

## VarSet

Catalog 2018
Low Voltage Capacitor Banks


# Your requirements... 

## Optimize energy <br> consumption

- By reducing electricity bills,
- By reducing power losses,
- By reducing $\mathrm{CO}_{2}$ emissions.



## Increase power availability

- Compensate for voltage sags detrimental to process operation,
- Avoid nuisance tripping and supply interruptions.


## Improve your business performance

- Optimize installation size,
- Reduce harmonic distortion to avoid the premature ageing of equipment and destruction of sensitive components.


## Our solutions...

## Reactive energy management

In electrical networks, reactive energy results in increased line currents for a given active energy transmitted to loads.

The main consequences are:

- Need for oversizing of transmission and distribution networks by utilities,
- Increased voltage drops and sags along the distribution lines,
- Additional power losses.

This results in increased electricity bills for industrial customers because of:

- Penalties applied by most utilities on reactive energy,
- Increased overall kVA demand,
- Increased energy consumption within the installations.

Reactive energy management aims to optimize your electrical installation by reducing energy consumption, and to improve power availability. Total $\mathrm{CO}_{2}$ emissions are also reduced.
Utility power bills are typically reduced by $5 \%$ to $10 \%$ *.
"Our energy
con-sumption
was reduced by
after we installed 10 capacitor banks with detuned reactors. Electricity bill optimised by 8\% and payback in 2 years."
Testifies Michelin Automotive in France.
"Energy
consumption reduced by

with LV capacitor bank
and active filter installed."
POMA OTIS Railways, Switzerland.
"70 capacitor banks with detuned reactors installed, energy consumption reduced by $10 \%$, electrcity bill optimised by $18 \%$, payback in just


Madrid Barrajas airport Spain.
"Our network performance improved significantly after we installed 225 LV Detuned capacitor banks. The capacitor banks incorporates advanced metering system and remote communication ensures continued operation and minimal down time."
Ministry of Electricity and Water, Kuwait.

[^0]
## Improve electrical networks and reduce energy costs



## Power Factor Correction

Every electric machine needs active power (kW) and reactive power (kVAR) to operate.

- The power rating of the installation in kVA is the combination of both:
$(k V A)^{2}=(k W)^{2}+(k V A R)^{2}$
- The Power Factor has been defined as the ratio of active power (kW) to apparent power (kVA).
Power Factor $=(k W) /(k V A)$


# The objective of Reactive Energy management is improvement of Power Factor, or "Power Factor Correction". 

This is typically achieved by producing reactive energy close to the consuming loads, through connection of capacitor banks to the network.

## Ensure reliability and safety on installations

## Quality and reliability

- Continuity of service thanks to the high performance and long life expectancy of capacitors.
- $100 \%$ testing in manufacturing plant.
- Design and engineering with the highest international standards.


## Safety

- Over-pressure system for safe disconnection at the end of life.

- All materials and components are free of PCB pollutants.


## Efficiency and productivity

- Product development including innovation
in ergonomics and ease of installation and connection.
- Specially designed components to save time on installation and maintenance.
- All components and solutions available through a network of distributors and partners in more than 100 countries.


Thanks to the know-how developed over 50 years, Schneider Electric ranks as the global specialist in Energy management providing a unique and comprehensive portfolio.

Schneider Electric helps you to make the most of your energy with innovative, reliable and safe solutions.


## Quality \& Environment



## Quality certified <br> ISO9001, ISO14001 and ISO50001

## A major strength

In each of its units, Schneider Electric has an operating organization whose main role is to verify quality and ensure compliance with standards. This procedure is:

- uniform for all departments;
- recognized by numerous customers and official organizations.

But, above all, its strict application has made it possible to obtain the recognition of independent organizations.

The quality system for design and manufacturing is certified in compliance with the requirements of the ISO 9001 and ISO 14001 Quality Assurance model.

## Stringent, systematic controls

During its manufacture, each equipment item undergoes systematic routine tests to verify its quality and compliance:

- dielectric testing;
- earth connection continuity test;
- functional test of probes \& ventilation;
- functional test of the PFC system;
- verification of protection settings;
- verification of compliance with drawings and diagrams.

The results obtained are recorded and initialled by the Quality Control Department on the specific test certificate for each device.

Schneider Electric undertakes to reduce the energy bill and $\mathrm{CO}_{2}$ emissions of its customers by proposing products, solutions and services which fit in with all levels of the energy value chain.

The Power Factor Correction and harmonic filtering offer form part of the energy efficiency approach.


## Energy Efficiency



# Immediate Savings* 

## General contents VarSet

## Power Factor correction Guidelines

Why reactive energy management?
Method for determining compensation
Typical solutions depending on applications
VarSet offer
OverviewSelection guide
VarSet Standard
VarSet Detuned
VarSet Fast
VarSet Hybrid
VarSet accessories
Construction of references
Typical dimensions
Appendix
Power factor of most common receiving devices
When should fixed power factor correction be used?
Automatic compensation: installation advice
General information about harmonics
Causes and effects of harmonics
VarPlus Logic series
Calculation of reactive power

## Power Factor correction Guidelines

## Power Factor correction Guidelines

Why reactive energy management? ..... 12
Method for determining compensation ..... 14
Typical solutions depending on applications ..... 19

## Power Factor correction Guidelines <br> Why reactive energy management?

Due to this higher supplied current, the circulation of reactive energy in distribution networks results in:

- Overload of transformers
- Higher temperature rise in power cables
- Additional losses
- Large voltage drops
- Higher energy consumption and cost
- Less distributed active power


Fig. 1 In this representation, the Power Factor (P/S) is equal to $\cos \varphi$.

## Principle of reactive energy management

All AC electrical networks consume two types of power: active power (kW) and reactive power (kVAR):

- The active power $\mathbf{P}$ (in kW ) is the real power transmitted to loads such as motors, lamps, heaters, computers, etc. The electrical active power is transformed into mechanical power, heat or light.
- The reactive power $\mathbf{Q}$ (in kVAR ) is used only to power the magnetic circuits of machines, motors and transformers.
The apparent power $S$ (in kVA ) is the vector combination of active and reactive power.
The circulation of reactive power in the electrical network has major technical and economic consequences. For the same active power $P$, a higher reactive power means a higher apparent power, and thus a higher current must be supplied.
The circulation of active power over time results in active energy (in kWh ).
The circulation of reactive power over time results in reactive energy (kVARh).
In an electrical circuit, the reactive energy is supplied in addition to the active energy.


Fig. 2 Reactive energy supplied and billed by the energy provider.


Fig. 4

For these reasons, there is a great advantage in generating reactive energy at the load level in order to prevent the unnecessary circulation of current in the network. This is what is known as "power factor correction". This is obtained by the connection of capacitors, which produce reactive energy in opposition to the energy absorbed by loads such as motors.
The result is a reduced apparent power, and an improved power factor P/S' as illustrated in the diagram opposite.
The power generation and transmission networks are partially relieved, reducing power losses and making additional transmission capacity available.


Fig. 3 The reactive power is supplied by capacitors. No billing of reactive power by the energy supplier

## Power Factor correction Guidelines <br> Why reactive energy management?

## Benefits of reactive energy management

Optimized reactive energy management brings economic and technical advantages as follows:

Savings on utility bill

- Eliminating penalties on reactive energy and decreasing kW / kVA.
- Reducing power losses generated in the transformers and conductors of the installation.

Example:
Loss reduction in a 630 kVA transformer $\mathrm{PW}=6,500 \mathrm{~W}$ with an initial Power Factor $=0.7$. With power factor correction, we obtain a final Power Factor $=0.98$.
The losses become: $3,316 \mathrm{~W}$, i.e. a reduction of $49 \%$.

Increasing service capacity
A high power factor optimizes an electrical installation by allowing better use of the components. The power available at the secondary of a MV/LV transformer can therefore be increased by fitting power factor correction equipment on the low voltage side.
The table opposite shows the increased available power at the transformer output through

| Power <br> factor | Increased <br> available <br> power |
| :--- | :--- |
| 0.7 | $0 \%$ |
| 0.8 | $+14 \%$ |
| 0.85 | $+21 \%$ |
| 0.90 | $+28 \%$ |
| 0.95 | $+36 \%$ |
| 1 | $+43 \%$ | improvement of the Power Factor from 0.7 to 1.

Reducing installation cost
Installing power factor correction equipment allows conductor cross-section to be reduced, since less

| Power <br> factor | Cable cross- <br> section <br> multiplying <br> factor |
| :--- | :--- |
| 1 | 1 |
| 0.80 | 1.25 |
| 0.60 | 1.67 |
| 0.40 | 2.50 |

current is absorbed by the compensated installation for the same active power.
The opposite table shows the multiplying factor for the conductor cross-section with different power factor values.

## Improved voltage regulation

Installing capacitors allows voltage drops to be reduced upstream of the point where the power factor correction device is connected.
This prevents overloading of the network and reduces harmonics, so that you will not have to overrate your installation.

## Power Factor correction Guidelines <br> Method for determining compensation



Fig. 5

The selection of Power Factor Correction equipment should follow the following 4-step process and must be done by any people having the relevant skills:

- Step 1: Calculation of the required reactive power.
- Step 2: Selection of the compensation mode:
» Central, for the complete installation
" By sector
" For individual loads, such as large motors.
- Step 3: Selection of the compensation type:
» Fixed, by connection of a fixed-value capacitor bank;
» Automatic, by connection of a different number of steps, allowing adjustment of the reactive energy to the required value;
» Dynamic, for compensation of highly fluctuating loads.
- Step 4: Allowance for operating conditions and harmonics.


## Step 1: Calculation of the required reactive power

The objective is to determine the required reactive power $Q_{c}(k V A R)$ to be installed, in order to improve the power factor $\cos \varphi$ and reduce the apparent power $S$.

For $\varphi^{\prime}<\varphi$, we obtain: $\cos \varphi^{\prime}>\cos \varphi$ and $\tan \varphi^{\prime}<\tan \varphi$.
This is illustrated in the diagram opposite.
$Q_{c}$ can be determined from the formula (see Fig. 5):
$Q_{c}=P .\left(\tan \varphi-\tan \varphi^{\prime}\right)$
where:
$Q_{\mathrm{c}}=$ power of the capacitor bank in kVAR.
$P=$ active power of the load in kW .
$\tan \varphi=$ tangent of phase shift angle before compensation.
$\tan \varphi^{\prime}=$ tangent of phase shift angle after compensation.
The parameters $\varphi$ and $\tan \varphi$ can be obtained from billing data, or from direct measurement in the installation.

