
# Technical Presentation

# Design Guideline of APFC, SVG and AHF

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# Presentation Outline


## Presenter

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## Presentation Outline

- PQ Problems - Reactive Power and Harmonics
- Possible Solutions - APFC, TSC, SVG and AHF
- How to specify Basic APFC
- How to specify Detuned APFC
- How to specify TSC APFC
- How to specify SVG
- How to specify AHF
- How to specify Hybrid  TSC APFC and Detuned APFC
- How to specify Hybrid  SVG and TSC APFC or Detuned APFC.

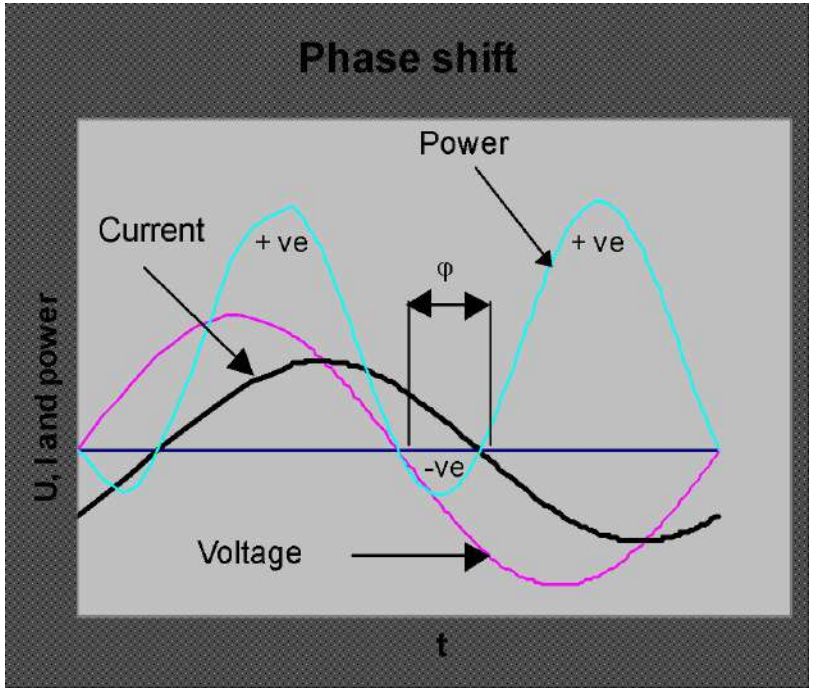

# Power Quality Problems

# Power Quality Problems

| Non-linear loads generate harmonics and distort power factor affecting both the distribution system equipment and the loads connected to it | | |
|---|---|---|
| Linear resistive loads<br>(Incandescent light bulb, Iron, resistive heating) | Linear inductive loads<br>(Motor with DOL or star delta starters) | Non linear loads<br>(Motors with VSD, UPS, Fluorescent and LED Lighting, Arc Furnace) |
| ▪ No Phase shift (U and I)<br>▪ PF = 1<br>▪ No reactive power<br>▪ No harmonics | ▪ Phase shift (U and I)<br>▪ Displacement PF < 1<br>▪ Reactive power<br>▪ No harmonics | ▪ Phase shift (U and I)<br>▪ PF Distortion<br>▪ Reactive power<br>▪ Harmonics |

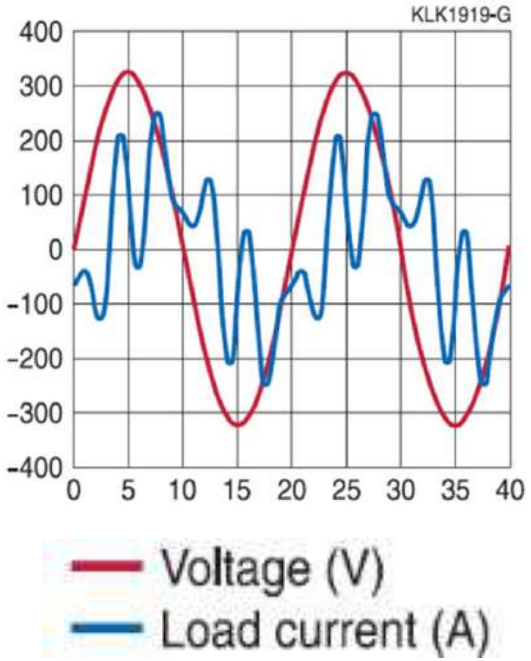
# Power Quality Problems

## Reactive Power




Linear loads – Phase shift
Displacement Power Factor
DPF = Cos φ

## Harmonics




Non linear loads-Phase shift and Harmonics
Total Power Factor including harmonics
TPF = P / S

