CB
540	12 x 45	45+45 + 90 + 90 + 90 + 90 + 90	6		•	1.1.2.2.2.2.2	n
585	13 x 45	45 + 90 + 90 + 90 + 90 + 90 + 90	7		•	1.2.2.2.2.2.2	CB
630	14 x 45	45+45 + 90 + 90 + 90 + 90 + 90 + 90	7		•	1.1.2.2.2.2.2.2	n
675	15 x 45	45 + 90 + 90 + 90 + 90 + 90 + 90 + 90	8		•	1.2.2.2.2.2.2.2	CB
720	16 x 45	45+45 + 90 + 90 + 90 + 90 + 90 + 90 + 90	8		•	1.1.2.2.2.2.2.2.2	n
765	17 x 45	45 + 90 + 90 + 90 + 90 + 90 + 90 + 90 + 90	9		•	1.2.2.2.2.2.2.2.2	CB
810	18 x 45	45+45 + 90 + 90 + 90 + 90 + 90 + 90 + 90 + 90	9		•	1.1.2.2.2.2.2.2.2.2	n

single module (green)

double module (pink)

CB : Varlogic controller setting for sequence 1.2.2.2 etc.
n : Varlogic controller setting for all sequence types

H type, 400 V, 50 Hz

reactive power (kvar)	step size (kvar)	power factor correction modules		controller			
		physical composition	nbr of modules	R6	R12	sequence	progr.
60	6 x 10	10+20 + 30	2	•		1.2.3	n
70	7 x 10	10+20 + 40	2	•		1.2.4	n
80	8 x 10	10+20 + 20 + 30	3	•		1.2.2.3	n
90	9 x 10	10+20 + 20+40	2	•		1.2.2.4	n
100	5 x 20	20+40 + 40	2	•		1.2.2	CB
120	6 x 20	20+40 + 60	2	•		1.2.3	n
140	7 x 20	20+40 + 40 + 40	3	•		1.2.2.2	CB
160	8 x 20	20+40 + 40 + 60	3	•		1.2.2.3	n
180	9 x 20	20+40 + 60 + 60	3	•		1.2.3.3	n
210	6 x 35	35+35 + 70 + 70	3	•		1.1.2.2	n
245	7 x 35	35 + 70 + 70 + 70	4	•		1.2.2.2	CB
280	8 x 35	35+35 + 70 + 70 + 70	4	•		1.1.2.2.2.	n
315	9 x 35	35 + 70 + 70 + 70 + 70	5	•		1.2.2.2.2	CB
350	10 x 35	35+35 + 70 + 70 + 70 + 70	5	•		1.1.2.2.2.2	n
385	11 x 35	35 + 70 + 70 + 70 + 70 + 70	6	•		1.2.2.2.2.2	CB
420	12 x 35	35+35 + 70 + 70 + 70 + 70 + 70	6		•	1.1.2.2.2.2.2	n
455	13 x 35	35 + 70 + 70 + 70 + 70 + 70 + 70	7		•	1.2.2.2.2.2.2	CB
490	14 x 35	35+35 + 70 + 70 + 70 + 70 + 70 + 70	7		•	1.1.2.2.2.2.2.2	n
560	8 x 70	70 + 70 + 70 + 70 + 70 + 70 + 70 + 70	8		•	1.1.1.1.1.1.1.1	CA
630	9 x 70	70 + 70 + 70 + 70 + 70 + 70 + 70 + 70 + 70	9		•	1.1.1.1.1.1.1.1.1	CA
700	10 x 70	70 + 70 + 70 + 70 + 70 + 70 + 70 + 70 + 70 + 70	10		•	1.1.1.1.1.1.1.1.1.1	CA

H type, 415 V, 50 Hz

reactive power (kvar)	step size (kvar)	power factor correction modules		controllers			
		physical composition	nbr of modules	R6	R12	sequence	progr.
50	4 x 12.5	12.5+12.5 + 25	2	•		1.1.2	n
62.5	5 x 12.5	12.5+25 + 25	2	•		1.2.2	CB
75	6 x 12.5	12.5+25 + 12,5+25	2	•		1.1.2.2	n
87.5	7 x 12.5	12.5+25 + 50	2	•		1.2.4	n
100	4 x 25	25+25 + 50	2	•		1.1.2	n
125	5 x 25	25+50 + 50	2	•		1.2.2	CB
150	6 x 25	25+50 + 75	2	•		1.2.3	n
175	7 x 25	25+50 + 50 + 50	3	•		1.2.2.2	CB
200	8 x 25	25+50 + 50 + 75	3	•		1.2.2.3	n
225	9 x 25	25+50 + 75 + 75	3	•		1.2.3.3	n
250	5 x 50	50 + 50 + 50 + 50 + 50	5	•		1.1.1.1.1	CA
275	11 x 25	25+50 + 50 + 75 + 75	4	•		1.2.2.3.3	n
300	6 x 50	50 + 50 + 50 + 50 + 50 + 50	6	•		1.1.1.1.1.1	CA
350	7 x 50	50 + 50 + 50 + 50 + 50 + 50 + 50	7		•	1.1.1.1.1.1.1	CA
375	5 x 75	75 + 75 + 75 + 75 + 75	5	•		1.1.1.1.1.	CA
400	8 x 50	50 + 50 + 50 + 50 + 50 + 50 + 50 + 50	8		•	1.1.1.1.1.1.1.1	CA
450	6 x 75	75 + 75 + 75 + 75 + 75 + 75	6	•		1.1.1.1.1.1	CA
525	7 x 75	75 + 75 + 75 + 75 + 75 + 75 + 75	7		•	1.1.1.1.1.1.1	CA
600	8 x 75	75 + 75 + 75 + 75 + 75 + 75 + 75 + 75	8		•	1.1.1.1.1.1.1.1	CA
675	9 x 75	75 + 75 + 75 + 75 + 75 + 75 + 75 + 75 + 75	9		•	1.1.1.1.1.1.1.1.1	CA
750	10 x 75	75 + 75 + 75 + 75 + 75 + 75 + 75 + 75 + 75 + 75	10		•	1.1.1.1.1.1.1.1.1.1	CA

single module (green)
double module (pink)

CA : Varlogic controller setting for sequence 1.1.1.1. etc.
CB : Varlogic controller setting for sequence 1.2.2.2 etc.
n : Varlogic controller setting for all sequence types.

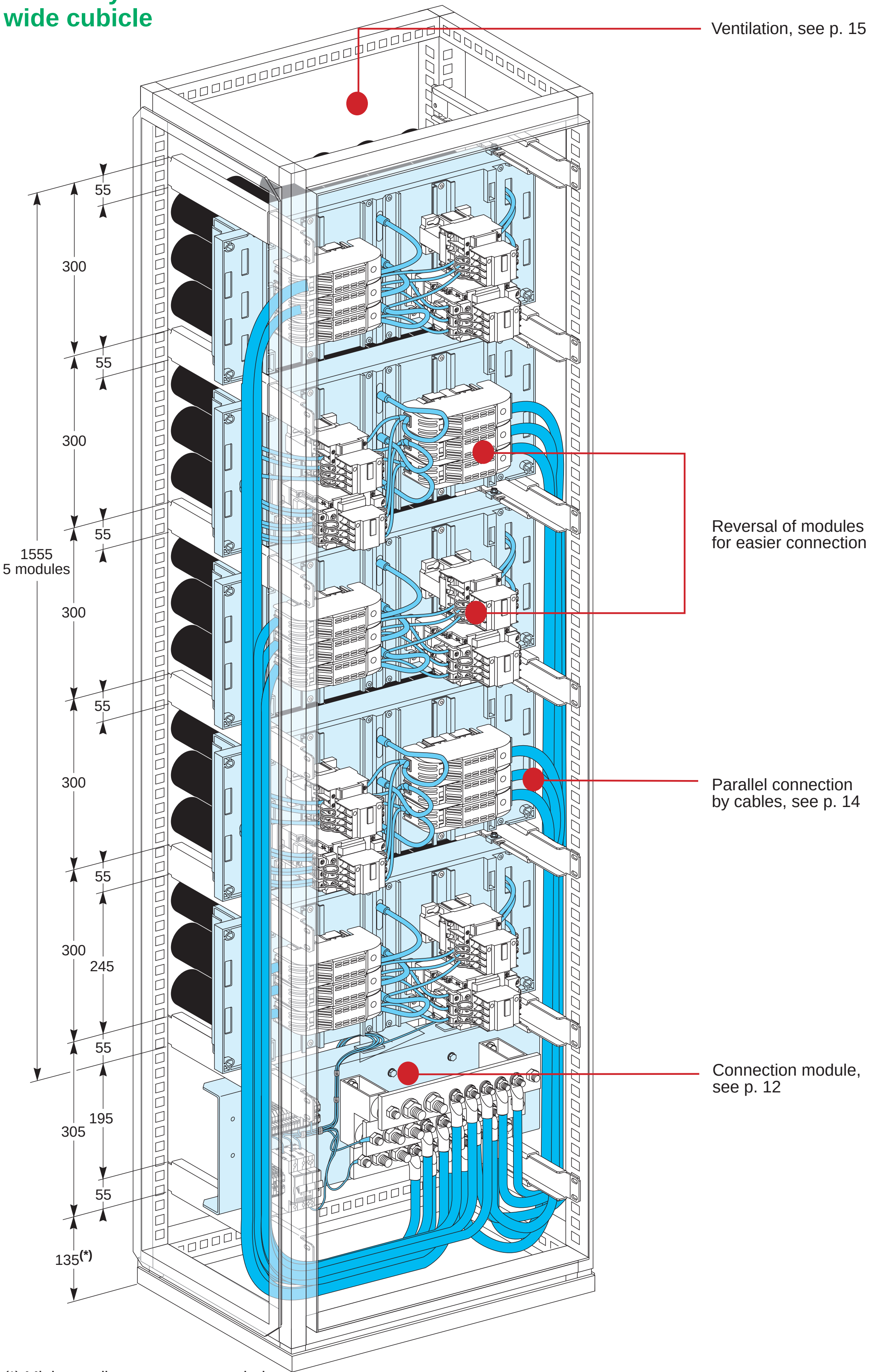
Installation in a unit column 400 or 500 mm deep

subassembly	400 or 500 mm deep cubicles 600, 700 or 800 mm wide
P400 power factor correction module IP 20	for 2000 mm high cubicle: 5 modules maximum + 1 connection module (optional) **and** reactive power per column less than or equal to 405 kvar, 400 V, 50 Hz ** Caution ■ Check that the height of the P400 modules + the height of the connection module and the distance between modules is less than the height available in the column (see assembly diagrams of the 3 types of cubicle, 600, 700 or 800 mm wide) ■ For 700 mm wide Prisma cubicle: 4 modules maximum + 1 connection module (option)
P45 cross-members (1 cat. no. = 1 set of 2 cross-mem)	cross-members common to all cubicle widths, cat. no. **52795** number to be ordered = n * + 1

subassembly	400 or 500 mm deep cubicles		
	600 mm wide	700 mm wide	800 mm wide
extension pieces	none	1 R700 extension piece per pfc module cat. no. **52794** number to be ordered = n*	1 R800 extension piece per pfc module, cat. no. **52796** number to be ordered = n*
parallel-connection of the power factor correction modules	cables	cables	cables or modular busbars IP 0: 1 per module ■ **52801** for module with fuse size 00 (p. 17) ■ **52802** for module with fuse size 0 (p. 17)
connection module IP 00 (delivered with 4 P45 cross-members + extension pieces for 700 and 800 mm wide cubicles)	**cat. no. 52800** number to be ordered = 1 per column		