The following table can be used for direct determination.

| Before compensation |  | Reactive power (kVAR) to be installed per kW of load, in order to get the required $\cos \varphi^{\prime}$ or $\tan \varphi^{\prime}$ |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | $\boldsymbol{\operatorname { t a n }} \varphi^{\prime}$ | 0.75 | 0.62 | 0.48 | 0.41 | 0.33 | 0.23 | 0.00 |
|  |  | $\boldsymbol{\operatorname { c o s }} \varphi^{\prime}$ | 0.80 | 0.85 | 0.90 | 0.925 | 0.95 | 0.975 | 1.000 |
| $\boldsymbol{\operatorname { t a n }} \varphi$ | $\boldsymbol{\operatorname { c o s }} \varphi$ |  |  |  |  |  |  |  |  |
| 1.73 | 0.5 |  | 0.98 | 1.11 | 1.25 | 1.32 | 1.40 | 1.50 | 1.73 |
| 1.02 | 0.70 |  | 0.27 | 0.40 | 0.54 | 0.61 | 0.69 | 0.79 | 1.02 |
| 0.96 | 0.72 |  | 0.21 | 0.34 | 0.48 | 0.55 | 0.64 | 0.74 | 0.96 |
| 0.91 | 0.74 |  | 0.16 | 0.29 | 0.42 | 0.50 | 0.58 | 0.68 | 0.91 |
| 0.86 | 0.76 |  | 0.11 | 0.24 | 0.37 | 0.44 | 0.53 | 0.63 | 0.86 |
| 0.80 | 0.78 |  | 0.05 | 0.18 | 0.32 | 0.39 | 0.47 | 0.57 | 0.80 |
| 0.75 | 0.80 |  |  | 0.13 | 0.27 | 0.34 | 0.42 | 0.52 | 0.75 |
| 0.70 | 0.82 |  |  | 0.08 | 0.21 | 0.29 | 0.37 | 0.47 | 0.70 |
| 0.65 | 0.84 |  |  | 0.03 | 0.16 | 0.24 | 0.32 | 0.42 | 0.65 |
| 0.59 | 0.86 |  |  |  | 0.11 | 0.18 | 0.26 | 0.37 | 0.59 |
| 0.54 | 0.88 |  |  |  | 0.06 | 0.13 | 0.21 | 0.31 | 0.54 |
| 0.48 | 0.90 |  |  |  |  | 0.07 | 0.16 | 0.26 | 0.48 |

## Example:

consider a 1000 kW motor with $\cos \varphi=0.8(\tan \varphi=0.75)$.
In order to obtain $\cos \varphi=0.95$, it is necessary to install a capacitor bank with a reactive power equal to $\mathrm{k} \times$ P, i.e.: $\mathrm{Qc}=0.42 \times 1000=420 \mathrm{kVAR}$.

## Power Factor correction Guidelines Method for determining compensation



## Step 2: Selection of the compensation mode

The location of low-voltage capacitors in an installation constitutes the mode of compensation, which may be central (one location for the entire installation), by sector (section-by-section), at load level, or some combination of the latter two. In principle, the ideal compensation is applied at a point of consumption and at the level required at any moment in time.

In practice, technical and economic factors govern the choice.
The location for connection of capacitor banks in the electrical network is determined by:

- the overall objective (avoid penalties on reactive energy, relieve transformer or cables, avoid voltage drops and sags)
- the operating mode (stable or fluctuating loads)
- the foreseeable influence of capacitors on the network characteristics
- the installation cost.


## Central compensation

The capacitor bank is connected at the head of the installation to be compensated in order to provide reactive energy for the whole installation.
This configuration is convenient for a stable and continuous load factor.

## Group compensation (by sector)

The capacitor bank is connected at the head of the feeders supplying one particular sector to be compensated. This configuration is convenient for a large installation, with workshops having different load factors.

The capacitor bank is connected right at the inductive load terminals (especially large motors). This configuration is very appropriate when the load power is significant

This is the ideal technical configuration, as the reactive energy is produced

## Compensation of individual loads

 compared to the subscribed power. exactly where it is needed, and adjusted to the demand.
## Power Factor correction Guidelines Method for determining compensation

## Step 3: Selection of the compensation type

Different types of compensation should be adopted depending on the performance requirements and complexity of control:

- Fixed, by connection of a fixed-value capacitor bank
- Automatic, by connection of a different number of steps, allowing adjustment of the reactive energy to the required value
- Dynamic, for compensation of highly fluctuating loads.


## Fixed compensation

This arrangement uses one or more capacitor(s) to provide a constant level of compensation. Control may be:

- Manual: by circuit-breaker or load-break switch
- Semi-automatic: by contactor
- Direct connection to an appliance and switched with it.

These capacitors are installed:

- At the terminals of inductive loads (mainly motors)
- At busbars supplying numerous small motors and inductive appliances for which individual compensation would be too costly
- In cases where the load factor is reasonably constant.


## Automatic compensation

This kind of compensation provides automatic control and adapts the quantity of reactive power to the variations of the installation in order to maintain the targeted $\cos \varphi$. The equipment is installed at points in an installation where the active-power and/or reactivepower variations are relatively large, for example:

- on the busbars of a main distribution switchboard
- on the terminals of a heavily-loaded feeder cable.

Where the kVAR rating of the capacitors is less than or equal to $15 \%$ of the power supply transformer rating, a fixed value of compensation is appropriate. Above the $15 \%$ level, it is advisable to install an automatically-controlled capacitor bank.

Control is usually provided by an electronic device (Power Factor Controller) which monitors the actual power factor and orders the connection or disconnection of capacitors in order to obtain the targeted power factor. The reactive energy is thus controlled by steps. In addition, the Power Factor Controller provides information on the network characteristics (voltage amplitude and distortion, power factor, actual active and reactive power...) and equipment status. Alarm signals are transmitted in case of malfunction.

Connection is usually provided by contactors. For compensation of highly fluctuating loads, the use of active filters or Electronic Var Compensators (EVC) is recommened. Contact Schneider Electric for electronic compensation solutions.

## Dynamic compensation

This kind of compensation is required when fluctuating loads are present, and voltage fluctuations have to be prevented. The principle of dynamic compensation is to associate a fixed capacitor bank and an electronic var compensator, providing either leading or lagging reactive currents.

The result is continuously varying fast compensation, perfectly suitable for loads such as lifts, crushers, spot welding, etc.

## Step 4: Allowance for operating conditions and harmonics

Capacitor banks should be selected depending on the working conditions expected during their lifetime.

## Allowing for operating conditions

The operating conditions have a great influence on the life expectancy of capacitors. The following parameters should be taken into account:

- Ambient Temperature $\left({ }^{\circ} \mathrm{C}\right)$
- Expected over-current, related to voltage disturbances, including maximum sustained overvoltage
- Maximum number of switching operations/year
- Required life expectancy.

Our Power Factor Correction equipment are not suitable for a use in an environment with an explosive atmosphere (ATEX).

## Choice of compensation type

Devices using power electronics (variable speed drives, rectifiers, UPSs, arc furnaces, fluorescent lamps, etc.) generate harmonic currents in electrical networks.
Such harmonics can interfere with the operation of many devices, including capacitors, which are highly sensitive to harmonics. A high level of harmonics causes capacitors to overheat and age prematurely (breakdown).
Different types of compensation must be chosen according to the power of the harmonic generators: standard or detuned. They can be selected as shown on the following page.

## Power Factor correction Guidelines <br> Method for determining compensation

## Choice of compensation type (cont'd)

The chart below indicates the standard or detuned compensation choices.


Sn : apparent power of the transformer
Gh: apparent power of harmonics-generating receivers (variable speed motors, static converters, power electronics, etc.)

Qc: power of the compensation equipment
V: network voltage

# Power Factor correction Guidelines Typical solutions depending on applications 

## Customer requirements

The table below shows the solutions most frequently used in different types of applications.


In all cases, it is strongly recommended that measurements be carried out on site in order to validate the solution.

| Types of applications | VarSet Standard | VarSet Detuned | VarSet Fast |
| :---: | :---: | :---: | :---: |
| Industry |  |  |  |
| Food and drink |  |  |  |
| Textiles |  |  |  |
| Wood |  |  |  |
| Paper |  |  |  |
| Printing |  |  |  |
| Chemicals - pharmaceuticals |  |  |  |
| Plastics |  |  |  |
| Glass - ceramics |  |  |  |
| Steel production |  |  |  |
| Metallurgy |  |  |  |
| Automotive |  |  |  |
| Cement works |  |  |  |
| Mining |  |  |  |
| Refineries |  |  |  |
| Microelectronics |  |  |  |
| Tertiary |  |  |  |
| Banks - insurance |  |  |  |
| Supermarkets |  |  |  |
| Hospitals |  |  |  |
| Stadiums |  |  |  |
| Amusement parks |  |  |  |
| Hotels - offices |  |  |  |
| Energy and infrastructure |  |  |  |
| Substations |  |  |  |
| Water distribution |  |  |  |
| Internet |  |  |  |
| Railway transport |  |  |  |
| Airports |  |  |  |
| Underground train systems |  |  |  |
| Bridges |  |  |  |
| Tunnels |  |  |  |
| Wind turbines |  |  |  |

VarSet offer

## VarSet offer

Overview ..... 22
Selection guide ..... 24
VarSet Standard ..... 26
VarSet Detuned ..... 28
VarSet Fast ..... 30
VarSet Hybrid ..... 32
VarSet accessories ..... 33
Construction of references ..... 34
Typical dimensions ..... 35
Appendix ..... 36

VarSet offer Overview

## VarSet





The entire VarSet range offers a unique combination of abilities to give you more convenience, reliability and performance across a broad range of applications.

Forward-thinking design and meticulous manufacturing quality means you can count on VarSet capacitor banks to deliver dependable, long-term service.

Embedded communication features will allow you to optimize surveillance, maintenance and performance of your capacitor bank asset.

## Eco=struxure

Innovation At Every Level

## EcoStruxure ${ }^{\text {T" }}$ Power ready

- Seemless integration thanks to embedded Modbus communication
- Remote equipment follow up \& control
- Remote troubleshooting
- Enable analytics \& mobile benefits of EcoStruxure ${ }^{\text {TM }}$ Power


## Safety

> Protection

- overload protection for each stage
- short-circuit protection for each stage
- thermal monitoring device
- 3 phase overPressure Disconnection System on each capacitor
> Robust Enclosure System
- NEMA 1 for indoor application
- high quality welding and painting
- IK10 protection against mechanical shocks
> Tested and certified
- fully type tested and certified to CSA 22.2 No. 190 and to UL 810


## Reliability

> Long-life performance

- Schneider capacitor engineered for harsh environment and long life*
- multi level and redundancy of protections
- reduced switching inrush current thanks to special design contactor or detuned reactors
- integration of high quality Schneider components
> Easy maintenance
- automatic step size detection
- self diagnosis of capacitor output \& derating
- alarm functions available (temperature, Harmonics, Voltage, Overload , hunting...)


## Performance

> Easy installation \& commissioning

- automatic step size detection
- current transformer polarity auto-detection
> Advanced measurement and monitoring functions
- real time step monitoring (remaining power, number of switches)
- harmonic control till the 19th harmonic
- 4 quadrant operations
- overload assessment thru harmonics
> Future-ready: "Connectable product"
* Cf. Low voltage components catalog PFCED310003EN


## VarSet offer

## Selection guide



## Compensation type

## - Automatic compensation:

This compensation type is used for unstable loads.
The VarSet LV equipment will automatically adjust the reactive power according to variations in load and/or power factor. Schneider Electric recommends the use of automatic compensation when the capacitor bank's power is more than $15 \%$ of the power of the transformer, in order to avoid overcompensation.

## - Fixed compensation:

This compensation type is used for stable loads, with synchronised voltage and current. The equipment will supply a constant reactive power irrespective of load variations.

## Network harmonics

Non-linear loads, such as devices using power electronics, generate harmonics on the network.

The selection of the appropriate power factor correction solution has to be adapted depending on the level of network pollution.

The selection is based on the value of the Gh/Sn ratio, with:

- Gh = total power of the non-linear loads
- $\mathrm{Sn}=$ rated power of the supply transformer

The selection can also be made according to the percentage of total harmonic current distortion THDi or total harmonic voltage distortion THDu measured.

## VarSet offer Selection guide

The compensation needs of your installation vary depending on factors such as load variation, network harmonic content and the characteristics of the installation. Find out the right level of compensation for your network with the help of the chart below.