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# Power Quality Problems

## What is Reactive Power ?

Electrical machines work on the principle of conversion of electromagnetic energy.(e.g. electric motors, transformers). A part of input energy is consumed for creating and maintaining the magnetic field. This part of the input energy cannot be converted into active energy and is returned to the electrical network on removal of the magnetic field. This power is known as “reactive“ power ***Q*** and is defined as follows.

$Q = \sqrt{3} \cdot U \cdot I \cdot \sin \varphi$ [ VAr ]

## Why is it useful to compensate reactive power ?

- System kVA- release – higher kW loading
- Reduction of ohmic losses – lower electrical power bill
- Reduction of PF Charges – 56.07 Baht/kVAr
- Power Quality improvement – stabilize voltage
- Reduction of $CO_2$ - improve climate conditions

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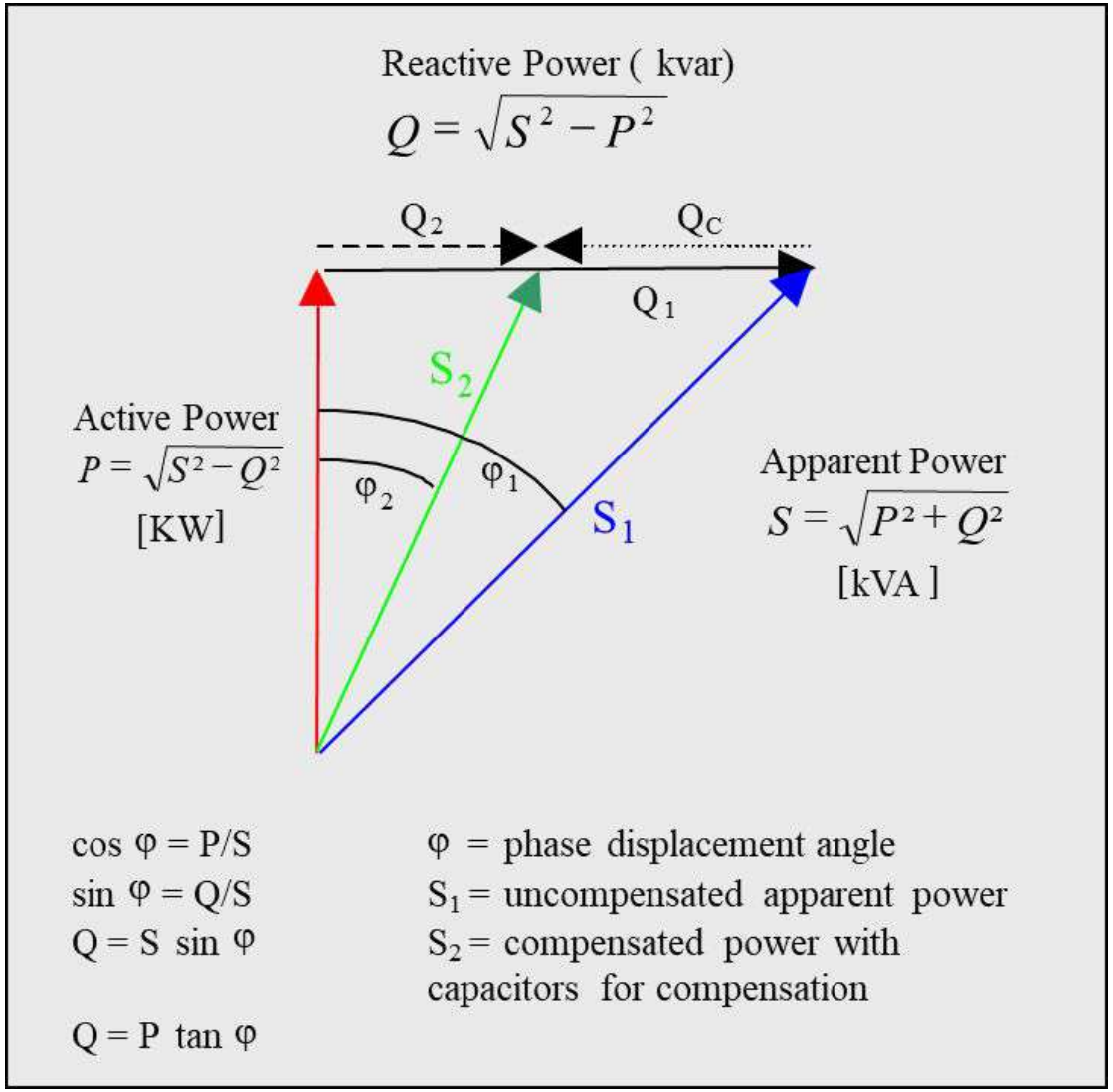
# Power Quality Problems