* n = number of 400 mm deep power factor correction modules
** This power may be greater in air conditioned electrical rooms (consult us)

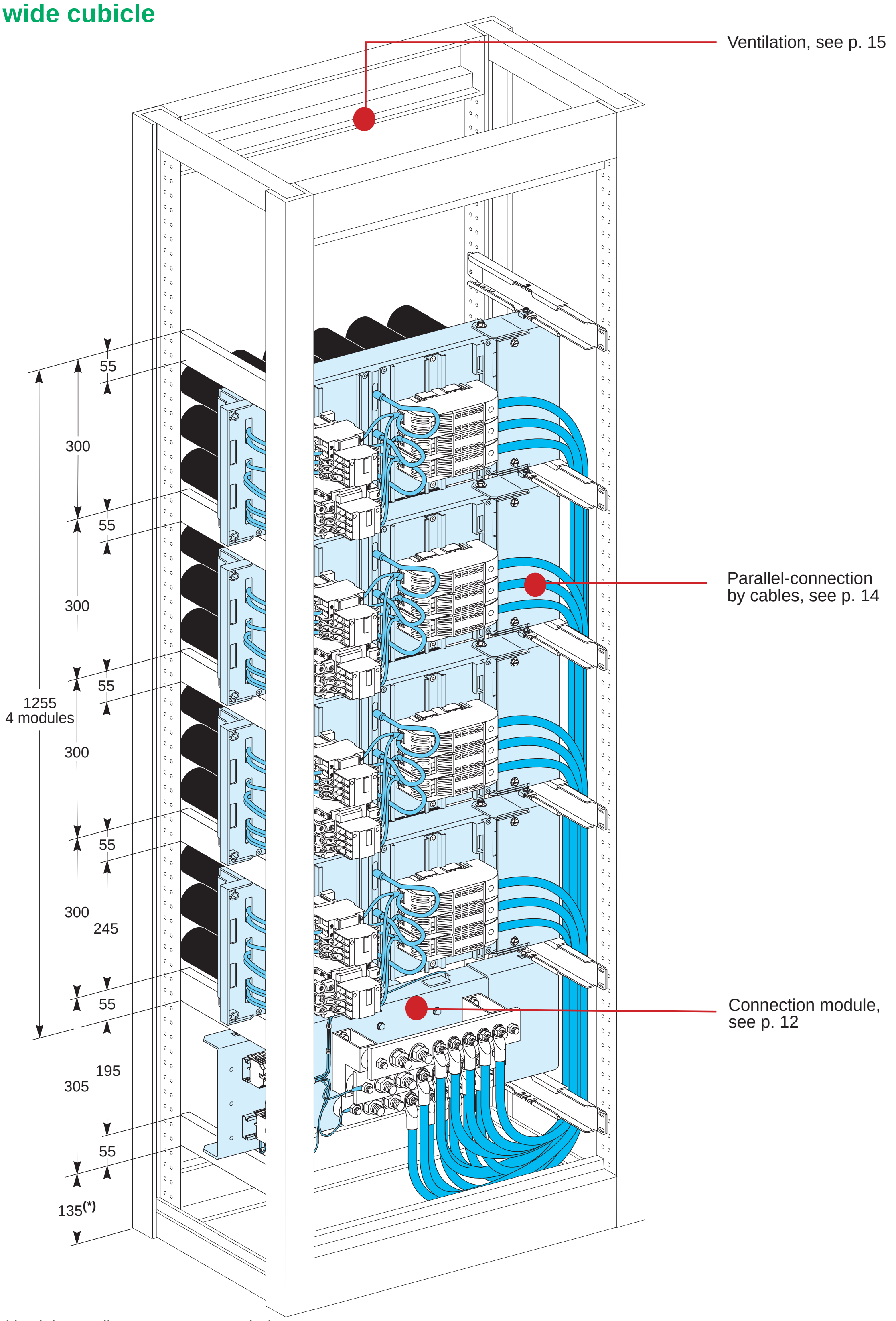
Assembly in 600 mm wide cubicle



(*) Minimum distance recommended for easy connection

Minimum distance between modules = 55 mm

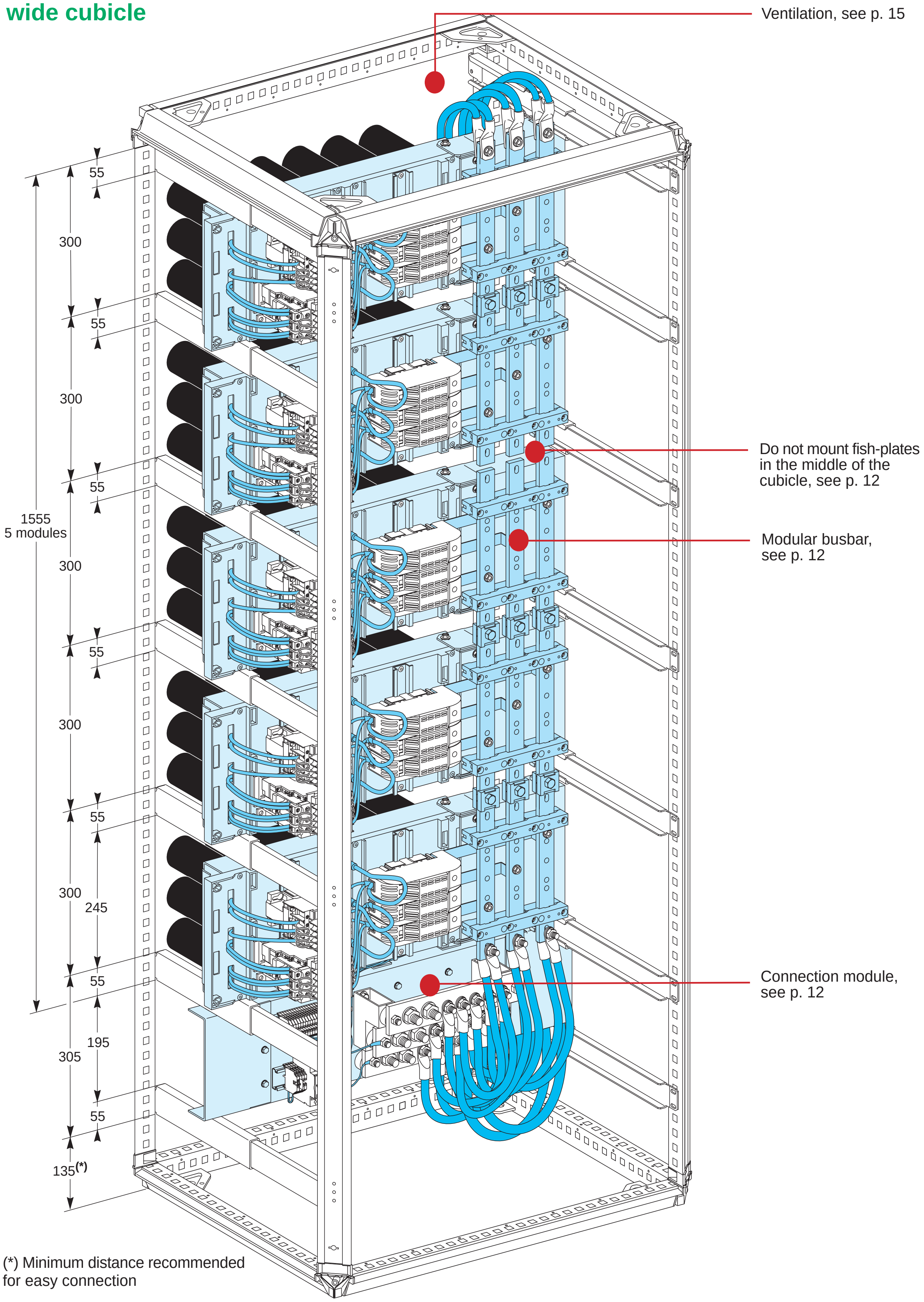
Assembly in 700 mm wide cubicle



(*) Minimum distance recommended
for easy connection

Minimum distance between modules = 55 mm

Assembly in 800 mm wide cubicle



(*) Minimum distance recommended for easy connection

Minimum distance between modules = 55 mm
Power factor correction modules parallel connection is possible by cables, see p. 10

Accessories

P45 fastening cross-members
Specially designed horizontal cross-members allow easy installation of the power factor correction modules in all types of universal cubicles, 400 and 500 mm deep.
Possible fixing centre distances are :
325, 337, 349, 425, 437, 449 ± 4 mm.
Automatically ensure proper depth positioning of the module and maintain the 55 mm distance between modules.
The P45 cross-members, sold in pairs, must be ordered separately.

Extension pieces for 700 and 800 wide cubicles
Allow the extension of the correction modules for 700 and 800 mm wide cubicles.
The extension pieces are delivered with the 4 fixing screws for the module.

IP 00 modular busbars for 800 mm wide cubicles
Maximum constant current :
■ Imp ⩽ 630 A
1 single busbar from top to bottom
Incoming cable at bottom of cubicle
W: fish-plates
■ Imp > 630 A
2 separate busbars
Incoming cable at bottom of cubicle
Incoming cable at top of cubicle
W: fish-plates
Do not mount fish-plates in the middle of the cubicle to separate the 2 busbars.

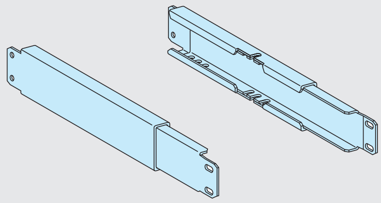
2 busbar catalogue numbers:
■ for fuse size 00
■ for fuse size 0.
Application requiring use of the R800 extension.

IP 00 connection module
Used to connect :
■ the power and control cables of the power factor correction module contactors (5 power factor correction modules maximum)
■ the cubicle supply cables

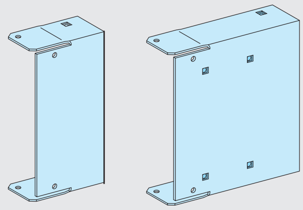
It is supplied with:
■ 4 P45 cross-members
■ 2 extension pieces.

O 3 power connection bars (800 A maxi), marked L1, L2, L3
P Control circuit transformer supplying contactor coils 400/230 V, 250 VA
Q Control circuit protection fuses
R Contactor control distribution terminal block
S P45 sliding cross-members, for mounting in 400 and 500 mm deep cubicles
T Extension pieces for mounting in 700 or 800 mm wide cubicles
U power factor correction module connection : 5 x ø 10 holes per phase
V customer incomer cable connection : 2 x M12 bolts per phase

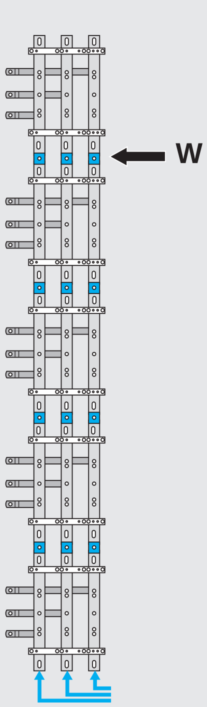
To simplify connection of supply cables, we recommend that you install the connection module at least 19 cm from the ground.