## Your load variation

## Variable or unstable load

Automatic compensation

Network harmonics


Choose VarSet Standard


480 V 60 Hz
from 75 kVAR to 300 kVAR
See page 26


Choose VarSet Detuned


480 V - 60 Hz
from 75 kVAR to 800 kVAR
See page 28

Load sensitive to transient switching

Automatic and transient-free


480 V 60 Hz
from 450 kVAR to 1200 kVAR
See page 30

## VarSet offer

## VarSet Standard

Automatic compensation - standard, $480 \mathrm{~V} / 60 \mathrm{~Hz}$


## Environment

- Installation: Indoor
- Ambient temperature: $15^{\circ} \mathrm{F}$ to $104^{\circ} \mathrm{F}$ ( $-10^{\circ} \mathrm{C}$ to $40^{\circ} \mathrm{C}$ )
- Humidity: up to $95 \%$
- Maximum altitude: 6500 feet ( 2000 m )


## Standards

- CSA 22.2 No. 190
- UL810, UL508a


## Environment certifications

Produced in 14001 certified plants, product environmental profile available

General characteristics

| Electrical Characteristics |  |
| :---: | :---: |
| Rated Voltage | $480 \mathrm{~V} / 60 \mathrm{~Hz}$ |
| Capacitance Tolerance | -5\%, +10\% |
| Connection type | Three-phase |
| Power losses | < $2.5 \mathrm{~W} / \mathrm{kVAR}$ |
| Maximum permissible over current | 1.35 In |
| Maximum permissible over voltage | 1.1 x Un, 8 h every 24 h |
| Enclosure |  |
| Degree of protection | NEMA 1 |
| Colour | RAL 7035 |
| Degree of mechanical resistance | IK10 and Sec 43 UL810 |
| Controller |  |
| VarPlus Logic | VarPlus Logic controller with embedded Modbus communication |
| Head circuit breaker protection |  |
| Without incoming circuit breaker | Lug connection |
|  | LV PFC Bank must be protected by a circuit breaker or by a fused disconnector on upstream switchboard |
| With incoming circuit breaker | PowerPact with rotary handle |
| Step |  |
| Capacitors Type | Varplus Can 575 V for network voltage 480V |
|  | Maximum over current: 1.8 In |
|  | 3-phase overpressure protection |
|  | Discharge resistance 50 V-1 min |
| Contactors | Dedicated to capacitor switching |
| Circuit breaker protection | PowerPact |
| Temperature control |  |
| Double control | By thermostat and by controller |
| Communication |  |
| ModBus | RS485 |
| Installation |  |
| Customer connection | Top entry |
| Auxilliary transformer | 120 V included - no need for additional supply |
| CT not included (see page 34) | 5 VA - secondary 1 or 5 A |
|  | To be installed upstream of the load and capacitor bank |
| GenSet contact | Available for disconnection with generator |
| Alarm contact | Available for remote warning signal |

## VarSet offer <br> VarSet Standard

## Automatic compensation - standard, 480 V / 60 Hz



Network voltage 480V-60Hz


## VarSet offer

## VarSet Detuned

Automatic compensation - detuned, $480 \mathrm{~V} / 60 \mathrm{~Hz}$ Tuning order 4.2


## Environment

- Installation: Indoor
- Ambient temperature: $-5^{\circ} \mathrm{C}$ to $40^{\circ} \mathrm{C}$
- Humidity: up to $95 \%$
- Maximum altitude: 2000 m


## Standards

- CSA 22.2 No. 190
- UL810, UL508a


## Environment certifications

RoHS compliant, produced in 14001 certified plants, product environmental profile available

General characteristics

| Electrical Characteristics |  |
| :---: | :---: |
| Rated Voltage | $480 \mathrm{~V}-60 \mathrm{~Hz}$ |
| Capacitance Tolerance | -5\%, +10\% |
| Connection type | Three-phase |
| Power losses | < 6 W/kVAR |
| Maximum permissible over current | $1.3 \times \mathrm{ln}$ |
| Maximum permissible over voltage | $1.1 \times$ Un, 8 h every 24 h |
| Enclosure |  |
| Degree of protection | NEMA 1 |
| Colour | RAL 7035 ( VLV model ) / ASA 49 ( AV/BV Model ) |
| Degree of mechanical resistance | IK10 for VLV, Sec 43 UL810 for VLV and AV/BV models |
| Controller |  |
| VarPlus Logic | VarPlus Logic controller with embedded Modbus communication |
| Head circuit breaker protection |  |
| Without incoming circuit breaker | Lug connection |
|  | LV PFC Bank must be protected by a circuit breaker or by a fused disconnector on upstream switchboard |
| With incoming circuit breaker | PowerPact with rotary handle |
| Step |  |
| Capacitors Type | Varplus Can 575 V for network voltage 480 V |
|  | Maximum overcurrent 1,8xIn |
|  | 3 ph overpressure disconnection system |
|  | Discharge resistor $50 \mathrm{~V}-1 \mathrm{mn}$ |
| Contactors | Dedicated to capacitor switching |
| Detuned reactor | Varplus DR |
|  | Overheating protection by thermostat |
| Circuit breaker protection | PowerPact |
| Temperature control |  |
| Double control | By thermostat and by controller |
| Communication |  |
| ModBUS | RS485 |
| Installation |  |
| Customer connection | Top Entry |
| Auxilliary transformer | 120 V included - no need for additionnal supply |
| CT not included (see page 34) | 5 VA - secondary 1 or 5 A |
|  | To be installed upstream of the load and capacitor bank |
| GenSet contact | Available for disconnection with generator |
| Alarm contact | Available for remote warning signal |

## Options available on request:

- Fixed stages (by controller programming)
- Custom staging ratios
- Other voltages and frequencies
- Outdoor arrangement - built to NEMA 3R ( AV/BV models only )
- Bottom cable entry to main lugs (AV models only)
- Bottom cable entry to main breaker (BV models only)


# Automatic compensation - detuned, $480 \mathrm{~V} / 60 \mathrm{~Hz}$ <br> Tuning order 4.2 

| References | Power (kVAR) | Smallest step | Resolution | No. of electrical steps | No. of physical steps | Breaking capacity | Main Circuit breaker | Enclosure type | Enclosure size ( $\mathrm{H} \times \mathrm{W} \times \mathrm{D}$ ) $\mathrm{mm} /$ in | Max weight (kg/lb) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| With incoming circuit breaker |  |  |  |  |  |  |  |  |  |  |
| VLVAF4P66075AB | 75 | 25 | $25+50$ | 6 | 2 | 65 kA | HLF36125 | VLVAF4P | $\begin{aligned} & 1200 \times 1300 \times 400 \\ & 47.2 \times 51.2 \times 15.7 \mathrm{in} \end{aligned}$ | 265/585 |
| VLVAF4P66100AB | 100 | 25 | $25+25+50$ | 4 | 3 |  | JLF36175 |  |  |  |
| VLVAF4P66125AB | 125 | 25 | $25+2 \times 50$ | 5 | 3 |  | JLF36200 |  |  |  |
| VLVAF4P66150AB | 150 | 25 | $25+25+2 \times 50$ | 6 | 4 |  | LLF36600U31X |  |  |  |
| VLVAF4P66175AB | 175 | 25 | $25+3 \times 50$ | 7 | 4 |  | LLF36600U31X |  |  |  |
| VLVAF4P66200AB | 200 | 50 | $4 \times 50$ | 5 | 4 |  | LLF36600U31X |  |  |  |
| BV025046CV5F1N | 250 | 50 | $50+2 \times 100$ | 5 | 3 | 65 kA | RKL type | BV 1 Section | $\begin{aligned} & 2324 \times 762 \times 915 \\ & 91.5 \times 30 \times 36 \text { in } \end{aligned}$ | 747 / 650 |
| BV030046BV5F1N | 300 | 50 | $50+50+2 \times 100$ | 6 | 4 |  | RKL type |  |  | 793/1750 |
| BV035046CV5F2N | 350 | 50 | $50+3 \times 100$ | 7 | 4 |  | RKL type | BV 2 <br> Sections | $\begin{aligned} & 2324 \times 1524 \times 91 \\ & 91.5 \times 60 \times 36 \text { in } \end{aligned}$ | 1110 / 2450 |
| BV040046AV8F2N | 400 | 100 | $4 \times 100$ | 4 | 4 |  | RKL type |  |  | 1155/2550 |
| BV045046CV5F2N | 450 | 50 | $50+4 \times 100$ | 9 | 5 |  | RKL type |  |  | 1223 / 2700 |
| BV050046AV8F2N | 500 | 100 | $5 \times 100$ | 5 | 5 |  | RKL type |  |  | 1291/2850 |
| BV055046CV5F2N | 550 | 50 | $50+5 \times 100$ | 11 | 6 |  | RKL type |  |  | 1359 / 3000 |
| BV060046AV8F2N | 600 | 100 | $6 \times 100$ | 6 | 6 |  | RKL type |  |  | 1427 / 3150 |
| BV065046CV5F2N | 650 | 50 | $50+6 \times 100$ | 13 | 7 |  | RKL type |  |  | 1495 / 3300 |
| BV070046AV8F2N | 700 | 100 | $7 \times 100$ | 7 | 7 |  | RKL type |  |  | 1563 / 3450 |
| BV075046CV5F3N | 750 | 50 | $50+7 \times 100$ | 15 | 8 |  | RKL type | BV 3 <br> Sections | $\begin{aligned} & 2324 \times 2286 \times 915 \\ & 91.5 \times 90 \times 36 \text { in } \end{aligned}$ | 1835/4050 |
| BV080046AV8F3N | 800 | 100 | $8 \times 100$ | 8 | 8 |  | RKL type |  |  | 1903/4200 |


| References | Power (kVAR) | Smallest step | Regulation | No. of electrical steps | No. of physical steps | Shorttime withstand current | Recommended upstream protection | Enclosure type | Enclosure size ( $\mathrm{H} \times \mathrm{W} \times \mathrm{D}$ ) $\mathrm{mm} / \mathrm{in}$ | Max weight (kg/lb) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| With main lugs |  |  |  |  |  |  |  |  |  |  |
| VLVAF4P66075AA | 75 | 25 | $25+50$ | 6 | 2 | 3 cycles | HLF36125 | VLVAF4P | $\begin{aligned} & 1200 \times 1300 \times 400 \\ & 47.2 \times 51.2 \times 15.7 \text { in } \end{aligned}$ | 265/585 |
| VLVAF4P66100AA | 100 | 25 | $25+25+50$ | 4 | 3 |  | JLF36175 |  |  |  |
| VLVAF4P66125AA | 125 | 25 | $25+2 \times 50$ | 5 | 3 |  | JLF36200 |  |  |  |
| VLVAF4P66150AA | 150 | 25 | $25+25+2 \times 50$ | 6 | 4 |  | LLF36600U31X |  |  |  |
| VLVAF4P66175AA | 175 | 25 | $25+3 \times 50$ | 7 | 4 |  | LLF36600U31X |  |  |  |
| VLVAF4P66200AA | 200 | 50 | $4 \times 50$ | 5 | 4 |  | LLF36600U31X |  |  |  |
| AV025046CV5F1N | 250 | 50 | $50+2 \times 100$ | 5 | 3 | 4 cycles | RKL type | AV 1 Section | $\begin{aligned} & 2324 \times 762 \times 915 \\ & 91.5 \times 30 \times 36 \text { in } \end{aligned}$ | $612 / 1350$ |
| AV030046BV5F1N | 300 | 50 | $50+50+2 \times 100$ | 6 | 4 |  | RKL type |  |  | 657 / 1450 |
| AV035046CV5F1N | 350 | 50 | $50+3 \times 100$ | 7 | 4 |  | RKL type |  |  | 725/1600 |
| AV040046AV8F1N | 400 | 100 | $4 \times 100$ | 4 | 4 |  | RKL type |  |  | 793 / 1750 |
| AV045046CV5F2N | 450 | 50 | $50+4 \times 100$ | 9 | 5 |  | RKL type | AV 2 <br> Sections | $\begin{aligned} & 2324 \times 1524 \times 915 \\ & 91.5 \times 60 \times 36 \text { in } \end{aligned}$ | $1132 / 2500$ |
| AV050046AV8F2N | 500 | 100 | $5 \times 100$ | 5 | 5 |  | RKL type |  |  | 1200 / 2650 |
| AV055046CV5F2N | 550 | 50 | $50+5 \times 100$ | 11 | 6 |  | RKL type |  |  | 1268 / 2800 |
| AV060046AV8F2N | 600 | 100 | $6 \times 100$ | 6 | 6 |  | RKL type |  |  | 1336 / 2950 |
| AV065046CV5F2N | 650 | 50 | $50+6 \times 100$ | 13 | 7 |  | RKL type |  |  | 1404 / 3100 |
| AV070046AV8F2N | 700 | 100 | $7 \times 100$ | 7 | 7 |  | RKL type |  |  | 1472 / 3250 |
| AV075046CV5F2N | 750 | 50 | $50+7 \times 100$ | 15 | 8 |  | RKL type |  |  | 1540 / 3400 |
| AV080046AV8F2N | 800 | 100 | $8 \times 100$ | 8 | 8 |  | RKL type |  |  | 1608 / 3550 |