## Reactive Power Compensation by *Power Factor Correction*

- Power factor correction is the process of compensating the reactive power present in the grid to increase the efficiency and stability of the grid. This is often done with the help of capacitors that generate opposing reactive power and thus reduce the total reactive power in the grid.

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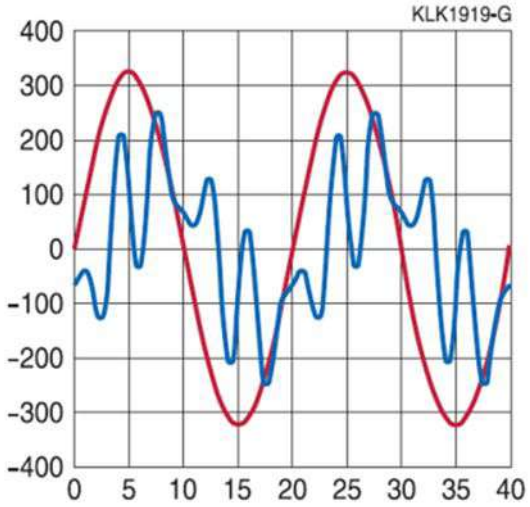
# Power Quality Problems

Harmonic disturbances are created by non-linear loads!




## Non linear loads

Loads which have non linear voltage-current characteristics are called non linear loads. When connected to a sinusoidal voltage, these loads produce non sinusoidal currents.

Non linear devices can be classified under the following three major categories:

1. Power electronics: e.g. rectifiers, VSD, UPS systems, inverters, ...
2. Ferromagnetic devices: e.g. transformers (non linear magnetizing characteristics)
3. Arcing devices: e.g. arc furnace equipment

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# Power Quality Problems

What is the difference between DPF and TPF ?

Displacement power factor is the phase shift between the current and voltage fundamental sine waves, thus it does not take into account the effect of harmonics.

DPF = Cos φ

Total Power Factor (TPF) is the ratio between active power and total apparent power including harmonic distortion reactive power.

TPF = P (kW) / S (kVA)