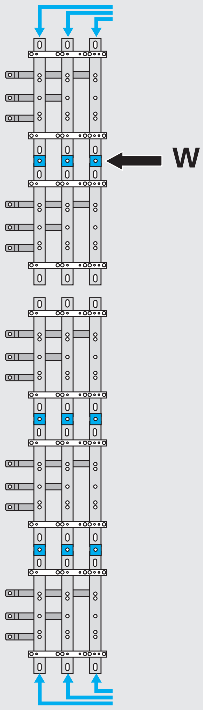
P45 cross-members



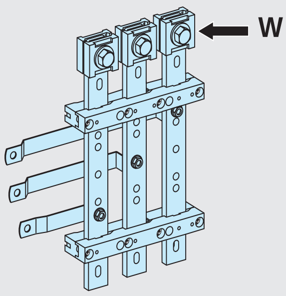
Extension pieces for 700 and 800 wide cubicles



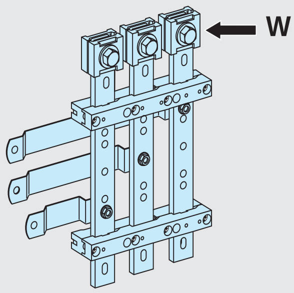
1 busbar for Imp ⩽ 630 A



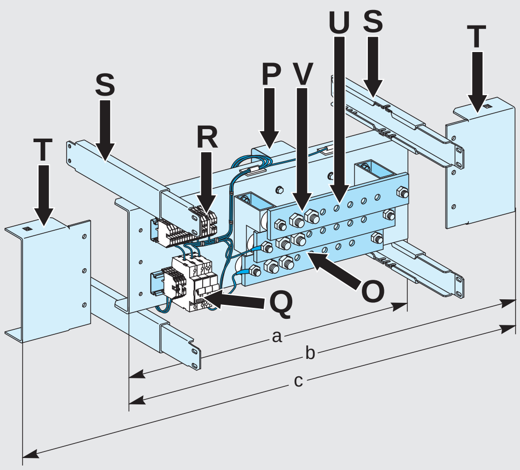
2 busbars for Imp > 630 A



Drawing of busbar with fuse 00

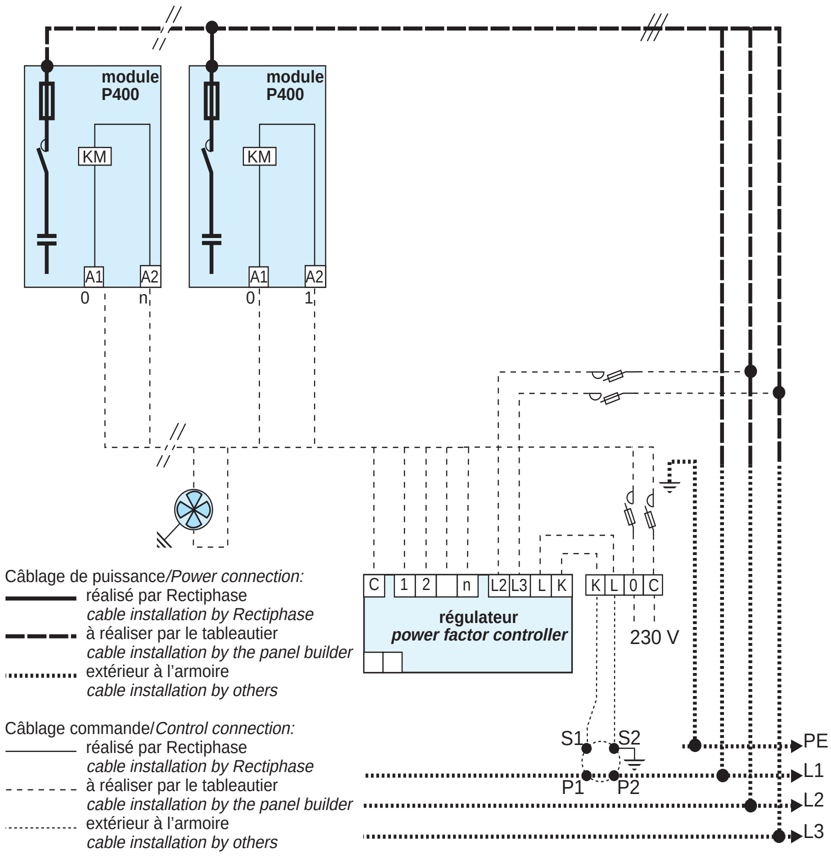


Drawing of busbar with fuse 0

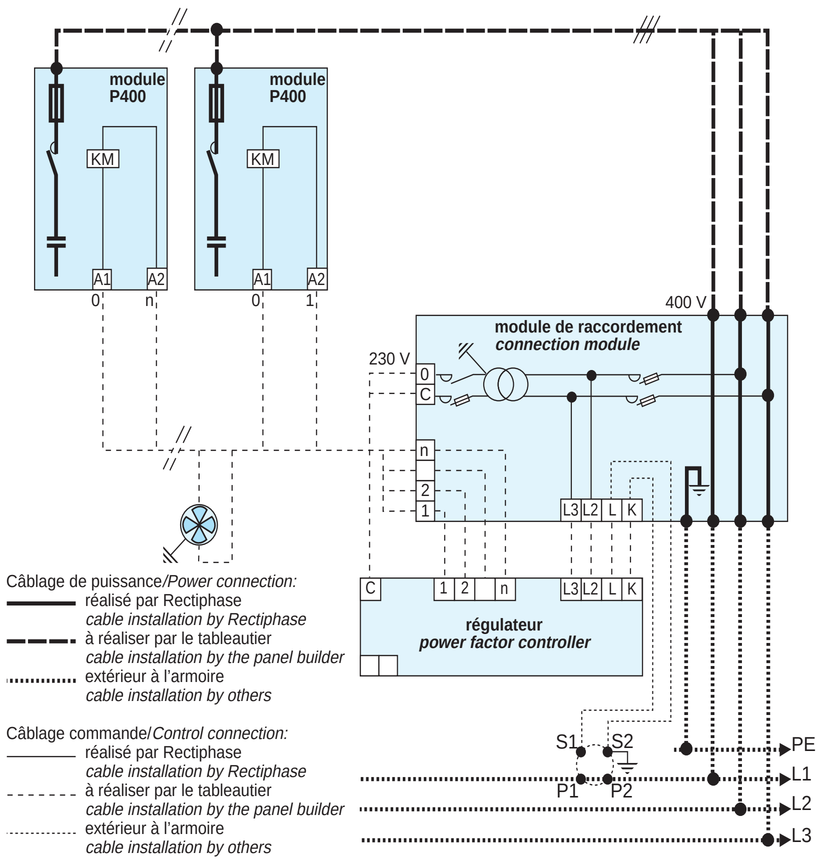


Connection module

Standard single-line diagram of a correction cubicle, without using the connection module



Standard single-line diagram of a correction cubicle, using the connection module



Recommended busbar and cable cross-sections

The cables allowing parallel-connection of the power factor correction modules on the connection module must be sized for a temperature of 50°C and for the maximum constant currents (Imp):

- 1.36 In for standard type module
- 1.43 In for H type module.

(see the In values of the modules, p. 17)

The connection cables and busbars of the correction cubicle must be sized according to the same rules as above (minimum sizing rules, not allowing for any correction factors: temperature, installation method).

$$In = \frac{Q}{U\sqrt{3}}$$

In: nominal current of the power factor correction cubicle or module
U: network voltage
Q: reactive power of the power factor correction cubicle

Recommended general protection

Circuit-breakers

We recommend that you provide general overload and short-circuit protection of the power factor correction cubicles by circuit-breaker.

- Setting the thermal protection:
  - 1.36 In for standard type
  - 1.43 In for H type.
- Setting the short-circuit protection: 10 In for standard and H type.

Fuses

The HPC fuses must be of the Gg type and sized at 1.5 In.

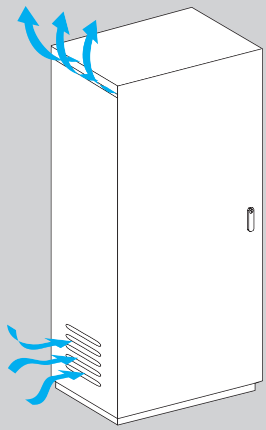
Ventilation

The capacitors, contactors, fuses and electrical connections dissipate heat: 2.5 W/kvar.
The ventilation rules apply if the ambient air temperature around the electric cubicle complies with the following limits:
- maximum temperature: 40 °C
- average temperature over 24 hours: 35 °C
- average temperature over 1 year: 25 °C.

Ventilation rules

These rules apply to cubicles of height H = 2000 mm, width W = 600, 700 and 800 mm, depth D = 400 and 500 mm and power less than or equal to 405 kvar/ 400 V - 50 Hz per column

- The air flow inside the cubicle must flow upwards.
- The cross-section of the top opening must be at least 1.1 times that of the bottom opening.
- The openings must be compatible with the degree of protection (IP).



If the degree of protection of the cubicle (IP) is ⩽ 3X

reactive power (kvar at 400 V - 50 Hz)	type of ventilation	air inlet	min. air flow (m^3/hour)
power ⩽ 100 kvar	natural	200 cm^2	
power from 100 to 200 kvar	natural	400 cm^2	
power > 200 kvar	forced		⩾ 0.75 times power in kvar

If the degree of protection of the cubicle (IP) is > 3X

reactive power (kvar at 400 V - 50 Hz)	type of ventilation	min. air flow (m^3/hour)
all powers	forced	⩾ 0.75 times power in kvar

Quotation assistance

correction cubicle power: ....
voltage: ....

electrical control: ....
frequency: ....

description	quantity	cat. number	unit price	total
single correction module				
double correction module				
cross-members (quantity per column: n * + 1)				
extension piece for cubicle W = 700 (1 per module)				
extension piece for cubicle W = 800 (1 per module)				
modular busbars for parallel-connection of modules in 800 mm wide cubicle (1 busbar per module) ■ for fuse size 0 **				
■ for fuse size 00 **				
connection module for 600, 700 or 800 mm wide cubicles				
Varlogic controller				
fan				
power cables				
control wiring				
cubicles				
auxiliaries***: ■ controller protection				
■ 230 V auxiliary supply protection				
■ fan protection				
■ 400/230 V **** transformer				
miscellaneous/accessories				
labour				

* n = number of correction modules per column
** See tables, page 17
*** Necessary if the connection module is not used
**** 400/230 V transformer: 250 VA for 6 contactors maximum and 400 VA for 7 to 12 contactors.