## VarSet offer

## VarSet Fast

## Automatic and transient free compensation - detuned, $480 \mathrm{~V} / 60 \mathrm{~Hz}$ Tuning order 4.2



General characteristics

| Electrical Characteristics |  |
| :---: | :---: |
| Rated Voltage | $480 \mathrm{~V} / 60 \mathrm{~Hz}$ |
| Capacitance Tolerance | -5\% +10\% |
| Connection type | Three-phase |
| Power losses | < 13 W per kVAR |
| Maximum permissible over current | 1,3 $\times$ In |
| Maximum permissible over voltage | 1,1 $\times$ Un, 8 h per 24 h |
| Enclosure |  |
| Degree of protection | NEMA 1 |
| Colour | ASA 49 (AT Model) |
| Degree of mechanical resistance | Sec 43 UL810 |
| Controller |  |
| VarPlus Logic | VarPlus Logic controller with embedded Modbus communication |
| Head circuit breaker protection |  |
| Without incoming circuit breaker | Lug connection |
|  | LV PFC Bank must be protected by a circuit breaker or by a fused disconnector on upstream switchboard |
| With incoming circuit breaker | PowerPact with rotary handle |
| Step |  |
| Capacitors Type | Varplus Can 575 V for network voltage 480V |
|  | Maximum overcurrent 1,8xIn |
|  | 3 ph overpressure disconnection system |
|  | Discharge resistor: $50 \mathrm{~V}-1 \mathrm{mn}$ |
| Transient-free switches | Electronically controlled to avoid capacitor switching transients |
| Detuned Reactor | Varplus DR |
|  | Overheating protection by thermostat |
| Circuit breaker protection | PowerPact |
| Temperature control |  |
| Double control | By thermostat and controller |
| Communication |  |
| ModBUS | RS485 |
| Installation |  |
| Customer connection | Top entry |
| Auxiliary transformer | 120 V included - no need of additionnal supply |
| TI not included | 5 VA - secondary 1 A or 5 A |
|  | To be installed upstream of the load and capacitor bank |
| GenSet contact | Available for disconnection with the generator |
| Alarm contact | Available for remote warning signal |

## Options available on request:

- Fixed stages (by controller programming)
- Custom staging ratios
- Other voltages and frequencies
- Outdoor arrangement - Built to NEMA 3R (AV/BV models only)
- Bottom cable entry to main lugs or main breaker requires incoming cubicle


## VarSet offer VarSet Fast

## Automatic and transient free compensation - detuned, $480 \mathrm{~V} / 60 \mathrm{~Hz}$

 Tuning order 4.2Network 480V-60Hz

| References | Power (kVAR) | Smallest step | Resolution | No. of electrical and physical steps | Breaking Capacity | Main Circuit breaker | Enclosure type | Enclosure size ( $\mathrm{H} \times \mathrm{W} \times \mathrm{D}$ ) $\mathrm{mm} /$ in | Max weight (kg/lb) |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| With incoming circuit breaker |  |  |  |  |  |  |  |  |  |
| BT045046AVBF2N | 450 | 150 | $3 \times 150$ | 6 | 65 kA | RKL type | BT 1 Section | $\begin{aligned} & 2324 \times 762 \times 915 \\ & 91.5 \times 30 \times 36 \text { in } \end{aligned}$ | $\begin{aligned} & 900 / \\ & 2000 \end{aligned}$ |
| BT060046AVBF2N | 600 | 150 | $4 \times 150$ | 4 |  | RKL type | BT 2 Sections | $\begin{aligned} & 2324 \times 1524 \times 915 \\ & 91.5 \times 60 \times 36 \text { in } \end{aligned}$ | $\begin{aligned} & 1400 / 1 \\ & 3100 \end{aligned}$ |
| BT090046AVBF3N | 900 | 150 | $6 \times 150$ | 5 |  | RKL type | BT 2 Sections | $\begin{aligned} & 2324 \times 1524 \times 915 \\ & 91.5 \times 60 \times 36 \text { in } \end{aligned}$ | $\begin{aligned} & 1540 / / \\ & 3400 \end{aligned}$ |
| BT120046AVBF3N | 1200 | 150 | $8 \times 150$ | 6 |  | RKL type | BT 3 Sections | $\begin{aligned} & 2324 \times 2286 \times 915 \\ & 91.5 \times 90 \times 36 \text { in } \end{aligned}$ | $\begin{aligned} & \hline 2310 / \\ & 5100 \end{aligned}$ |
| References | Power (kVAR) | Smallest step | Resolution | No. of electrical and physical steps | Short-time withstand current | Recommended upstream protection | Enclosure type | Enclosure size ( $\mathrm{H} \times \mathrm{W} \times \mathrm{D}$ ) $\mathrm{mm} /$ in | Max weight (kg/lb) |
| With main lugs |  |  |  |  |  |  |  |  |  |
| AT045046AVBF2N | 450 | 150 | $3 \times 150$ | 6 | 4 cycles | RKL type | AT 1 Section | $\begin{aligned} & 2324 \times 762 \times 915 \\ & 91.5 \times 30 \times 36 \end{aligned}$ | $\begin{aligned} & 770 / \\ & 1700 \end{aligned}$ |
| AT060046AVBF2N | 600 | 150 | $4 \times 150$ | 4 |  | RKL type | AT 2 Sections | $\begin{aligned} & 2324 \times 1524 \times 915 \\ & 91.5 \times 60 \times 36 \text { in } \end{aligned}$ | $\begin{aligned} & 1360 / / \\ & 3000 \end{aligned}$ |
| AT090046AVBF3N | 900 | 150 | $6 \times 150$ | 5 |  | RKL type | AT 2 Sections | $\begin{aligned} & 2324 \times 1524 \times 915 \\ & 91.5 \times 60 \times 36 \text { in } \end{aligned}$ | $\begin{aligned} & 1500 / / \\ & 3300 \end{aligned}$ |
| AT120046AVBF3N | 1200 | 150 | $8 \times 150$ | 6 |  | RKL type | AT 3 Sections | $\begin{aligned} & 2324 \times 2286 \times 915 \\ & 91.5 \times 90 \times 36 \text { in } \end{aligned}$ | $\begin{aligned} & 2270 / / \\ & 5000 \end{aligned}$ |

## VarSet offer

## VarSet Hybrid <br> Hybrid Compensator System - 480V / 60Hz



Your Schneider Electric representative can help you select the correct Hybrid solution for your specific needs.

To learn more, contact us at powersolutions@schneider-electric.com

VarSet Hybrid provides real time power factor correction, voltage support, and harmonic suppression.
This is a custom, engineered to order solution that is comprised of a VarSet Detuned Capacitor Bank with either an Active Harmonic Filter (AccuSine PCS+) or an AccuSine Electronic Var Compensator (AccuSine PFV + ).
The VarSet Hybrid provides instantaneous and infinitely variable power factor correction for industrial networks containing highly transient or unstable loads, as well as system compensation for large AC motor inrush current.
It integrates conventional power factor correction systems and the latest IGBT-based solutions to provide ultra rapid response and infinitely variable kVAR control never before seen in a power factor correction product. Specifically designed for the instantaneous support required by welding equipment, the VarSet Hybrid eliminates voltage sags and voltage flicker while increasing system capacity, providing energy savings and improving weld quality. It also provides current inrush support for applications such as large horsepower motor starting.

## Product features

- Ultra fast reactive current compensation for transient or cyclical loads
- Infinitely variable control
- Instantaneous response for inrush support
- Independently compensates each phase
- Heavy duty dry capacitors provide no risk of fluid leakage, no environmental pollution and no need for drip pans
- Detuned iron core reactors prevent resonance
- IGBT based power electronic technology
- Stepless power factor correction
- Best-in-class harmonic cancellation up to 50th harmonic and less than 3\% THDi
- Energy efficient 3-level IGBT inverter technology
- All major components from Schneider Electric



## VarSet offer <br> VarSet accessories

## A current transformer is required for automatic control

In order to have automatic control, a current transformer must be ordered in addition to the PFC bank.
A current transformer (not included) is necessary to provide accurate network information to the VarSet's controller in order to apply the correct quantity of kVAR at any given time.
Note: CT must be sized to your network and have a secondary rating of 5 A .
CT catalog number: TRAI****SC^^ where **** is current rate code of bus/cable and $\# \#$ is window size code. Codes are listed in the table below. E.g. TRAI1000SC07 is a CT for 1000 A bus with 7 " $\times 4$ " window.