# Power Quality Problems

## What is the difference between DPF and TPF ?

$DPF = P / S_1$

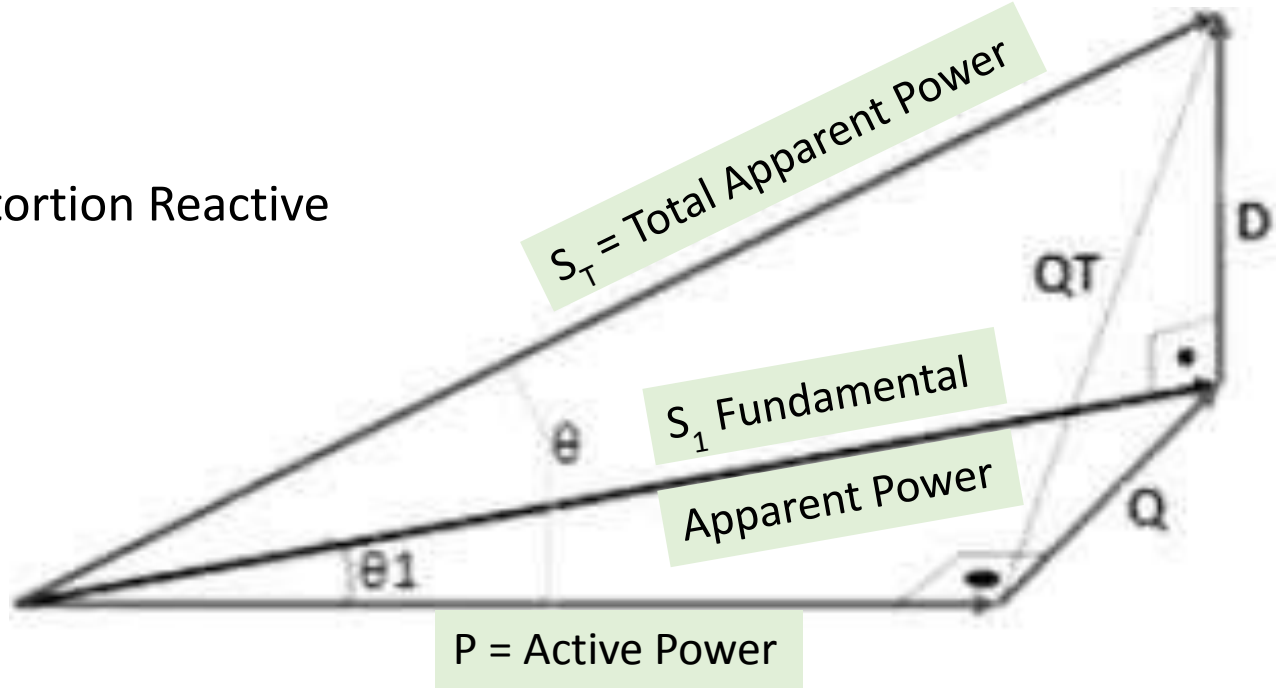
$TPF = P / S_T$

$S = \sqrt{P^2 + Q^2 + D^2}$ ; D = Harmonic Distortion Reactive Power

$P / S = (P / S_1) \times (S_1 / S_T)$ or

$P / S = (P / S1) \times (I_1 / I_T)$

TPF = DPF x Distortion PF



# Power Quality Problems

- TPF = DPF x Distortion PF
- $PF_{Distortion} = I_{Fundamential} / I_{Total}$
- $PF_{Distortion} = \sqrt{1 / ( 1 + THDi^2 )}$

To improve Total Power Factor, both THDi and Fundamental Reactive Power must be compensated.


# Possible Power Quality Solutions

# Possible Power Quality Solutions

1. Basic  Capacitor Bank with contactor switching (Basic APFC)
2. Detuned Capacitor Bank with contactor switching (Detuned APFC)
3. Detuned Capacitor Bank with thyristor switching (TSC APFC)
4. Static Var Generator (SVG)
5. Active Harmonic Filters and Power Optimizers (AHF)
6. Hybrid TSC APFC and Detuned APFC
7. Hybrid SVG and TSC APFC
8. Hybrid SVG and Detuned APFC

Note: APFC is an abbreviation for the

Automatic Power Factor Correction Capacitor Banks.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# 1. Design Guideline of Basic Capacitor Bank (Basic APFC)

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# Basic Capacitor Bank

## Scope of work:

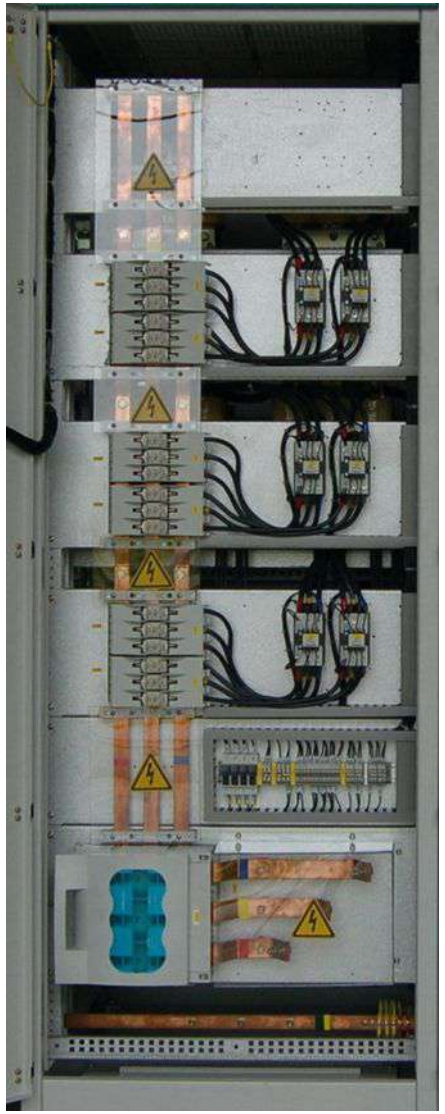
The Contractor shall supply and install the Basic Automatic Power Factor Correction Capacitor Bank (Basic APFC) ready for connection and use in low voltage systems.
The power ratings are according to the single line diagram.