Supplied by Rectiphase (rows from single correction module to Varlogic controller)
Supplied by Panel-builder (rows from fan to labour)

Range and catalogue numbers

power (kvar)	type	In (A)	fuse size	cat. number
P400 correction modules				
standard type, network 400/415 V, 50 Hz				
25	single	36	00	**52748**
30	single	44	00	**52749**
45	single	65	00	**52750**
50	single	72	00	**52751**
60	single	87	00	**52752**
75	single	108	0	**52753**
90	single	130	0	**52754**
12.5 + 25	double	54	00	**52755**
15 + 30	double	65	00	**52756**
15 + 45	double	87	00	**52757**
25 + 25	double	72	00	**52758**
25 + 50	double	108	00	**52759**
30 + 30	double	87	00	**52760**
30 + 60	double	130	0	**52761**
45 + 45	double	130	0	**52762**
H type, network 400 V, 50 Hz (470 V dielectric)				
20	single	29	00	**52763**
30	single	44	00	**52764**
35	single	51	00	**52803**
40	single	58	00	**52765**
50	single	72	00	**52766**
60	single	87	00	**52767**
70	single	101	0	**52768**
10 + 20	double	40	00	**52769**
10 + 30	double	58	00	**52770**
10 + 40	double	72	00	**52771**
20 + 40	double	87	00	**52772**
30 + 30	double	87	00	**52773**
35 + 35	double	101	0	**52774**
H type, network 415 V, 50 Hz (470 V dielectric)				
25	single	35	00	**52779**
50	single	70	00	**52780**
75	single	104	0	**52781**
12.5 + 12.5	double	35	00	**52775**
12.5 + 25	double	52	00	**52776**
25 + 25	double	70	00	**52777**
25 + 50	double	104	0	**52778**
connection module				
with its fastening kit (600, 700, 800)				**52800**
accessories				
fastening cross-members				
set of 2 P45 cross-members				**52795**
correction module extension				
for cubicle W = 700				**52794**
for cubicle W = 800				**52796**
modular busbars for 800 modules				
for fuses size 00				**52801**
for fuses size 0				**52802**
controllers				
R6 (6 steps)				**52400**
R12 (12 steps)				**52401**

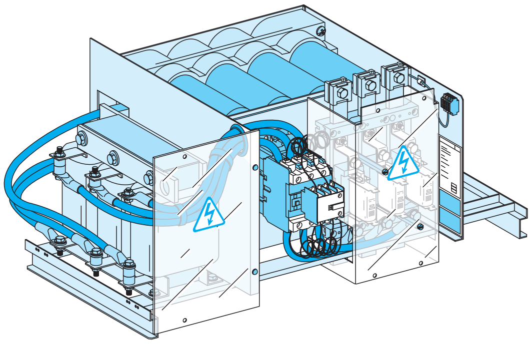
The reactive power solution !

Simplified installation

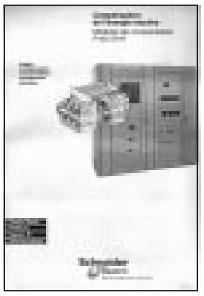
*The P400 DR power factor correction module allows for optimal use of your cubicle, **including those that are only 400 mm deep.***
The P400 DR power factor correction module ensures you benefit from Rectiphase's proven expertise in the area of power factor correction.
You benefit from a simple solution that is easy to install and that allows you to optimise the assembly of a complete system.

The P400 DR power factor correction module is a unique solution, compatible with all enclosures

■ A single physical size for 3 powers and 3 tuning frequencies to standardise your cubicles.
■ An adjustable fastening support, adaptable to the dimensions of all cubicles (width and depth).
■ A modular busbar.



P400 DR power factor correction module



Detailed guide

Increased simplicity

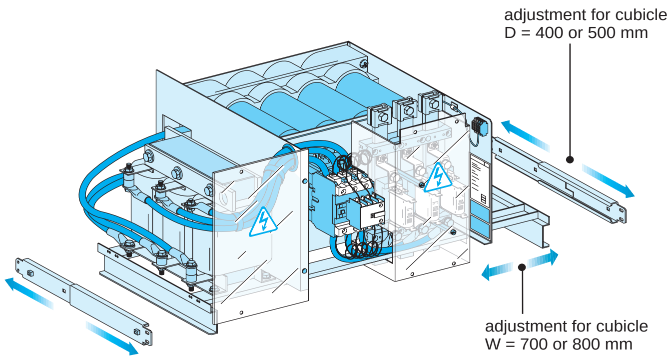
■ Design and ordering of the correction components simplified by a detailed guide.
■ Reduced assembly time:
□ precabled components
□ fastening system adaptable to any enclosure size
□ detailed assembly and connection manual, supplied with each module

Increased safety

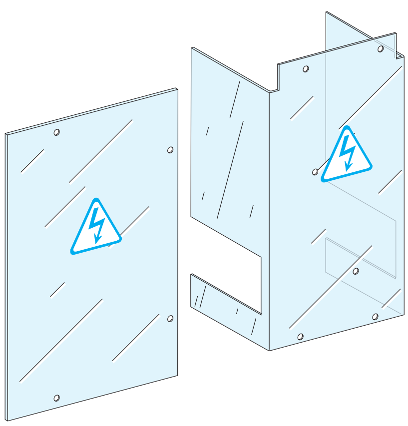
■ Materials and design backed by extensive testing provide proven reliability, longevity and safety unsurpassed in the industry.
■ Detailed instructions guide you through all of the critical aspects of assembling a complete system.
■ The front face of the module is manufactured with accessories, guaranteeing protection against direct contact.
■ The detuned reactor is equipped with a temperature probe.

Increased peace of mind

■ Module design is backed by Rectiphase's proven design expertise.
■ Rigorous testing of the module design ensures reliable operation.
■ Each module is completely tested prior to dispatch.



Fastening system adaptable to the various cubicle sizes

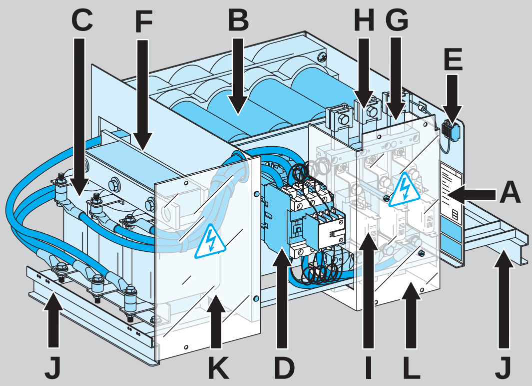


Screens protecting the detuned reactor and modular busbar against direct contact

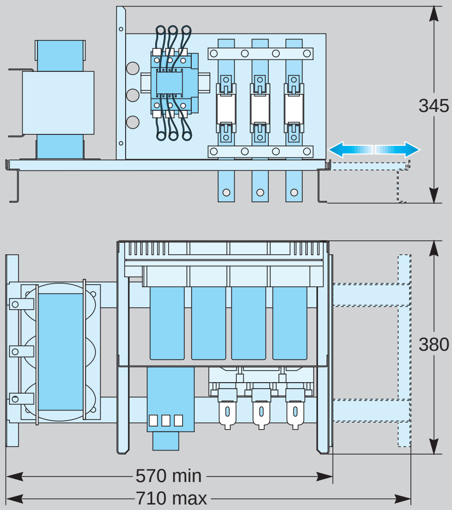
P400 DR correction modules

The P400 DR, 400 V, 50 Hz power factor correction module is a subassembly precabled and tested in the factory. It consists of:
■ 1 indication marking **(A)**
■ 1 Varplus M1 or M4 capacitor **(B)**, rating 470 V, each component of which is protected by an overpressure disconnect device, associated with a HBC fuse (HQ system)
■ 1 detuned reactor **(C)**, with a tuning frequency of 135, 190 or 215 Hz
■ 1 thermal protection **(F)**, included in the detuned reactor
■ 1 detuned reactor direct contact protection device **(K)**
■ 1 contactor **(D)**, adapted to capacitive breaking, with 230 V, 50 Hz coil
■ 1 connection terminal block **(E)** for the contactor coil
■ 1 set of HBC fuses **(I)**, size 00
■ 1 modular busbar **(G)** 30 x 10 mm with fishplates **(H)**, for parallel connection of several modules and connection
Maximum constant current: Imp = 630 A
■ 1 modular busbar direct contact protection device **(L)**
■ 2 support rails **(J)**, (width adjusted)
■ 2 sliding cross-members, used to install the correction modules in all 400 or 500 mm deep universal cubicles and for inter-module spacing ensuring good dissipation of losses.

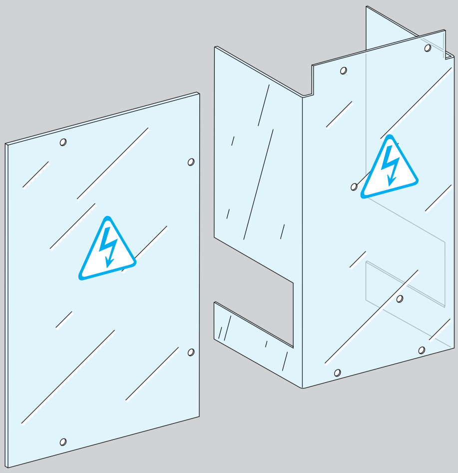
The correction module is incorporated into cubicles 700 or 800 mm wide and 400 or 500 mm deep by means of support rails and adjustable cross-members:
■ the support rails allow width adjustment of 570 to 710 mm
■ the two sliding cross-members ensure the following fastening centre distances in depth:
□ 320 to 354 mm (± 4 mm)
□ 420 to 454 mm (± 4 mm).
In the case of a cubicle deeper than 500 mm, provide two intermediate vertical uprights.

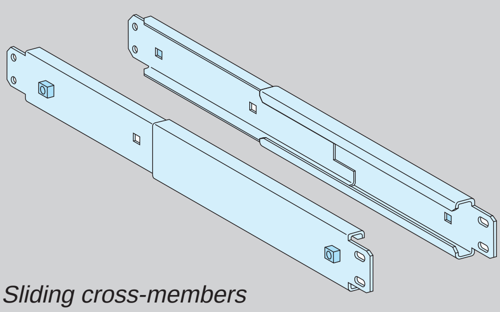


P400 DR module



Module dimensions


Protective covers


Sliding cross-members

Type of power factor correction module

Depending upon the degree of harmonic pollution, Rectiphase provides 3 types of correction modules:
- P400 standard and P400 H
- P400 DR (with detuned reactors).

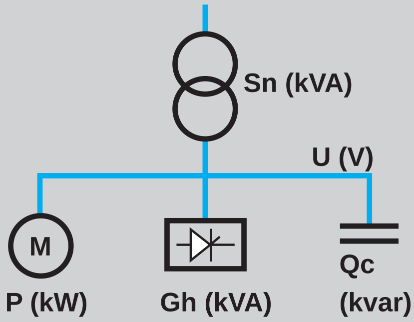
Main harmonic generators:
- variable speed drives
- rectifiers
- electronic starters
- welding machines
- UPS
- arc furnaces, etc.

The Gh/Sn ratio allows you to determine the appropriate type of equipment.

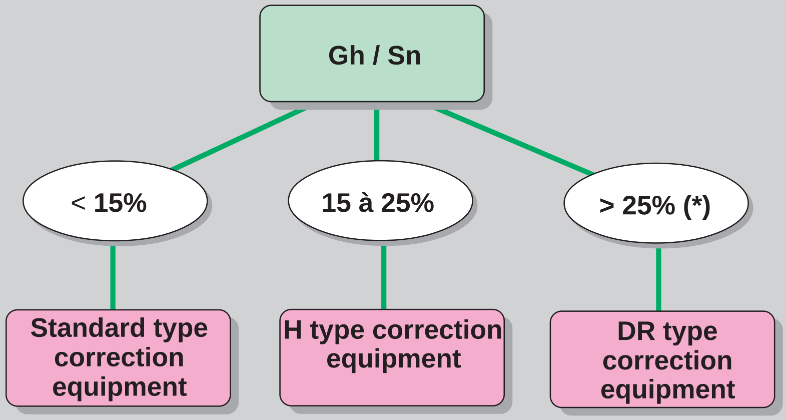
Example 1
U = 400 V
Sn = 800 kVA
P = 450 kW
Gh = 50 kVA
$\frac{Gh}{Sn}$ = 6,2 % → Standard equipment

Example 2
U = 400 V
Sn = 800 kVA
P = 300 kW
Gh = 150 kVA
$\frac{Gh}{Sn}$ = 18,75 % → H type equipment

Example 3
U = 400 V
Sn = 800 kVA
P = 100 kW
Gh = 400 kVA
$\frac{Gh}{Sn}$ = 50 % → DR type equipment



***Sn**: transformer apparent power*
***Gh**: apparent power of the harmonic-generating loads (variable speed drives, static switches, power electronics, etc.)*
***Qc**: correction equipment power*
***U**: network voltage*



(*) Beyond 60 %, a harmonic filtering study is recommended by Rectiphase

Selecting the correct reactive power module

In the event of a customer specification detailing the size and number of steps, refer to page 11 for selection of the relevant modules.
The modules must be chosen according to the control sequences of the power factor controller.