CT selection table

| Current rating of Bus/Cable |  | Window size |  |
| :---: | :---: | :---: | :---: |
| Amperes | Rating Code | 7" $\times 4$ " size code | $11^{\prime \prime} \times 4$ " size code |
| 600 | 0600 | 07 | N/A |
| 800 | 0800 | 07 | N/A |
| 1000 | 1000 | 07 | N/A |
| 1200 | 1200 | 07 | 11 |
| 1500 | 1500 | 07 | N/A |
| 1600 | 1600 | 07 | N/A |
| 2000 | 2000 | 07 | 11 |
| 2500 | 2500 | 07 | 11 |
| 3000 | 3000 | 07 | 11 |
| 3500 | 3500 | 07 | 11 |
| 4000 | 4000 | 07 | 11 |
| 5000 | 5000 | N/A | 11 |
| 6000 | 6000 | N/A | 11 |

## Floor mounting of VLVAW2N and VLVAW3N models



| For enclosure | Order the following parts |
| :--- | :--- |
| VLVAW2N | NSYSPF8100 + NSYSPS4100 |
| VLVAW3N | NSYSPF10100 + NSYSPS4100 |

## VarSet offer

## Construction of references

VarSet Standard \& VarSet Detuned

| VLVAW2N | 6 | 6 | 1 | 0 | 0 | AA |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: |
| Equipment type <br> (7 digits) | Voltage | Frequency |  | Power <br> (3 digits) | Used to differentiate incomer <br> $\mathbf{( 2 ~ d i g i t s ) ~}$ |  |
| VLVAW2N: small-size standard <br> VLVAW3N: mid-size standard | $6=480 \mathrm{~V}$ | $6=60 \mathrm{~Hz}$ |  | e.g $100=100 \mathrm{kVAR}$ | $\mathrm{AB}=$ lugs |  |
| VLVAF4P: detuned |  |  |  |  |  |  |

VarSet Detuned \& VarSet Fast

| A V | 0300 | 4 | 6 | A | V | 5 | F | 1 | N |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Equipment type (2 digits) | Power (4 digits) | Voltage | Series designation | Stage ratio of controller | Cable entry | Smallest step size (kVAR) | Enclosure type and paint | Lug size per phase | N |
| $\mathrm{AV}=$ automatic standard with main lugs <br> $B V=$ automatic standard with main circuit breaker <br> AT = automatic transient free with main lugs <br> BT = automatic transient free with main circuit breaker | $\begin{gathered} \text { eg. } \\ 0300=300 \mathrm{kVAR} \end{gathered}$ | $4=480 \mathrm{~V}$ | $6=$ Detuned | $\begin{aligned} & A=1: 1: 1: 1: 1: 1 \ldots \\ & B=1: 1: 2: 2: 2: 2 \ldots \\ & C=1: 2: 2: 2: 2: 2 \ldots \end{aligned}$ | V = Top | $\begin{aligned} & 5=50 \\ & 8=100 \\ & B=150 \end{aligned}$ | F=NEMA 1 <br> ASA 49 paint <br> G=NEMA 1 with drip guard ASA 49 paint | Copper saddle clamp <br> $1=2 \times 1 / 0$ to 500MCM $2=4 \times 1 / 0 \text { to }$ 500MCM $3=6 \times 1 / 0 \text { to }$ 500MCM | No option |

## VarSet offer <br> Typical dimensions

## VLVAW2N and VLVAW3N



## VLVAF4P



## Dimensions and weight

| Type | Dimensions (mm / inches) |  |  |  |
| :--- | :--- | :--- | :--- | :--- |
|  | H | W | D | D1 |
| VLVAW2N | $850 / 33.5$ | $800 / 31.5$ | $400 / 15.7$ | $1200 / 47.2$ |
| VLVAW3N | $1200 / 47.2$ | $1000 / 39.4$ | $400 / 15.7$ | $1400 / 55.1$ |
| VLVAF4P | $1200 / 47.2$ | $1300 / 51.2$ | $400 / 15.7$ | $1200 / 47.2$ |
| AV/BVIAT/BT 1 section | $2324 / 91.5^{*}$ | $762 / 30$ | $915 / 36$ | $1626 / 64$ |
| AV/BVIAT/BT 2 sections | $2324 / 91.5^{*}$ | $1524 / 60$ | $915 / 36$ | $1626 / 64$ |
| AV/BVIAT/BT 3 sections | $2324 / 91.5^{*}$ | $2286 / 90$ | $915 / 36$ | $1626 / 64$ |

* With cable entry 24 ", H=2934 / 115.5 - Entry cable supplied but to be fitted on field
* With cable entry 12", H=2629 / 103.5 - Entry cable supplied but to be fitted on field

AV,BV,AT,BT models


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## Appendix

## Appendix

Power factor of most common receiving devices ..... 38
When should fixed power factor correction be used? ..... 39
Automatic compensation: installation advice ..... 41
General information about harmonics ..... 42
Causes and effects of harmonics ..... 44
VarPlus Logic series. ..... 46
Calculation of reactive power ..... 49
Other chapters
Power Factor correction Guidelines ..... 10
VarSet offer ..... 20

## Appendix <br> Power factor of most common receiving devices

Practical calculation of reactive power

| Type of circuit | Apparent power S(kVA) | Active power P(kW) | Reactive power Q (kVAR) |
| :---: | :---: | :---: | :---: |
| Single phase $(\mathrm{Ph}+\mathrm{N})$ <br> Single phase (Ph + Ph) | $\begin{aligned} & S=V \times I \\ & S=U \times I \end{aligned}$ | $\begin{aligned} & P=V \times I \times \cos \varphi \\ & P=U \times I \times \cos \varphi \end{aligned}$ | $\begin{aligned} & P=V \times I \times \sin \varphi \\ & P=U \times I \times \sin \varphi \end{aligned}$ |
| Example: <br> 5 kW load <br> $\operatorname{Cos} \varphi=0.5$ | 10 kVA | 5 kW | 8.7 kVAR |
| Three-phase (3Ph or 3Ph+N) | $S=\sqrt{3} \times U \times 1$ | $P=\sqrt{3} \times U \times 1 \times \cos \varphi$ | $Q=\sqrt{ } 3 \times U \times I \times \sin \varphi$ |
| Example of Motor with $\mathrm{Pn}=51 \mathrm{~kW}$ $\cos \varphi=0.86$ efficiency $=0.91$ | 65 kVA | 56 kW | 33 kVAR |

Calculations in the three-phase example were as follows:
$\mathrm{Pn}=$ power supplied to the rotary axis $=51 \mathrm{~kW}$
$\mathrm{P}=$ active consumed power $=\mathrm{Pn} / \mathrm{\rho}=56 \mathrm{~kW}$
$S=$ apparent power $\quad=\mathrm{P} / \cos \varphi=\mathrm{P} / 0.86=65 \mathrm{kVA}$
Hence:
$Q=\sqrt{\left(S^{2}-P^{2}\right)}=\sqrt{\left(65^{2}-56^{2}\right)}=33 \mathrm{kVAR}$
The average power factor values for various loads are given below.

Power factor of the most common loads

| Device | Load | $\cos \varphi$ | tg $\varphi$ |
| :--- | :--- | :--- | :--- |
|  | $0 \%$ | 0.17 | 5.8 |
|  | $25 \%$ | 0.55 | 1.52 |
|  | $50 \%$ | 0.73 | 0.94 |
|  | $75 \%$ | 0.8 | 0.75 |
|  | $100 \%$ | 0.85 | 0.62 |
| Incandescent lamps |  | 1 | 0 |
| Fluorescent lamps |  | 0.5 | 1.73 |
| Discharge lamps |  | 0.4 to 0.6 | 2.29 to 1.33 |
| Resistance furnaces |  | 1 | 0 |
| Induction furnaces |  | 0.85 | 0.62 |
| Dielectric heating furnaces |  | 0.85 | 0.62 |
| Resistance welding machine to 0.9 | 0.75 to 0.48 |  |  |
| Single-phase static arc-welding centres |  | 0.5 | 1.73 |
| Rotary arc-welding sets |  | 0.7 to 0.9 | 1.02 |
| Arc-welding transformers/rectifiers |  | 0.8 | 1.02 to 0.9 |
| Arc furnaces |  | 0.75 |  |

$\operatorname{Cos} \varphi$ of the most commonly-used devices.

## When should fixed power factor correction be used?



Fig. 7 Power flow in an installation with an uncompensated transformer.


Fig. 8 Power flow in an installation where the transformer is compensated by a fixed power factor correction device.

## Fixed power factor correction for transformer

A transformer consumes a reactive power that can be determined approximately by adding:

- a fixed part that depends on the magnetising off-load current lo: Qo $=I_{0} \times U n \times \sqrt{3}$
- a part that is proportional to the square of the apparent power that it conveys: $\mathrm{Q}=\mathrm{Usc} \times \mathrm{S}^{2} / \mathrm{Sn}$

Usc: short-circuit voltage of the transformer in p.u.
S: apparent power conveyed by the transformer
Sn : apparent nominal power of the transformer
Un: nominal phase-to-phase voltage
The total reactive power consumed by the transformer is: $\mathrm{Qt}=\mathrm{Qo}+\mathrm{Q}$.
If this correction is of the individual type, it can be performed at the actual terminals of the transformer.

If this correction is performed globally with load correction on the busbar of the main switchboard, it can be of the fixed type provided that total power does not exceed $15 \%$ of transformer nominal power(otherwise use banks with automatic regulation).
The individual correction values specific to the transformer, depending on transformer nominal power, are listed in the table below.

| Transformer | Oil bath |  | Dry |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- |
| $\mathbf{S}(\mathbf{k V A})$ | Usc (\%) | No-load | Load | No-load | Load |
| 100 | 4 | 2.5 | 5.9 | 2.5 | 8.2 |
| 160 | 4 | 3.7 | 9.6 | 3.7 | 12.9 |
| 250 | 4 | 5.3 | 14.7 | 5.0 | 19.5 |
| 315 | 4 | 6.3 | 18.3 | 5.7 | 24 |
| 400 | 4 | 7.6 | 22.9 | 6.0 | 29.4 |
| 500 | 4 | 9.5 | 28.7 | 7.5 | 36.8 |
| 630 | 4 | 11.3 | 35.7 | 8.2 | 45.2 |
| 800 | 4 | 20.0 | 66.8 | 10.4 | 57.5 |
| 1000 | 6 | 24.0 | 82.6 | 12 | 71 |
| 1250 | 5.5 | 27.5 | 100.8 | 15 | 88.8 |
| 1600 | 6 | 32 | 126 | 19.2 | 113.9 |
| 2000 | 7 | 38 | 155.3 | 22 | 140.6 |
| 2500 | 7 | 45 | 191.5 | 30 | 178.2 |

## Appendix

## When should fixed power factor correction be used?



Fig. 9 Mounting capacitors at motor terminals.


Fig. 10 Parallel-mounting of capacitors with separate operating mechanism.

## Fixed power factor correction for asynchronous motor

The $\cos \varphi$ of motors is normally very poor off-load and when slightly loaded, and poor in normal operating conditions. Installation of capacitors is therefore recommended for this type of load. The table opposite gives, by way of an example, the values for capacitor bank power in kVAR to be installed according to motor power.

| Rated power | Number of revolutions per minute Reactive power in kVAR |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| kW | HP | 3000 | 1500 | 1000 | 750 |
| 11 | 15 | 2.5 | 2.5 | 2.5 | 5 |
| 18 | 25 | 5 | 5 | 7.5 | 7.5 |
| 30 | 40 | 7.5 | 10 | 11 | 12.5 |
| 45 | 60 | 11 | 13 | 14 | 17 |
| 55 | 75 | 13 | 17 | 18 | 21 |
| 75 | 100 | 17 | 22 | 25 | 28 |
| 90 | 125 | 20 | 25 | 27 | 30 |
| 110 | 150 | 24 | 29 | 33 | 37 |
| 132 | 180 | 31 | 36 | 38 | 43 |
| 160 | 218 | 35 | 41 | 44 | 52 |
| 200 | 274 | 43 | 47 | 53 | 61 |
| 250 | 340 | 52 | 57 | 63 | 71 |
| 280 | 380 | 57 | 63 | 70 | 79 |
| 355 | 485 | 67 | 76 | 86 | 98 |
| 400 | 544 | 78 | 82 | 97 | 106 |
| 450 | 610 | 87 | 93 | 107 | 117 |

When a motor drives a high inertia load, it may, after breaking of supply voltage, continue to rotate using its kinetic energy and be self-excited by a capacitor bank mounted at its terminals. The capacitors supply the reactive energy required for it to operate in asynchronous generator mode. Such self-excitation results in voltage holding and sometimes in high overvoltages.