## Electrical environment:

The basic APFC with contactor switching shall be used in case of

- Non-linear loads < 15% and
- Non-frequent load changes and
- Non-light flicker

The connection of a basic APFC onto a system containing harmonics and frequent load changes may reduce its life time. In these cases, other suitable solutions can be used in place of the basic APFC.



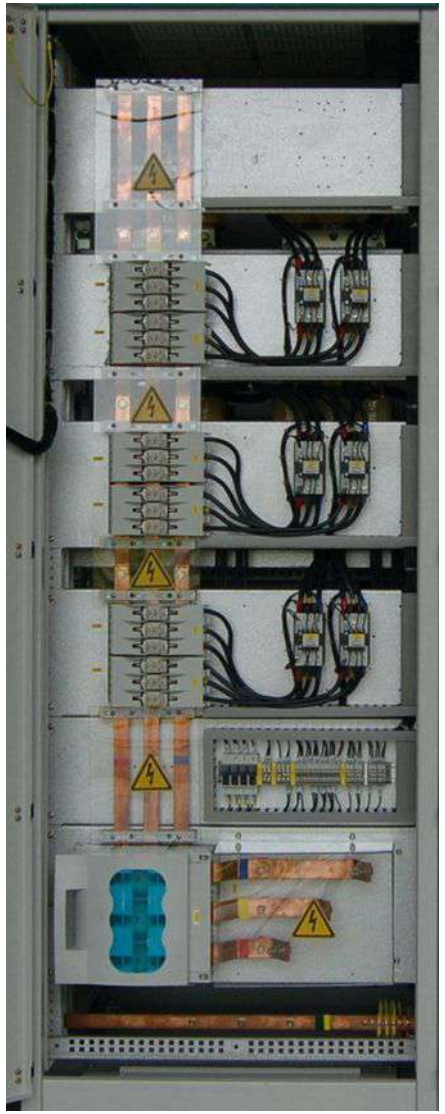
# Basic Capacitor Bank

## Design:

The modules on a galvanized sheet-steel chassis are fitted with busbar mounting fuse bases including shock protection cover, capacitor contactors with damping resistors, discharge reactors for fast discharges of capacitors, and dry-type capacitors. For connecting the modules together and for the connection to the power system via cable, each module has a 60 mm busbar support system and 30x10 mm copper busbars with insulation cover mounted at the front.

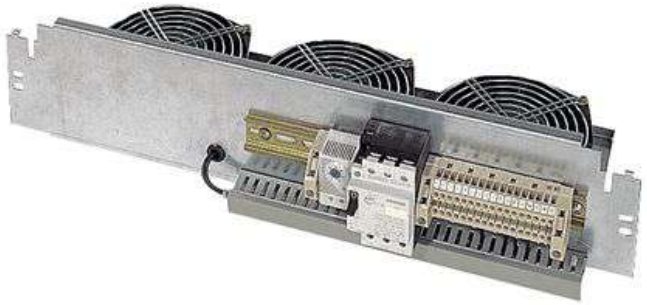
The connection of the module on the control side to the pf controller and to the control voltage is made by control cables via terminal blocks. This control cables shall be routed in cable ducts.

The maximum effective power per section (cubicle) shall not be higher than 400 kvar. For higher power ratings, capacitor section(s) shall be added. The dimension of each 400 kvar section should not be less than HxWxD 2250x800x600 mm. and each section shall have ventilation slots (louver) and axial fans.



# Basic Capacitor Bank

Cooling fans 230 V, 50 Hz, air flow not less than 800 cubic meter per hour per 400 kvar section. The operating fans shall be controlled by aux. contacts (NO Contacts) of capacitor contactors.



PF Controller, contactor coils and fans shall be protected by control fuse size 10x38, 500 V, 2 - 6 A mounted in fuse switch holder size 10x38, 690 V, 32 A, AC-22B.