The 6 and 12 step Varlogic power factor controllers allow the following control sequences to be selected:
1-1-1-1-1-1 etc.
1-1-2-2-2-2 etc.
1-2-2-2-2-2 etc.
1-2-3-3-3-3 etc.
1-2-3-4-4-4 etc.
1-2-4-4-4-4 etc.
1-1-2-3-3-3 etc.
1-2-2-3-3-3 etc.

If there are no specifications, we recommend that you use the optimisation tables defined by Rectiphase (see p. 7)

Example:
Assume a power factor bank 75 kvar, 400 V, 3 phases, 50 Hz, made up of:
2 modules + 2 modules
12.5 +12.5 kvar 25 + 25 kvar
Step size is : 6 x 12.5 kvar
and the programming sequence: 1-1-2-2

Choice of detuned reactor tuning frequency

The P400 DR, 400 V, 50 Hz power factor correction module range offers a wide selection of tuning frequencies: 135, 190 or 215 Hz.

Reminder

The aim of a detuned reactor is to protect capacitors and prevent amplification of harmonics. However, use of detuned reactors can reduce pollution by absorbing part of the harmonic currents generated. Improvements are particularly noticeable when detuned reactor tuning frequency approaches the harmonic frequency domain.
A reactor tuned at 215 Hz will absorb more 5th order harmonic current than a reactor at 190 Hz or 135 Hz.

Tuning frequency must be chosen according to:
■ the harmonic frequencies present on the installation (tuning frequency must always be less than the harmonic frequency domain)
■ the remote control frequencies, if any, used by electrical utilities.

DR, 400 V, 50 Hz tuning frequency selection table

harmonic generators (Gh)	remote control frequency (Ft)			
	none	165 < Ft ⩽ 250 Hz	250 < Ft ⩽ 350 Hz	Ft > 350 Hz
three-phase: variable speed drives, rectifiers, UPS, starters	tuning frequency 135 Hz 190 Hz 215 Hz *	tuning frequency 135 Hz	tuning frequency 190 Hz	tuning frequency 215 Hz
single-phase: discharge lamps, lamps with electronic ballast, fluorescent lamps, UPS, variable speed drives, welding machines	tuning frequency 135 Hz	tuning frequency 135 Hz	tuning frequency 135 Hz	tuning frequency 135 Hz
three-phase + single-phase: Gh 1Ph < 10 % of Sn	tuning frequency 135 Hz 190 Hz 215 Hz *	tuning frequency 135 Hz	tuning frequency 190 Hz	tuning frequency 215 Hz
Gh 1 Ph > 10 % of Sn	135 Hz	135 Hz	135 Hz	135 Hz

* Recommended tuning frequency, allowing a greater reduction in 5th order harmonic pollution than the other tuning frequencies.
Gh 1Ph: power of single-phase harmonic generators in kVA.

Concordance between tuning frequency, tuning order and relative impedance (400 V, 50 Hz network)

tuning frequency (fr)	tuning order (n = fr/f)	relative impedance ($P = 1/n^2$) as a %
135 Hz	2.7	13.7 %
190 Hz	3.8	6.92 %
215 Hz	4.3	5.4 %

Optimisation table

DR type, 400 V, 50 Hz

Tuning: 135, 190 or 215 Hz

reactive power (kvar)	step size (kvar) *	power factor correction modules		controller			
		physical composition	nbr of modules	R6	R12	sequence	progr.
25	2 x 12.5	12.5 + 12.5	2	•		1.1	CA
37.5	3 x 12.5	12.5 + 25	2	•		1.2	CB
50	4 x 12.5	12.5 + 12.5 + 25	3	•		1.1.2	n
62.5	5 x 12.5	12.5 + 25 + 25	3	•		1.2.2	CB
75	6 x 12.5	12.5 + 12.5 + 25 + 25	4	•		1.1.2.2	n
	3 x 25	25 + 50	2	•		1.2	CB
87.5	7 x 12.5	12.5 + 25 + 50	3	•		1.2.4	n
100	4 x 25	25 + 25 + 50	3	•		1.1.2	n
125	5 x 25	25 + 50 + 50	3	•		1.2.2	CB
150	6 x 25	25 + 25 + 50 + 50	4	•		1.1.2.2	n
175	7 x 25	25 + 50 + 50 + 50	4	•		1.2.2.2	CB
200	4 x 50	50 + 50 + 50 + 50	4	•		1.1.1.1	CA
225	9 x 25	25 + 50 + 50 + 50 + 50	5	•		1.2.2.2.2	CB
250	5 x 50	50 + 50 + 50 + 50 + 50	5	•		1.1.1.1.1	CA
275	11 x 25	25 + 50 + 50 + 50 + 50 + 50	6	•		1.2.2.2.2.2	CB
300	6 x 50	50 + 50 + 50 + 50 + 50 + 50	6	•		1.1.1.1.1.1	CA
350	6 x 50	50 + 50 + 50 + 50 + 50 + 50 + 50	7		•	1.1.1.1.1.1.1	CA
400	8 x 50	50 + 50 + 50 + 50 + 50 + 50 + 50 + 50	8		•	1.1.1.1.1.1.1.1	CA
450	9 x 50	50 + 50 + 50 + 50 + 50 + 50 + 50 + 50 + 50	9		•	1.1.1.1.1.1.1.1.1	CA
500	10 x 50	50 + 50 + 50 + 50 + 50 + 50 + 50 + 50 + 50 + 50	10		•	1.1.1.1.1.1.1.1.1.1	CA

(*) Suggestion if no specification given
Other powers and step sizes are possible by combining existing modules (see p. 11).

Example : 150 kvar, 400 V, 50 Hz
possible step sizes: 12 x 12.5 kvar
6 x 25 kvar
3 x 50 kvar

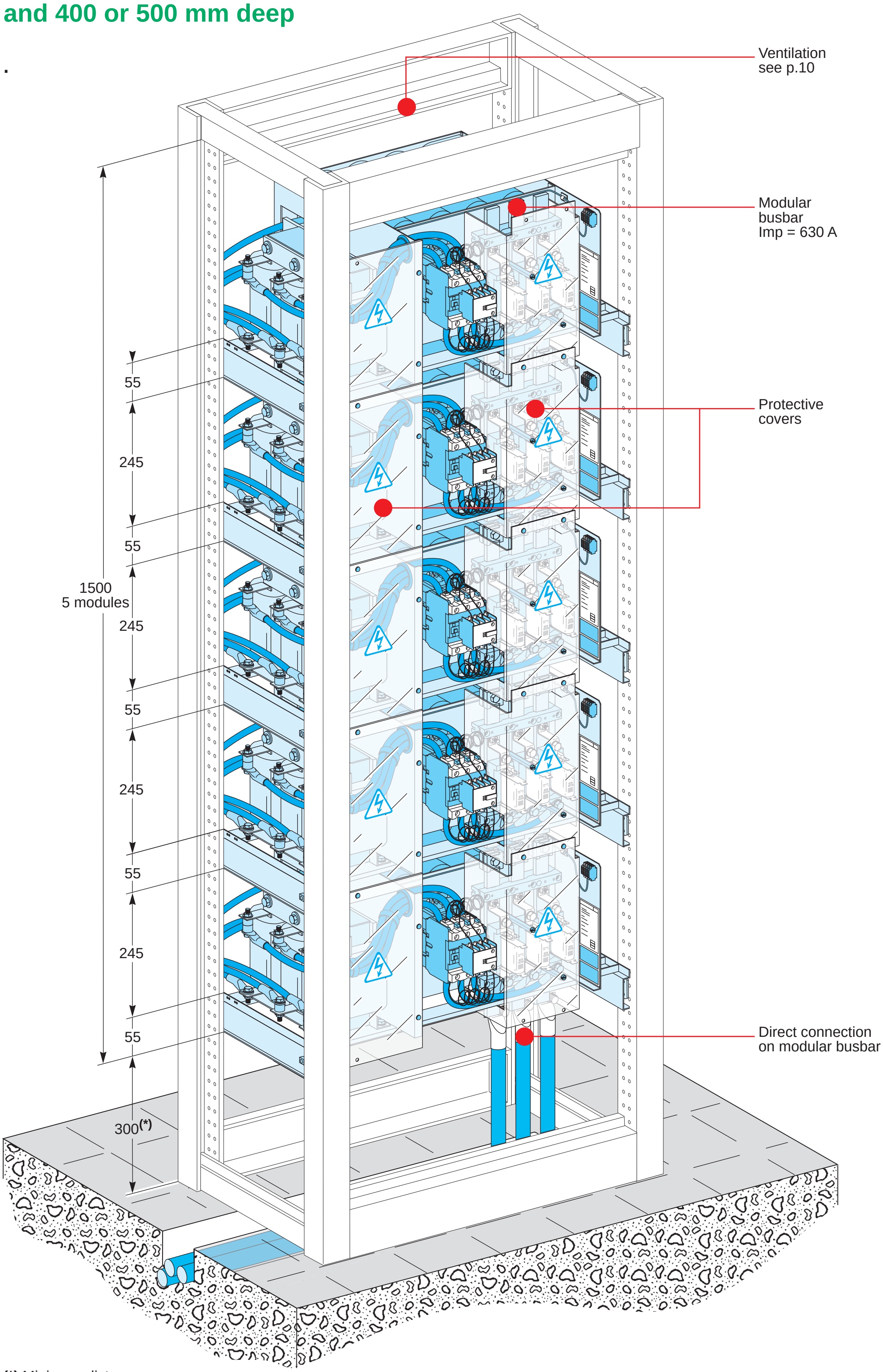
CA: Varlogic controller setting for sequence 1.1.1.1 etc.
CB: Varlogic controller setting for sequence 1.2.2.2 etc.
n : Varlogic controller setting for all sequence types

Installation in the cubicle

Assembly in cubicle 700 or 800 mm wide and 400 or 500 mm deep

.