## Correction requirements of asynchronous motors

## - Case of mounting capacitors at the motor terminals

To avoid dangerous overvoltages caused by the self-excitation phenomenon, you must ensure that capacitor bank power verifies the following equation:
Qc $\leq 0,9 \times \sqrt{ } 3 \times U n \times 10$

- $I_{0}$ : motor off-load current lo can be estimated by the following expression:
$I_{0}=2 \times I_{n} \times\left(I-\cos \varphi_{n}\right)$
- $I_{n}$ : value of motor nominal current
- $\operatorname{Cos} \varphi_{n}: \cos \varphi$ of the motor at nominal power
- $U_{n}$ : nominal phase-to-phase voltage
- Case of parallel-mounting of capacitors with separate operating mechanism

To avoid dangerous overvoltages due to self-excitation or in cases in which the motor starts by means of special switchgear (resistors, reactors, autotransformers), the capacitors will only be switched after starting.
Likewise, the capacitors must be disconnected before the motor is de-energised. In this case, motor reactive power can be fully corrected on full load.
Caution: if several banks of this type are connected in the same network, inrush current limiting reactors should be fitted.

# Automatic compensation: installation advice 



Fig. 11 Diagram of connection to a single LV busbar and CT location.


Fig. 12 Diagram of connection to independent LV busbars and CT location.


Fig. 13 Diagram of various transformers connected in parallel and TI location.

## Single busbar compensation

## General

An installation with a single LV busbar is that most often encountered. This type of installation requires that the reactive power can change with respect to the methods defined previously.

Compensation uses all the receiving devices of the installation and the amperage of the current transformer is determined according to the total current conducted through the main protection circuit breaker.

## Precautions during installation

As mentioned previously, it will be necessary to ensure a complementary installation of the current transformer so that it can read the total consumption of the installation.
It is indispensable to set up the current transformer (CT) in accordance with Fig. 11, and installing the system at any of the points indicated by a cross would result in the system malfunctioning.

## Compensation with several busbars

## Independent LV busbars

Another installation possibility is to have the various independent busbars which do not require to be connected to two identical transformers. For this reason: the reactive power requirement will be different for each busbar and need to be evaluated separately using the methods defined previously.
Compensation will use all the receiving devices and the amperage of each current transformer will be determined according to the total current through the main protection circuit breaker of each busbar.

## Installation precautions

In a similar manner to the previous case, the location of each current transformer (CT) will need to be decided upon in the same way so that some transformers can read the consumption in each part of the installation separately.

## Compensation for a busbar supplied by various transformers

An installation differing from the above is one in which there are many transformers connected in parallel on the low voltage side.

## Separate distribution transformers

Compensation in this installation can be obtained by placing together the two automatic batteries and their respective current transformers.

## Equal distribution transformers

In this case, it will be possible to obtain compensation with a single bank in which the controller is powered by a summing transformer, itself powered by the two CTs of each transformer.
The maximum number of summing inputs is 5 (Fig. 13).

## Installation precautions

- Separate distribution transformers:

Each bank is powered by a separate CT connected to the output of each transformer. The settings and the installation must be made as if these were independent busbars.

## - Equal distribution transformers:

Compensation uses a single bank and the only precaution is to be made on start up: the C/K relation that needs to be programmed into the controller must consider the sum of all the CTs feeding the summing circuit.

## Appendix <br> General information about harmonics



Fig. 14 Decomposition of a distorted wave.


Fig. 15 Typical graph of the frequency spectrum The frequency spectrum, also known as the spectral analysis, indicates the types of harmonic generator present on the network.

## Introduction

Harmonics are usually defined by two main characteristics:

- Their amplitude:
value of the harmonic voltage or current.
- Their order:
value of their frequency with respect to the fundamental frequency $(50 \mathrm{~Hz})$.
Under such conditions, the frequency of a 5th order harmonic is five times greater than the fundamental frequency, i.e. $5 \times 50 \mathrm{~Hz}=250 \mathrm{~Hz}$.


## The root mean square value

The rms value of a distorted wave is obtained by calculating the quadratic sum of the different values of the wave for all the harmonic orders that exist for this wave:

Rms value of I:
$I(A)=\sqrt{I_{1}{ }^{2}+I_{2}{ }^{2}+\ldots+I_{n}{ }^{2}}$
The rms value of all the harmonic components is deduced from this calculation:
$I_{h}(A)=\sqrt{I_{2}{ }^{2}+\ldots+I_{n}{ }^{2}}$
This calculation shows one of the main effects of harmonics, i.e. the increased rms current passing through an installation, due to the harmonic components with which a distorted wave is associated.
Usually, the switchgear and cables or the busbar trunking of the installation is defined from the rated current at the fundamental frequency; all these installation components are not designed to withstand excessive harmonic current.

## General information about harmonics



Fig. 16 Harmonic spectrum for single phase industrial devices, induction furnaces, welding machines, rectifiers,etc.


Fig. 17 Harmonic spectrum for 3 phases variable speed drives, asynchronous motors or direct current motors.

## Harmonic measurement: distortion

The presence of varying amounts of harmonics on a network is called distortion. It is measured by the harmonic distortion rates:

## - Th: individual distortion rate

It indicates, as a \%, the magnitude of each harmonic with respect to the value of the fundamental frequency:
$\mathrm{Th}(\%)=\mathrm{Ah} / \mathrm{A} 1$
Where:
$\mathrm{Ah}=$ the value of the voltage or current of the h -order harmonic.
$A 1=$ the value of the voltage or current at the fundamental frequency $(50 \mathrm{~Hz})$.

## - THD: Total Harmonic Distortion

It indicates, as a \%, the magnitude of the total distortion with respect to the fundamental frequency or with respect to the total value of the wave.

$$
\mathrm{THD}_{\text {CIGREE }}=\frac{\sqrt{\Sigma_{2}{ }^{h} A_{h}^{2}}}{A_{1}} \quad \mathrm{THD}_{\text {IEC } 555}=\frac{\sqrt{\sum_{2}{ }^{h} A_{h}^{2}}}{\sum_{1}{ }^{h} A_{h}{ }^{2}}
$$

The operating values used to find the true situation of the installations with respect to the degree of harmonic contamination are:

- The total harmonic voltage distortion [THD(U)] indicating the voltage wave distortion and the ratio of the sum of the harmonic voltages to the fundamental frequency voltage, all expressed as a \%.
- The total harmonic current distortion [THD(I)] determining the current wave distortion and the ratio of the sum of the harmonic currents to the fundamental frequency current, expressed as a \%.
- The frequency spectrum (TFT) is a diagram that gives the magnitude of each harmonic according to its order.
By studying it, we can determine which harmonics are present and their respective magnitude.


## Interharmonics

Interharmonics are sinusoidal components with frequencies that are not integral multiples of the fundamental frequency (and therefore situated between the harmonics). They are the result of periodic or random variations of the power absorbed by different loads such as arc furnaces, welding machines and frequency converters (variable speed drives, cycloconvertors).

## Appendix <br> Causes and effects of harmonics



Fig. 18 Linear loads such as inductors, capacitors and resistors do not generate harmonics.


Fig. 19 Non-linear loads are those that generate harmonics.


## Harmonic generators

Harmonics are generally produced by non-linear loads which, although powered by a sinusoidal voltage, absorb a non-sinusoidal current.
In short, non-linear loads are considered to behave as current sources that inject harmonics into the network.

The most common non-linear harmonic loads are those found in devices fed by power electronics, such as variable speed drives, rectifiers, converters, etc.

Loads such as saturable reactors, welding equipment, arc furnaces etc. also inject harmonics.
Other loads have a linear behaviour and do not generate harmonics: inductors, resistors and capacitors.

## Main harmonic sources

We differentiate between these loads, according to whether they are used for industrial or residential applications:

- Industrial loads:
» power electronics devices: variable speed drives, rectifiers, UPS, etc.
» loads using an electric arc: arc furnaces, welding machines, lighting (fluorescent lamps, etc.); harmonics (temporary) are also generated when motors are started with an electronic starter and when power transformers come into service.
- Residential loads: TVs, microwave ovens, induction plates, computers, printers, fluorescent lamps, etc.
The following table is a guide to the various loads with information on the injected harmonic current spectrum.

Indications about the harmonic spectrum injected by various loads

| Type of load | Harmonics generated | Comments |
| :--- | :--- | :--- |
| Transformer | Even and odd order | DC component |
| Asynchronous motors | Odd order | Interharmonics and subharmonics |
| Discharge lamp | $3 .^{\circ}+$ odd | Can reach $30 \%$ of II |
| Arc welding | $3 .^{\circ}$ |  |
| AC arc furnaces | Unstable variable spectrum | Non linear - asymmetric |
| Inductive filter rectifier | $\mathrm{h}=\mathrm{K} \times \mathrm{P} \pm 1$ <br> $\mathrm{lh}=I 1 / \mathrm{h}$ | UPS - variable speed drives V |
| Capacitive filter rectifier | $\mathrm{h}=\mathrm{K} \times \mathrm{P} \pm 1$ <br> $\mathrm{Ih}=I 1 / \mathrm{h}$ | Electronic device power supply |
| Cycloconvertor | Variables | Variable speed drives V |
| PWM controllers | Variables | UPS - DC -AC converter |

## Causes and effects of harmonics



Fig. 20 Cables.


Fig. 22 VarplusCan capacitor.


Fig. 21 Induction furnace.

## The effects of harmonics on loads

The following two types of effects appear in the main equipment: immediate or short-term effects and long-term effects.

## Immediate or short-term effects:

- Unwanted tripping of protection devices,
- Induced interference from LV current systems (remote control, telecommunications),
- Abnormal vibrations and noise,
- Damage due to capacitor thermal overload,
- Faulty operation of non-linear loads.

Long-term effects associated with current overload that causes overheating and premature deterioration of the equipment.

## Affected devices and effects:

- Power capacitors:
» additional losses and overheating,
» fewer possibilities of use at full load,
" vibrations and mechanical wear,
» acoustic disComfort.
- Motors:
» additional losses and overheating,
" fewer possibilities of use at full load,
» vibrations and mechanical wear,
》 acoustic disComfort.
- Transformers:
" additional losses and overheating,
" mechanical vibrations,
" acoustic disComfort.
" automatic switch:
» unwanted tripping due to the peak current being exceeded.
- Cables:
" additional dielectric and chemical losses, especially on the neutral, when $3^{\text {rd }}$ order harmonics are present,
» overheating.
- Computers:
" functional disruptions causing data losses or faulty operation of control equipment.
- Power electronics:
» waveform interference: switching, synchronisation, etc.
Summary table of effects, causes and consequences of harmonics

| Effects of the harmonics | Causes | Consequences |
| :--- | :--- | :--- |
| On the conductors | - The harmonic currents cause the Irms to increase <br> - <br> The skin effect reduces the effective crosssection <br> of the conductors as the frequency increases | - Unwanted tripping of the protection devices <br> - Overheated conductors |
| On the neutral conductor | - A balanced three-phase + neutral load generates 3rd order <br> multiple odd harmonics | -Closure of homopolar harmonics on the neutral, causing <br> overheating and overcurrents <br> On the transformers <br> On the motors <br> - Increased IRMS |
| On capacitors | - Similar to those for the transformers and generation <br> of a field added to the main one | Increased overheating due to the Joule effect in the windings <br> Increased losses in iron |

## Appendix <br> VarPlus Logic series <br> VL6, VL12

VarPlus Logic has all what you need for the simple and efficient operation of your automatic power factor correction equipment to maintain your power factor.

It is a simple and intelligent relay which measure, monitor and controls the reactive energy. Easy commissioning, step size detection and monitoring makes it different from others in the market.