For a 2000 mm high cubicle: 5 modules maximum
and reactive power less than or equal to 250 kvar, 400 V, 50 Hz



(*) Minimum distance recommended for easy connection

Standard single-line diagram for a DR power factor correction cubicle

The cables used to connect the power factor correction cubicle must be sized for the following maximum constant currents (Imp):

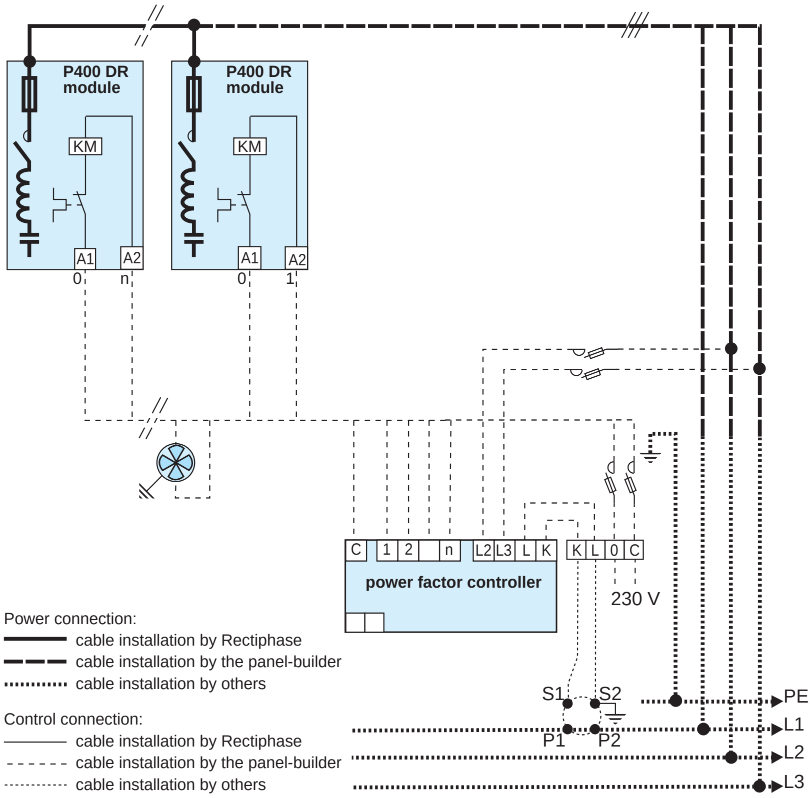
400 V/50 Hz

tuning frequency	tuning order	relative impedance	Imp
135 Hz	2.7	13.7 %	1.12 In
190 Hz	3.8	6.9 %	1.19 In
215 Hz	4.3	5.4 %	1.31 In

(minimum sizing rules, not allowing for any correction factors: temperature, installation method).

$$In = \frac{Q}{U\sqrt{3}}$$

In : nominal current of the power factor correction cubicle
U : network voltage
Q : reactive power of the power factor correction cubicle



Recommended general protection

Circuit-breakers

We recommend that you provide general overload and short-circuit protection of the power factor correction cubicles by circuit-breaker.

■ Setting the thermal protection Imp:

400 V/50 Hz

tuning frequency	tuning order	relative impedance	Imp
135 Hz	2.7	13.7 %	1.12 In
190 Hz	3.8	6.9 %	1.19 In
215 Hz	4.3	5.4 %	1.31 In

■ Setting the short-circuit protection: 10 In.

Fuses

The HBC fuses must be of the Gg type and sized as in the table below.

400 V/50 Hz

tuning frequency	tuning order	relative impedance	fuse current rating
135 Hz	2.7	13.7 %	1.23 In
190 Hz	3.8	6.9 %	1.3 In
215 Hz	4.3	5.4 %	1.44 In

Ambient air temperature

The ambient air temperature around the electrical cubicle must comply with the following limits:

- maximum temperature: 40 °C
- average temperature over 24 hours: 35 °C
- average temperature over 1 year: 25 °C.

Ventilation rules

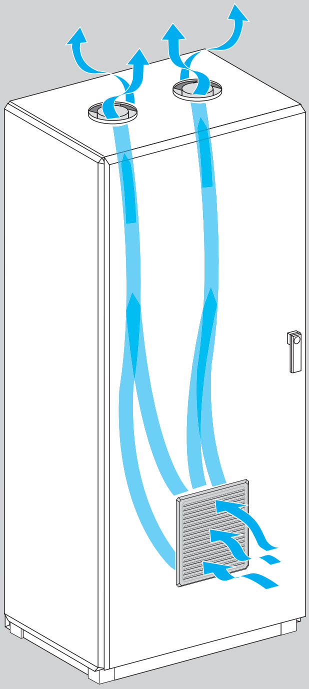
The capacitors, detuned reactors, contactors, fuses and electrical connections dissipate heat: 8 W/kvar.

The following ventilation rules must therefore be complied with:

- ventilation must be forced
- the **real** air flow (m^3/h - allow for pressure drops of incoming and outgoing air) must be greater than or equal to twice installed power (kvar).
For example: for an installed power of 200 kvar, real air flow must be 400 m^3/h
- air inside the cubicle must flow upwards.
We recommend that you install extractor type fans on the roof of the cubicle.

Applications

These rules apply to cubicles of height H = 2000 mm, width W = 700 and 800 mm, depth D = 400 and 500 mm and power less than or equal to 250 kvar/400 V - 50 Hz per column and for all degrees of protection (IP) of the cubicle.



P400 DR, 400/415 V, 50 Hz power factor correction modules

tuning frequency	power (kvar)	weight (kg)	HBC fuse rating (A)	catalogue number
135 Hz	12.5	29	40	**52782**
	25	42	63	**52783**
	50	59	125	**52784**
190 Hz	12.5	26	40	**52785**
	25	34	63	**52786**
	50	48	125	**52787**
215 Hz	12.5	27	40	**52788**
	25	36	63	**52789**
	50	49	125	**52790**
accessories				
controllers	R6 (6 steps)			**52400**
	R12 (12 steps)			**52401**

Quotation Assistance

power factor correction cubicle power: ....
voltage: ....
electrical control: ....
frequency: ....

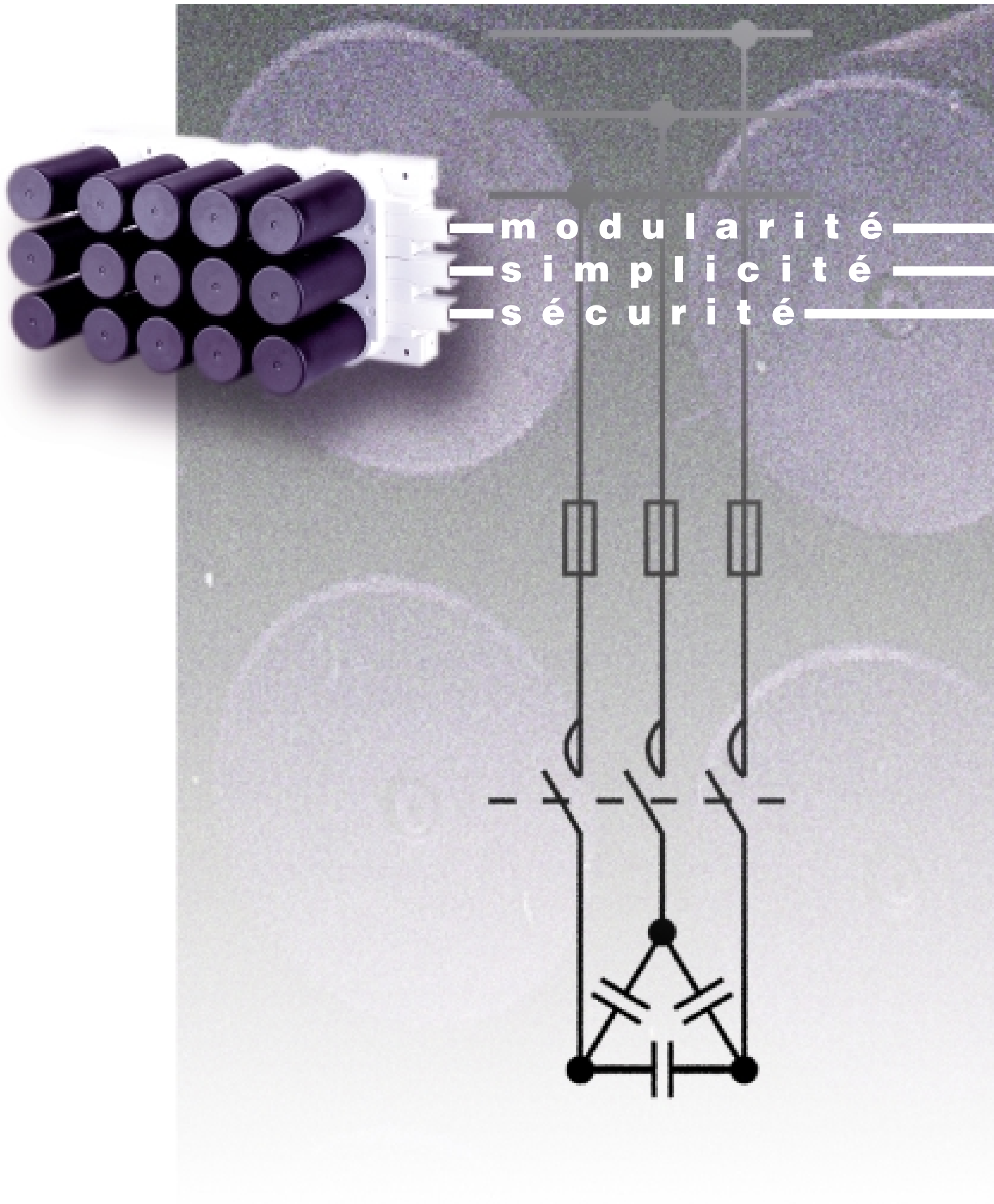
description	quantity	cat. number	unit price	Total
power factor correction module				
Varlogic controller				
fan				
power cables				
control wiring				
cubicles				
auxiliaries: ■ controller protection				
■ 230 V auxiliary supply protection				
■ fan protection				
■ 400/230 V transformer*				
miscellaneous/accessories				
labour				

* 400/230 V transformer: 250 VA for 6 contactors maximum and 400 VA for 7 to 12 contactors.

Supplied by Rectiphase

Supplied by Panel-builder

Condensateurs BT
Varplus M



Merlin Gerin
Modicon
Square D
Telemecanique

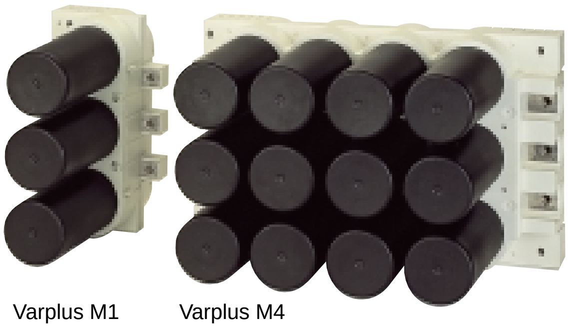
Schneider Electric
Qui fait autant avancer l'électricité ?

Une offre modulaire

Les condensateurs Varplus M permettent de couvrir une large gamme de tension (de 230 V à 690 V) et de puissance (de 5 à 100 kvar sous 400 V 50 Hz) à partir d'un nombre limité de références.
Les puissances sont obtenues par :

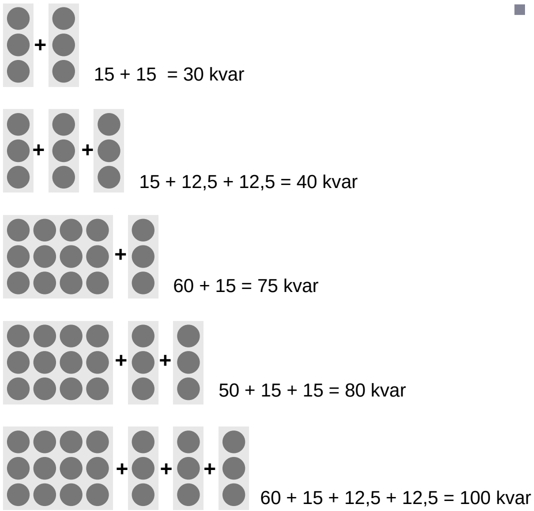
- l'utilisation des condensateurs Varplus M1 ou Varplus M4 seuls,
- l'assemblage de plusieurs condensateurs Varplus M1,
- l'assemblage d'un condensateur Varplus M4 avec plusieurs condensateurs Varplus M1.

Avec ces solutions d'assemblage la gestion des stocks et les évolutions de puissance sont simplifiés.



Varplus M1 Varplus M4

Exemples d'assemblage 400 V 50 Hz



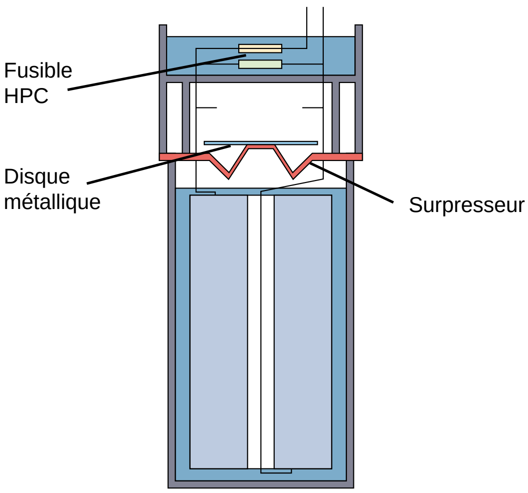
Puissances de base (kvar) 400 V 50 Hz*

	type standard	type H**
Varplus M1	5 7,5 10 12,5 15	5,5 7,5 10 11,5
Varplus M4	50 60	40 45

* autres tensions et fréquence 60 Hz disponibles
** condensateurs 440 V pour réseaux 400 V pollués (harmoniques)

La sécurité d'exploitation

- la technologie des condensateurs Varplus M repose sur l'utilisation d'un film polypropylène métallisé autocicatrisant ne nécessitant aucune imprégnation de gaz ou de liquide.



Coupe d'un élément de condensateur

- le système de protection HQ, intégré à chaque élément de condensateur assure la sécurité d'exploitation. De conception unique, breveté, il a été utilisé depuis plus de dix ans sur plusieurs millions d'éléments.
- le système HQ offre une protection contre les deux types de défauts rencontrés dans la fin de vie des condensateurs. La protection contre les défauts à courant fort est réalisée par un fusible à haut pouvoir de coupure. La protection contre les défauts à courant faible est réalisée par la combinaison d'un surpresseur et du fusible HPC.
- quel que soit le défaut, la pression dans l'élément est toujours limitée à une valeur plafond bien inférieure à la pression limite admissible.
- dans les deux cas de défaut, c'est un fusible HPC normalisé qui coupe le circuit électrique.
- l'enveloppe plastique des condensateurs Varplus M possède la double isolation électrique. Les matières plastiques utilisées offrent à la fois d'excellentes propriétés mécaniques et une auto-extinguibilité maximale (certification UL94 5 VA).

Simplicité de montage et de raccordement

■ la conception des condensateurs Varplus M respecte les grands principes des produits de distribution électrique basse tension auxquels ils sont associés dans les tableaux électriques : montage simple sur platine verticale, raccordement rapide sur plage.

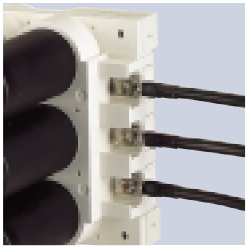
■ leur simplicité se vérifie dans les moindres détails : dimensions standardisées, cablage face avant ou face arrière, protection contre les contacts directs simple et originale, protection IP 42 par adjonction d'une boîte d'entrée de câble.

■ leur design original se traduit par un volume occupé très compact et favorise le refroidissement des éléments.

■ l'utilisation de platines équipées permet de standardiser l'intégration des condensateurs en armoire et de faciliter la maintenance des équipements.

Raccordement

Varplus M4

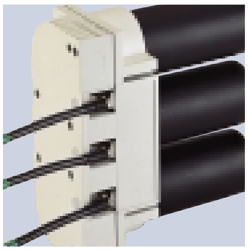


Câblage face avant

Câblage face arrière

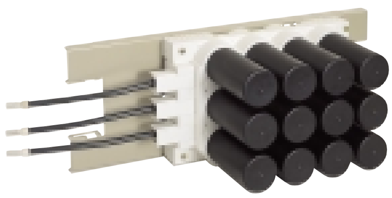
Varplus M1

Câblage face avant



Câblage face arrière

Applications



Platine de compensation fixe
câblage face avant

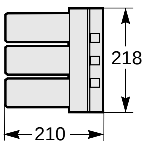
Gradin de compensation automatique
câblage face arrière

Platine de compensation fixe
câblage face avant

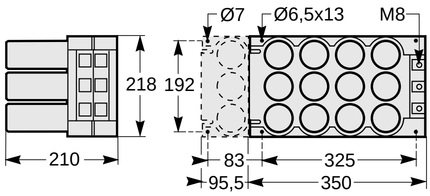
Gradin de compensation automatique
câblage face arrière (solution compacte)

Caractéristiques techniques des condensateurs

normes	CEI 831 1 et 2, NF C 54-104, VDE 0560 Teil 41, CSA 22-2 N° 190	
tolérance sur valeur de capacité	0, +10 %	
pertes	⩽ 0,5 W/kvar résistances de décharge incluses	
classe d'isolement	tenue 50 Hz 1 min : 6 kV tenue à l'onde de choc 1,2 / 50 µs : – 25 kV si la face arrière est distante d'au moins 15 mm de toute masse métallique – 11 kV si la face arrière est contre la masse métallique	
puissances maximales d'assemblage (400 V)	assemblage M1 + M1	60 kvar en câblage face avant 30 kvar en câblage face arrière
	assemblage M4 + M1	100 kvar
catégorie de température (400 V)	jusqu'à 65 kvar de 67,5 à 90 kvar de 92,5 à 100 kvar	– 25/D – 25/C – 25/B
surcharges admissibles en courant	type standard type H	30 % 40 %
surcharges admissibles en tension 8 h sur 24 h selon CEI 831 1 et 2	type standard type H	10 % 20 %
couleur	socle : RAL 9002 - pots : RAL 9005 - capots : RAL 9002	
masse	Varplus M1 : 2,6 kg - Varplus M4 : 10 kg	



Varplus M1



Varplus M4

Références

400 V 50 Hz type standard

kvar	réference
5	**52417**
7,5	**52418**
10	**52419**
12,5	**52420**
15	**52421**
50	**52422**
60	**52423**

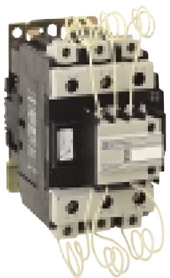
400 V 50 Hz type H

kvar	réference
5,5	**52425**
7,5	**52426**
10	**52427**
11,5	**52428**
40	**52429**
45	**52430**

Options

protection contre contacts directs	réf.
jeu de 3 capots pour Varplus M1 - câblage face avant	**52461**
jeu de 3 capots pour Varplus M1 - câblage face arrière	**52466**
jeu de 3 capots pour Varplus M4 câblage face avant/arrière	**52462**
jeu de 3 capots pour Varplus M4 câblage face arrière, cosse spéciale	**52463**
protection IP 42	
boîte d'entrée de câble tripolaire pour Varplus M1	**52460**
boîte d'entrée de câble tripolaire pour Varplus M4	**52464**
protection IP 54	
sur demande	

Offre complémentaire

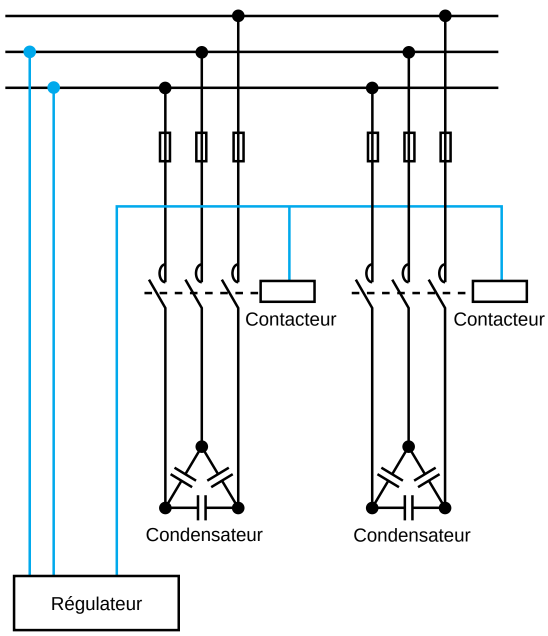


Contacteur

Les contacteurs Telemecanique LC1-D.K sont conçus pour la commande de condensateurs. Ils sont équipés d'un bloc de contacts de passage à fermeture et de résistances d'amortissement limitant le courant à l'enclenchement. Leur conception, brevetée, garantit la sécurité et la longévité des batteries de condensateurs.

Régulateur

Les régulateurs Merlin Gerin Varlogic, avec leur interface électronique et leurs fonctions intelligentes, simplifient les réglages, la mise en service et le contrôle des batteries de condensateurs. Ils facilitent la maintenance et la supervision. Ils garantissent la sécurité et la longévité des équipements de compensation d'énergie réactive et de filtrage des harmoniques.



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Schneider Electric Industries SA

Rectiphase
BP10
74371 Pringy cedex
France
Tel.: (33) 04 50 66 95 00
Fax: (33) 04 50 27 24 19

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Impression : Colorpress - 1000 ex.

Varlogic N power factor controller

A new range of power factor controllers designed with two benefits in mind:

Simplicity

- simplified programming and possibility of intelligent self set-up,
- ergonomic layout of control buttons.

User-friendliness

- large, easy to read backlit display,
- easy to use, intuative menus,
- direct display of main measurements.

The Varlogic N power factor controller:

- **analyses and provides information on network characteristics**
- **controls the reactive power required to obtain the target power factor**
- **monitors and provides information on equipment status**
- **communicates on the Modbus network (Varlogic NRC12).**

a brand of Schneider Electric

Merlin Gerin

Varlogic NR6 and NR12

User-friendly interface

The backlighted display allows:

■ direct viewing of installation electrical information and capacitor stage condition,
■ direct reading of set-up configuration,
■ intuative browsing in the various menus (indication, commissioning, configuration),
■ alarm indication.

Performance

■ access to a wealth of network and capacitor bank data,
■ new control algorithm designed to reduce the number of switching operations and quickly attain the required power factor.

Simplified installation and set-up

■ quick and simple mounting and wiring,
■ insensitive to current transformer polarity and phase rotation polarity,
■ a special menu allows controller self-configuration.

Monitoring and protection

Alarms

■ should an anomaly occur on the network or the capacitor bank, alarms are indicated on the screen and alarm contact closure is initiated,
■ the alarm message is maintained on the screen once the fault clears until it is manually removed.

Protection

■ if necessary, the capacitor steps are automatically disconnected to protect the equipment.