VarPlus Logic VL6, VL12

## Capacitor bank step monitoring

- Monitoring of all the connected capacitor steps.
- Real time power in "kVAR" for the connected steps .
- Remaining step capacity per step as a \% of the original power since installation.
- Derating since installation.
- Number of switching operations of every connected step.


## System Measurement and monitoring

- THD(u) and THD(u) Spectrum 3rd to 19th - Measurement, Display and Alarm.
- Measurement of DQ - "kVAR" required to achieve target cos phi.
- Present cabinet temperature and maximum recorded temperature.
- System parameters - Voltage, Current, Active, reactive and apparent power.
- Large LCD display to monitor real step status and other parameters.


## Easy Commissioning

- Automatic Initialization and automatic step detection to do a auto commissioning
- Automatic wiring correction - voltage and current input wiring correction.
- 1 A or 5 A CT secondary compatible.


## Flexibility to the panel builder and retrofitting

- No step sequence restriction like in the traditional relays
- Any step sequences with auto detect. No programming needed.
- Easy to retrofit the faulty capacitor with different power.
- Quick and simple mounting and wiring.
- Connect to the digitized Schneider solutions through RS485 communication in Modbus protocol.
- Seamless connection to the Schneider software and gateways.


## Do more with VarPlus Logic

- Programmable alarms with last 5 alarms log.
- Suitable for medium voltage applications.
- Suitable for 4 quadrant operations.
- Dual cos phi control through digital inputs or export power detection.
- Dedicated alarm and fan control relays.
- Advance expert programming Menu to configure the controller the way you need.
- New control algorithm designed to reduce the number of switching operations and quickly attain the targeted power fact.


## Alarms

- Faulty Step
- Configurable alarm for step derating.
- THDu Limit alarm.
- Temperature alarm.
- Self correction by switching off the steps at the event of THDu alarm, temperature alarm and overload limit alarm.
- Under compensation alarm.
- Under/Over Voltage Alarm.
- Low/High Current Alarm.
- Overload limit alarm.
- Hunting alarm.
- Maximum operational limits - Time and number of switching.


## Range

| Type | Number of step output contacts | Part number |
| :--- | :--- | :--- |
| VL6 | 06 | VPL06N |
| VL12 | 12 | VPL12N |

## Appendix VarPlus Logic series

| General characteristics |  |
| :---: | :---: |
| Voltage and current Input |  |
| Direct supply voltage | $90-550 \mathrm{~V}, 1 \mathrm{ph}, 50 / 60 \mathrm{~Hz}$ |
|  | VA Burden: 6 VA |
|  | 300 V LN / 519 V LL CAT III or 550 V CAT II |
| Type of input connection | Phase to phase or phase to neutral |
| Protection against voltage dips | Automatic disconnection of steps for dips > 15 ms (protection of capacitor) |
| CT secondary | 1 A or 5 A compatible |
| CT primary range | Up to 9600 A |
| Current | $15 \mathrm{~mA}-6 \mathrm{~A}, 1 \mathrm{PH}$, |
|  | VA Burden : < 1 VA |
| Connection terminals | Screw type, pluggable. Section: $0.2-2.5 \mathrm{~mm}^{2}$ (0.2-1 $\mathrm{mm}^{2}$ for Modbus and digital inputs) |
| Power factor settings \& algorithm selection |  |
| Regulation setting Programmable | From Cos Phi 0.7 c to 0.7 i |
| Reconnection time Programmable | From 1 to 6500 s |
| Response time Programmable | From 1 to 6500 s |
| Possibility of dual cos Phi target | Yes, Through Digital Input or if export power detected |
| Program algorithm | AUTOMATIC (best fit) - Default |
|  | LIFO |
|  | PROGRESSIVE |
| Import export application compatibility | 4-Quadrant operation for generator application |
| Program intelligence |  |
| Automatic Initialization and Automatic bank detection | Yes |
| Detection and display of power, number of switching \& derating of all connected steps | Yes |
| Capacitor bank step sequence | Any sequence. No restriction/limitation on sequence |

## Dimensions


$\frac{\mathrm{mm}}{\mathrm{in} .}$


Mounting


## Appendix

VarPlus Logic series
VL6, VL12


Phase-to-Phase with VTs (3PH3W)

(A) Upstream protection

Voltage input: 2 A certified circuit breakers or fuses
B Shorting block for CT
( VT primary fuses and disconnect switch
(D) Output relays: 10 A (max.) certified circuit breakers or fuses (Applicable for applications with voltage transformers only)
E Capacitor primary fuses or CB's

| General characteristics |  |
| :---: | :---: |
| Alarm and control |  |
| Control outputs (step output) | VL6: 6 relays VL12: 12 relays ( NO contact) |
|  | 250 V LN or LL (CAT III) |
|  | DC Rating : 48 V DC / 1 A |
|  | AC Rating : 250 V AC / 5 A |
|  | Common root: 10 A max. |
| Dedicated fan control relay | Yes. Normal open contact (NO) |
|  | 48 V DC / 1 A, 250 V AC / 5 A |
| Alarm contact | The relay contact is open when the controller is energized with no alarm and will close in the event of an alarm. The relay is a NC (Normally Close) when the controller is not energized. |
|  | Rating : 48 V DC / 1 A, 250 V AC / 5 A |
| Digital Input for Cos phi2 target | Dry contact (internal supply $5 \mathrm{~V}, 10 \mathrm{~mA}$ ) |
| Modbus RS-485 serial port (RTU) | Line polarization / termination, not included |
| Communication protocol | Modbus |
| Interface TTL | Service port. Only for internal use |
| Internal Temperature probe | Yes |
| Display and measurement |  |
| Display | LCD graphic $56 \times 25$ (Backlit) |
| Alarms log | 5 last alarms |
| Voltage Harmonic Distortion measurement | THDu ; Individual odd harmonics distortion from H 3 to H19 |
| Measurement displayed and accuracy | Voltage, Current \& Frequency: $\pm 1 \%$ |
|  | Energy measurements, Cos Phi, THD(u): $\pm 2 \%$ |
|  | Individual Voltage harmonics ( H 3 to H 19 ): $\pm 3 \%$ |
|  | Temperature measurement : $\pm 3{ }^{\circ} \mathrm{C}$ |
| Testing standards and conformities |  |
| Standards | IEC 61010-1 |
|  | IEC 61000 6-2 |
|  | IEC 61000 6-4: level B |
|  | IEC 61326-1 |
|  | UL 61010 |
| Conformity and listing | Conformity and listing CE, NRTL, c NRTL, EAC |
| Mechanical specifications |  |
| Case | Front: Instrument case plastic RAL 7016 |
|  | Rear: Metal |
| Degree of Protection | Front: IP41, (IP54 by using a gasket) |
|  | Rear: IP20 |
| Weight | 0.6 kg |
| Size | $144 \times 144 \times 58 \mathrm{~mm}(\mathrm{H} \times \mathrm{W} \times \mathrm{D})$ |
| Panel Cutout | $138 \times 138(+0.5) \mathrm{mm}$, thickness $1-3 \mathrm{~mm}$ |
| Panel Mounting | Flush mounting |
| Storage condition |  |
| Temperature for operation | $-20^{\circ} \mathrm{C}+60^{\circ} \mathrm{C}$ |
| Storage | $-40^{\circ} \mathrm{C}+85^{\circ} \mathrm{C}$ |
| Humidity | 0\% -95\%, without condensation for operation and storage |
| Maximum pollution degree | 2 |
| Maximum altitude | $\leq 2000 \mathrm{~m}$ |

Appendix VarPlus Logic series

## Calculation of reactive power: Selection table

The table gives a coefficient, according to the $\cos \varphi$ of the installation before and after power factor correction. Multiplying this figure by the active power gives the reactive power to be installed.