Varlogic NRC12

An even greater level of information and control

In addition to the functions of Varlogic NR6/NR12, the Varlogic NRC12 provides the following additional features:

■ measurement of total current harmonic distortion,
■ spectral analysis of network harmonic currents and voltages,
■ immediate display of the network's main parameters,
■ possibility of a dual target power factor,
■ configuration possible with fixed step,
■ step condition monitoring (capacitance loss),
■ on-line user help menus.

A communicating model

■ optional communication auxiliary (RS485 Modbus).

Technical data

General data

- operating temperature: 0…60°C
- storage temperature: –20°C…60°C
- colour: RAL 7016
- standards: EMC: IEC 61326
  electrical: IEC/EN 61010-1.
- panel mounting or mounting on 35 mm DIN rail (EN 50022)
- protection class in panel mounting: front face: IP41
  rear face: IP20
- display: NR6, NR12 type: 65 x 21 mm backlighted screen
  NRC12 type: 55 x 28 mm backlighted screen
  languages: English, French, German, Portuguese, Spanish
- alarm contact
- internal temperature probe
- separate fan relay contact
- access alarm history.

Inputs

- type of connection: phase-to-phase or phase-to-neutral
- insensitive to CT polarity
- insensitive to phase rotation polarity
- current input: NR6, NR12 type: CT… X/5 A
  NRC12 type: CT… X/5 A and X/1 A

Outputs

- potential free output contacts: AC: 1 A/400 V, 2 A/250 V, 5 A/120 V
  DC: 0.3 A/110 V, 0.6 A/60 V, 2 A/24 V

Settings and parameters

- target cos φ setting: 0.85 ind…0.9 cap
- possibility of a dual cos φ target (NRC12 type)
- manual or automatic setting of all controller parameters
- a choice of programs: linear, normal, circular, optimal
- main step sequences: 1.1.1.1.1 - 1.2.2.2.2 - 1.2.3.4.4 - 1.1.2.2.2 - 1.2.3.3.3 - 1.2.4.4.4 - 1.1.2.3.3 - 1.2.4.8.8
- custom-made sequences possible on the NRC12
- stage delay between successive switching:
  - NR6, NR12 type: 10 … 600 s
  - NRC12 type: 10 … 900 s
- step configuration programming: fixed, auto, disconnected (NRC12 type)
- 4-quadrant operation for generator application (NRC12 type)
- manual switching.

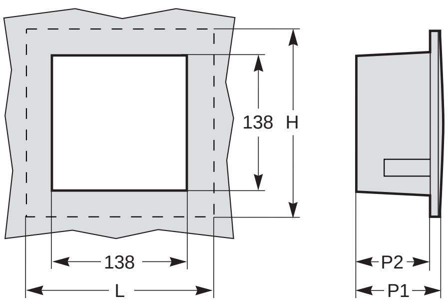
Type	Number of step output contacts	Supply voltage (V) 50-60 Hz network	Measuring voltage (V)	References
NR6	6	110-220/240-380/415	110-220/240-380/415	**52448**
NR12	12	110-220/240-380/415	110-220/240-380/415	**52449**
NRC12	12	110-220/240-380/415	110-220/240-380/415-690	**52450**

Varlogic N accessories	References
Communication RS485 Modbus auxiliary for NRC12	**52451**
Temperature external probe for NRC12. In addition to internal probe, allows measurement at the hotest point inside the capacitor bank. Better tuning of alarm and/or disconnection level.	**52452**

Information supplied	NR6/NR12	NRC12
Cos φ	■	■
Connected steps	■	■
Switching cycles and connected time counter	■	■
Step configuration (fixed step, auto, disconnected)		■
Step output status (capacitance loss monitoring)		■
Network technical data: load and reactive currents, voltage, powers (S, P, Q)	■	■
Ambient temperature inside the cubicle	■	■
Total voltage harmonic distortion THD (U)	■	■
Total current harmonic distortion THD (I)		■
Capacitor current overload (Irms/I_1)		■
Voltage and current harmonic spectrum (orders 3, 5, 7, 11, 13)		■
Alarm history	■	■

Alarms	Thresholds	Actions		NR6/NR12	NRC12
Low power factor		message and alarm contact		■	■
Hunting (unstable regulation)		message and alarm contact	disconnection (2)	■	■
Abnormal cos φ	< 0.5 ind or 0.8 cap	message and alarm contact		■	■
Overcompensation		message and alarm contact		■	■
Overcurrent	> 115% I_1	message and alarm contact		■	■
Voltage low	< 80% U_0 within 1 s	message and alarm contact	disconnection (2)	■	■
Overvoltage	> 110% U_0	message and alarm contact	disconnection (2)	■	■
Overtemperature	$\theta \geqslant \theta_0$ (θ_0 = 50°C max)(1)	message and alarm contact	disconnection (2)	■	■
	$\theta \geqslant \theta_0$ - 15°C	fan switch		■	■
Total harmonic distortion	> 7% (1)	message and alarm contact	disconnection (2)	■	■
Capacitor current overload	(Irms/I_1) > 1.5 (1)	message and alarm contact	disconnection (2)		■
Capacitor capacitance loss	- 25%	message and alarm contact	disconnection (2)		■
Low current	< 2.5%	message		■	■
High current	> 115%	message		■	■
Undervoltage	5% U_0	message			■

U_0: measuring voltage.
(1): alarm threshold values can be configured according to the installation.
(2): capacitor steps are automatically reconnected after fault clearance and a safety delay.



Dimensions and weight					
Type	Dimensions (mm)				Weight
	H	L	P1	P2	(kg)
Varlogic NR6/NR12	150	150	70	60	1
Varlogic NRC12	150	150	80	70	1

Schneider Electric Industries SAS

Rectiphase
399 rue de la Gare
74370 Pringy - France
Tel.: +33 (0)4 50 66 95 00
Fax: +33 (0)4 50 27 24 19

http://www.schneider-electric.com

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04/2004

Varlogic N power factor controller

The Varlogic N controllers permanently measure the reactive power of the installation and control connection and disconnection of capacitor steps in order to obtain the required power factor.

059646

Varlogic NR6/NR12

059648

Varlogic NRC12

Technical data

■ **general data**
□ operating temperature: 0…60 °C
□ storage temperature: -20° C…60 °C
□ colour: RAL 7016
□ standard:
- EMC: IEC 61326
- electrical: IEC/EN 61010-1.

□ panel mounting
□ mounting on 35 mm DIN rail (EN 50022)
□ protection class in panel mounting:
- front face: IP41
- rear face: IP20.

□ display:
- NR6, NR12 type: backlighted screen 65 x 21 mm
- NRC12 type: backlighted graphic screen 55 x 28 mm.
- languages: English, French, German, Portuguese, Spanish

□ alarm contact
□ temperature internal probe
□ separate contact to control fan inside the power factor correction bank
□ access to the history of alarm.

■ **inputs**
□ phase to phase or phase to neutral connection
□ insensitive to CT polarity
□ insensitive to phase rotation polarity
□ current input:
- NR6, NR12 type: CT… X/5 A
- NRC12 type: CT… X/5 A et X/1 A.

■ **outputs**
□ potential free output contacts:
- AC : 1 A/400 V, 2 A/250 V, 5 A/120 V
- DC : 0,3 A/110 V, 0,6 A/60 V, 2 A/24 V.

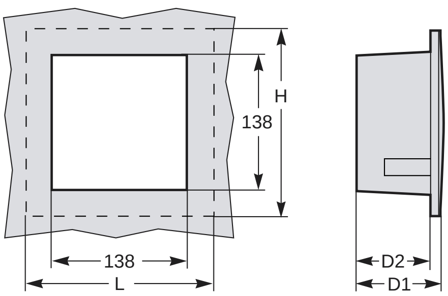
■ **settings and parameters**
□ target cos φ setting: 0,85 ind…0,9 cap
□ possibility of a dual cos φ target (type NRC12)
□ manual or automatic parameter setting of the power factor controller
□ choice of different stepping programs:
- linear
- normal
- circular
- optimal.

□ main step sequences:
1.1.1.1.1.1
1.2.2.2.2.2
1.2.3.4.4.4
1.1.2.2.2.2
1.2.3.3.3.3
1.2.4.4.4.4
1.1.2.3.3.3
1.2.4.8.8.8
□ personalized sequences for NRC12 type
□ delay between 2 successive switch on of a same step:
- NR6, NR12 type: 10 … 600 s
- NRC12 type: 10 … 900 s

□ step configuration programming (fixed/auto/disconnected) (NRC12 type)
□ 4 quadrant operation for generator application (NRC12 type)
□ manuel control for operating test.

Dimensions

E88926



Varlogic NR6, NR12, NRC12

Varlogic N	Dimensions (mm)				Weight
	H	L	D1	D2	(kg)
Varlogic NR6/NR12	150	150	70	60	1
Varlogic NRC12	150	150	80	70	1

Varlogic N power factor controller

Type	Number of step output contacts	Supply voltage (V) network 50-60 Hz	Measuring voltage (V)	ref.
NR6	6	110-220/240-380/415	110-220/240-380/415	**52448**
NR12	12	110-220/240-380/415	110-220/240-380/415	**52449**
NRC12	12	110-220/240-380/415	110-220/240-380/415-690	**52450**

Varlogic N accessories	ref.
Communication RS485 Modbus set for NRC12	**52451**
Temperature external probe for NRC12 type. In addition to internal proble, allows measurement at the hotest point inside the capacitor bank. Better tuning of alarm and/or disconnection level.	**52452**

Information supplied	NR6/NR12	NRC12
Cos φ	■	■
Connected steps	■	■
Switching cycles and connected time counter	■	■
Step configuration (fixed step, auto, disconnected)		■
Step output status (capacitance loss monitoring)		■
Network technical data: load and reactive currents, voltage, powers (S, P, Q)	■	■
Ambient temperature inside the cubicle	■	■
Total voltage harmonic distortion THD (U)	■	■
Total current harmonic distortion THD (I)		■
Capacitor current overload Irms/I_1		■
Voltage and current harmonic spectrum (orders 3, 5, 7, 11, 13)		■
History of alarms	■	■

Alarms	Threshold	Action		NR6/NR12	NRC12
Low power factor		message and alarm contact		■	■
Hunting (unstable regulation)		message and alarm contact	disconnection **(2)**	■	■
Abnormal cos φ	< 0.5 ind or 0.8 cap	message and alarm contact		■	■
Overcompensation		message and alarm contact		■	■
Overcurrent	> 115 % I_1	message and alarm contact		■	■
Voltage low	< 80 % Uo within 1 s	message and alarm contact	disconnection **(2)**	■	■
Overvoltage	> 110 % Uo	message and alarm contact	disconnection **(2)**	■	■
Overtemperature	$\theta \geqslant \theta o$ (θo = 50 °C max)**(1)**	message and alarm contact	disconnection **(2)**	■	■
	$\theta \geqslant \theta o$ - 15 °C	fan switch	disconnection **(2)**	■	■
Total harmonic distortion	> 7 % **(1)**	message and alarm contact	disconnection **(2)**	■	■
Capacitor current overload (Irms/I_1)	> 1.5 **(1)**	message and alarm contact	disconnection **(2)**		■
Capacitor capacitance loss	- 25 %	message and alarm contact	disconnection **(2)**		■
Low current	< 2,5 %	message		■	■
High current	> 115 %	message		■	■
Under voltage	5 % Uo	message			■

Uo: *input voltage (measurement)*
(1): *alarm threshold values can be modified according to the installation*
(2): *capacitor steps are automatically reconnected after fault clearance and a safety delay*