| Before compensation |  | Capacitor power in kVAR to be installed per kW of load to raise the power factor ( $\cos \varphi$ or $\operatorname{tg} \varphi)$ |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\boldsymbol{\operatorname { t g }} \varphi$ | $\boldsymbol{\operatorname { c o s }} \varphi$ | $\begin{aligned} & \operatorname{tg} \varphi \\ & \cos \varphi \end{aligned}$ | $\begin{aligned} & 0.75 \\ & 0.8 \end{aligned}$ | $\begin{aligned} & 0.59 \\ & 0.86 \end{aligned}$ | $\begin{aligned} & 0.48 \\ & 0.9 \end{aligned}$ | $\begin{aligned} & 0.45 \\ & 0.91 \end{aligned}$ | $\begin{aligned} & 0.42 \\ & 0.92 \end{aligned}$ | $\begin{aligned} & 0.39 \\ & 0.93 \end{aligned}$ | $\begin{aligned} & 0.36 \\ & 0.94 \end{aligned}$ | $\begin{aligned} & 0.32 \\ & 0.95 \end{aligned}$ | $\begin{aligned} & 0.29 \\ & 0.96 \end{aligned}$ | $\begin{aligned} & 0.25 \\ & 0.97 \end{aligned}$ | $\begin{aligned} & 0.20 \\ & 0.98 \end{aligned}$ | $\begin{aligned} & 0.14 \\ & 0.99 \end{aligned}$ | $\begin{aligned} & 0.00 \\ & 1 \end{aligned}$ |
| 2.29 | 0.40 |  | 1.541 | 1.698 | 1.807 | 1.836 | 1.865 | 1.896 | 1.928 | 1.963 | 2.000 | 2.041 | 2.088 | 2.149 | 2.291 |
| 2.22 | 0.40 |  | 1.475 | 1.631 | 1.740 | 1.769 | 1.799 | 1.829 | 1.862 | 1.896 | 1.933 | 1.974 | 2.022 | 2.082 | 2.225 |
| 2.16 | 0.42 |  | 1.411 | 1.567 | 1.676 | 1.705 | 1735 | 1.766 | 1.798 | 1.832 | 1.869 | 1.910 | 1.958 | 2.018 | 2.161 |
| 2.10 | 0.43 |  | 1.350 | 1.506 | 1.615 | 1.644 | 1.674 | 1.704 | 1.737 | 1.771 | 1.808 | 1.849 | 1.897 | 1.957 | 2.100 |
| 2.04 | 0.44 |  | 1.291 | 1.448 | 1.557 | 1.585 | 1.615 | 1.646 | 1.678 | 1.712 | 1.749 | 1.790 | 1.838 | 1.898 | 2.041 |
| 1.98 | 0.45 |  | 1.235 | 1.391 | 1.500 | 1.529 | 1.559 | 1.589 | 1.622 | 1.656 | 1.693 | 1.734 | 1.781 | 1.842 | 1.985 |
| 1.93 | 0.46 |  | 1.180 | 1.337 | 1.446 | 1.475 | 1.504 | 1.535 | 1.567 | 1.602 | 1.639 | 1.680 | 1.727 | 1.788 | 1.930 |
| 1.88 | 0.47 |  | 1.128 | 1.285 | 1.394 | 1.422 | 1.452 | 1.483 | 1.515 | 1.549 | 1.586 | 1.627 | 1.675 | 1.736 | 1.878 |
| 1.83 | 0.48 |  | 1.078 | 1.234 | 1.343 | 1.372 | 1.402 | 1.432 | 1.465 | 1.499 | 1.536 | 1.577 | 1.625 | 1.685 | 1.828 |
| 1.78 | 0.49 |  | 1.029 | 1.186 | 1.295 | 1.323 | 1.353 | 1.384 | 1.416 | 1.450 | 1.487 | 1.528 | 1.576 | 1.637 | 1.779 |
| 1.73 | 0.5 |  | 0.982 | 1.139 | 1.248 | 1.276 | 1.306 | 1.337 | 1.369 | 1.403 | 1.440 | 1.481 | 1.529 | 1.590 | 1.732 |
| 1.69 | 0.51 |  | 0.937 | 1.093 | 1.202 | 1.231 | 1.261 | 1.291 | 1.324 | 1.358 | 1.395 | 1.436 | 1.484 | 1.544 | 1.687 |
| 1.64 | 0.52 |  | 0.893 | 1.049 | 1.158 | 1.187 | 1.217 | 1.247 | 1.280 | 1.314 | 1.351 | 1.392 | 1.440 | 1.500 | 1.643 |
| 1.60 | 0.53 |  | 0.850 | 1.007 | 1.116 | 1.144 | 1.174 | 1.205 | 1.237 | 1.271 | 1.308 | 1.349 | 1.397 | 1.458 | 1.600 |
| 1.56 | 0.54 |  | 0.809 | 0.965 | 1.074 | 1.103 | 1.133 | 1.163 | 1.196 | 1.230 | 1.267 | 1.308 | 1.356 | 1.416 | 1.559 |
| 1.52 | 0.55 |  | 0.768 | 0.925 | 1.034 | 1.063 | 1.092 | 1.123 | 1.156 | 1.190 | 1.227 | 1.268 | 1.315 | 1.376 | 1.518 |
| 1.48 | 0.56 |  | 0.729 | 0.886 | 0.995 | 1.024 | 1.053 | 1.084 | 1.116 | 1.151 | 1.188 | 1.229 | 1.276 | 1.337 | 1.479 |
| 1.44 | 0.57 |  | 0.691 | 0.848 | 0.957 | 0.986 | 1.015 | 1.046 | 1.079 | 1.113 | 1.150 | 1.191 | 1.238 | 1.299 | 1.441 |
| 1.40 | 0.58 |  | 0.655 | 0.811 | 0.920 | 0.949 | 0.969 | 1.009 | 1.042 | 1.076 | 1.113 | 1.154 | 1.201 | 1.262 | 1.405 |
| 1.37 | 0.59 |  | 0.618 | 0.775 | 0.884 | 0.913 | 0.942 | 0.973 | 1.006 | 1.040 | 1.077 | 1.118 | 1.165 | 1.226 | 1.368 |
| 1.33 | 0.6 |  | 0.583 | 0.740 | 0.849 | 0.878 | 0.907 | 0.938 | 0.970 | 1.005 | 1.042 | 1.083 | 1.130 | 1.191 | 1.333 |
| 1.30 | 0.61 |  | 0.549 | 0.706 | 0.815 | 0.843 | 0.873 | 0.904 | 0.936 | 0.970 | 1.007 | 1.048 | 1.096 | 1.157 | 1.299 |
| 1.27 | 0.62 |  | 0.515 | 0.672 | 0.781 | 0.810 | 0.839 | 0.870 | 0.903 | 0.937 | 0.974 | 1.015 | 1.062 | 1.123 | 1.265 |
| 1.23 | 0.63 |  | 0.483 | 0.639 | 0.748 | 0.777 | 0.807 | 0.837 | 0.873 | 0.904 | 0.941 | 1.982 | 1.030 | 1.090 | 1.233 |
| 1.20 | 0.64 |  | 0.451 | 0.607 | 0.716 | 0.745 | 0.775 | 0.805 | 0.838 | 0.872 | 0.909 | 0.950 | 0.998 | 1.058 | 1.201 |
| 1.17 | 0.65 |  | 0.419 | 0.672 | 0.685 | 0.714 | 0.743 | 0.774 | 0.806 | 0.840 | 0.877 | 0.919 | 0.966 | 1.027 | 1.169 |
| 1.14 | 0.66 |  | 0.388 | 0.639 | 0.654 | 0.683 | 0.712 | 0.743 | 0.775 | 0.810 | 0.847 | 0.888 | 0.935 | 0.996 | 1.138 |
| 1.11 | 0.67 |  | 0.358 | 0.607 | 0.624 | 0.652 | 0.682 | 0.713 | 0.745 | 0.779 | 0.816 | 0.857 | 0.905 | 0.996 | 1.108 |
| 1.08 | 0.68 |  | 0.328 | 0.576 | 0.594 | 0.623 | 0.652 | 0.683 | 0.715 | 0.750 | 0.878 | 0.828 | 0.875 | 0.936 | 1.078 |
| 1.05 | 0.69 |  | 0.299 | 0.545 | 0.565 | 0.593 | 0.623 | 0.654 | 0.686 | 0.720 | 0.757 | 0.798 | 0.846 | 0.907 | 1.049 |
| 1.02 | 0.7 |  | 0.270 | 0.515 | 0.536 | 0.565 | 0.594 | 0.625 | 0.657 | 0.692 | 0.729 | 0.770 | 0.817 | 0.878 | 1.020 |
| 0.99 | 0.71 |  | 0.242 | 0.485 | 0.508 | 0.536 | 0.566 | 0.597 | 0.629 | 0.663 | 0.700 | 0.741 | 0.789 | 0.849 | 0.992 |
| 0.96 | 0.72 |  | 0.214 | 0.456 | 0.480 | 0.508 | 0.538 | 0.569 | 0.601 | 0.665 | 0.672 | 0.713 | 0.761 | 0.821 | 0.964 |
| 0.94 | 0.73 |  | 0.186 | 0.427 | 0.452 | 0.481 | 0.510 | 0.541 | 0.573 | 0.608 | 0.645 | 0.686 | 0.733 | 0.794 | 0.936 |
| 0.91 | 0.74 |  | 0.159 | 0.398 | 0.425 | 0.453 | 0.483 | 0.514 | 0.546 | 0.580 | 0.617 | 0.658 | 0.706 | 0.766 | 0.909 |
| 0.88 | 0.75 |  | 0.132 | 0.370 | 0.398 | 0.426 | 0.456 | 0.487 | 0.519 | 0.553 | 0.590 | 0.631 | 0.679 | 0.739 | 0.882 |
| 0.86 | 0.76 |  | 0.105 | 0.343 | 0.371 | 0.400 | 0.429 | 0.460 | 0.492 | 0.526 | 0.563 | 0.605 | 0.652 | 0.713 | 0.855 |
| 0.83 | 0.77 |  | 0.079 | 0.316 | 0.344 | 0.373 | 0.403 | 0.433 | 0.466 | 0.500 | 0.537 | 0.578 | 0.626 | 0.686 | 0.829 |
| 0.80 | 0.78 |  | 0.052 | 0.289 | 0.318 | 0.347 | 0.376 | 0.407 | 0.439 | 0.574 | 0.511 | 0.552 | 0.559 | 0.660 | 0.802 |
| 0.78 | 0.79 |  | 0.026 | 0.262 | 0.292 | 0.320 | 0.350 | 0.381 | 0.413 | 0.447 | 0.484 | 0.525 | 0.573 | 0.634 | 0.776 |
| 0.75 | 0.8 |  |  | 0.235 | 0.266 | 0.294 | 0.324 | 0.355 | 0.387 | 0.421 | 0.458 | 0.449 | 0.547 | 0.608 | 0.750 |
| 0.72 | 0.81 |  |  | 0.209 | 0.240 | 0.268 | 0.298 | 0.329 | 0.361 | 0.395 | 0.432 | 0.473 | 0.521 | 0.581 | 0.724 |
| 0.70 | 0.82 |  |  | 0.183 | 0.214 | 0.242 | 0.272 | 0.303 | 0.335 | 0.369 | 0.406 | 0.447 | 0.495 | 0.556 | 0.698 |
| 0.67 | 0.83 |  |  | 0.157 | 0.188 | 0.216 | 0.246 | 0.277 | 0.309 | 0.343 | 0.380 | 0.421 | 0.469 | 0.530 | 0.672 |
| 0.65 | 0.84 |  |  | 0.131 | 0.162 | 0.190 | 0.220 | 0.251 | 0.283 | 0.317 | 0.354 | 0.395 | 0.443 | 0.503 | 0.646 |
| 0.62 | 0.85 |  |  | 0.105 | 0.135 | 0.164 | 0.194 | 0.225 | 0.257 | 0.291 | 0.328 | 0.369 | 0.417 | 0.477 | 0.620 |
| 0.59 | 0.86 |  |  | 0.079 | 0.109 | 0.138 | 0.167 | 0.198 | 0.230 | 0.265 | 0.302 | 0.343 | 0.390 | 0.451 | 0.593 |
| 0.56 | 0.87 |  |  | 0.053 | 0.082 | 0.111 | 0.141 | 0.172 | 0.204 | 0.238 | 0.275 | 0.316 | 0.364 | 0.424 | 0.567 |
| 0.53 | 0.88 |  |  | 0.029 | 0.055 | 0.084 | 0.114 | 0.145 | 0.177 | 0.211 | 0.248 | 0.289 | 0.337 | 0.397 | 0.540 |
| 0.51 | 0.89 |  |  |  | 0.028 | 0.057 | 0.086 | 0.117 | 0.149 | 0.184 | 0.221 | 0.262 | 0.309 | 0.370 | 0.512 |
| 0.48 | 0.90 |  |  |  |  | 0.029 | 0.058 | 0.089 | 0.121 | 0.156 | 0.193 | 0.234 | 0.281 | 0.48 | 0.484 |

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## Relevant documents published by Schneider Electric

- Electrical Installation Guide.
- Expert Guide $n^{\circ} 4$ : "Harmonic detection \& filtering".
- Expert Guide $n^{\circ} 6$ : "Power Factor Correction and Harmonic Filtering Guide"
- Technical Guide 152: "Harmonic disturbances in networks, and their treatment".
- White paper: controlling the impact of Power Factor and Harmonics on Energy Efficiency.


## Relevant websites

- http://www.schneider-electric.us
- https://www.schneider-electric.us/powerquality
- http://engineering.electrical-equipment.org/
- http://www.electrical-installation.org


## Relevant standards

- CSA 22.2 No. 190 - Capacitors for power factor correction
- UL810-Capacitors
- UL508a - Standard for industrial panels


## Index of references

| Reference | Page(s) |
| :---: | :---: |
| VLVAW2N |  |
| VLVAW2N66075AB | 27 |
| VLVAW2N66100AB | 27 |
| VLVAW2N66075AA | 27 |
| VLVAW2N66100AA | 27 |
| VLVAW3N |  |
| VLVAW3N66125AB | 27 |
| VLVAW3N66150AB | 27 |
| VLVAW3N66175AB | 27 |
| VLVAW3N66200AB | 27 |
| VLVAW3N66225AB | 27 |
| VLVAW3N66250AB | 27 |
| VLVAW3N66275AB | 27 |
| VLVAW3N66300AB | 27 |
| VLVAW3N66125AA | 27 |
| VLVAW3N66150AA | 27 |
| VLVAW3N66175AA | 27 |
| VLVAW3N66200AA | 27 |
| VLVAW3N66225AA | 27 |
| VLVAW3N66250AA | 27 |
| VLVAF4P |  |
| VLVAF4P66075AB | 29 |
| VLVAF4P66100AB | 29 |
| VLVAF4P66125AB | 29 |
| VLVAF4P66150AB | 29 |
| VLVAF4P66175AB | 29 |
| VLVAF4P66200AB | 29 |
| VLVAF4P66075AA | 29 |
| VLVAF4P66100AA | 29 |
| VLVAF4P66125AA | 29 |
| VLVAF4P66150AA | 29 |
| VLVAF4P66175AA | 29 |
| VLVAF4P66200AA | 29 |



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