The Capacitor bank shall be installed in a separate cubicle from MDB and designed so that alteration or addition of the capacitor in future will not affect the systems. The unit shall be installed as recommended by the manufacturer.

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# Basic Capacitor Bank

## Main components:

- Power Factor Controller
- Fuse-switch or Fuse-base with HRC fuses
- Contactor with damping device for capacitor switching
- Power Factor Correction Capacitor
- Ventilation fans
- LV PFC Banks.

# Basic Capacitor Bank

Technical Data:

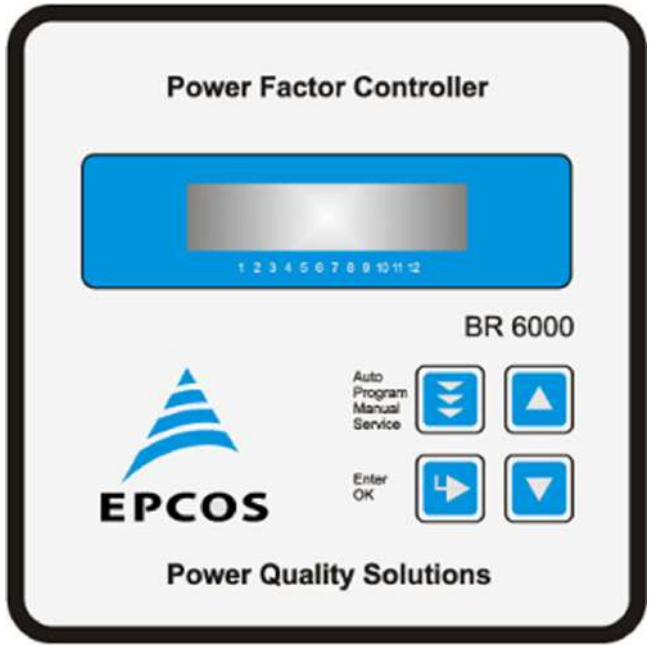
- Low-voltage basic APFC

Comply with the requirements of IEC 61921, IEC 61439-1 and IEC 61439-2.
Sheet steel cubicle shall have door and panel thickness 2 mm
Ambient temperature –20 to +35 degree C, 24 h average
Degree of protection IP 21
Short circuit strength of busbars Ipk = 75 kA, Icw = 42 kA, 1 sec.

# Basic Capacitor Bank

- Power Factor Controllers

Comply with the requirements of IEC 61000-4-2, IEC 61000-4-4 and IEC 61010-1.
Continuous LCD Display, Operating temp up to +60 degree C
Humidity class up to 95 %, Protection class IP 54 (Front)
Measurement current: x / 5 A, Target Power Factor : 0.3 ind – 0.3 cap
Power Factor display: 0.1 ind – 0.1 cap, Switching
and discharge time: 1-1200 sec, Control mode: LIFO, FIFO,
Intelligent mode, Minimum operating current or Sensitivity: 50 mA
Frequency: 50 Hz, Zero voltage release: < 15 ms
Switching outputs: 6 or 12 steps according to the drawing
Alarm relay: 1 NO Contact (250 V, 1000 W)
Display of V, A, W, VAR, KVA, Frequency, THDv, THDi,
individual harmonics up to 19$^{th}$, individual capacitor current, temp,
real time cos phi, target cos phi, kvar value to target cos phi
Alarm output of under/over compensation, under/over current, over temp,
harmonics exceeded Recall reorded values of number of contactor switching operations,
Vmax, KVAmax, THDmax, KWmax, KVARmax, TEMPmax, operation time of all capacitors.



# Basic Capacitor Bank

- Capacitor Contactors

Comply with the requirements of IEC 60947-4-1 / -5-1.
The capacitor contactor shall be equipped with Aux contact (1 NO) and damping resistors to reduce peak inrush current
Rated Insulation Voltage: 690 V
Utilization categories AC-6b according to IEC 60947-4-1 for switching of capacitor bank
Rated power: according to the drawing.


# Basic Capacitor Bank

- Discharge reactors

Rated voltage up to 690 V
Internal configuration: 2 winding in V arrangement
Discharge time: 400-690 V up to 25 kVAr < 5 s /
up to 50 kVAr < 10 s / up to 100 kVAr < 20 s
Power losses: < 1.8 W
Insulation class T40/B
Ambient temp -5 +55° C (24 h mean)

# Basic Capacitor Bank

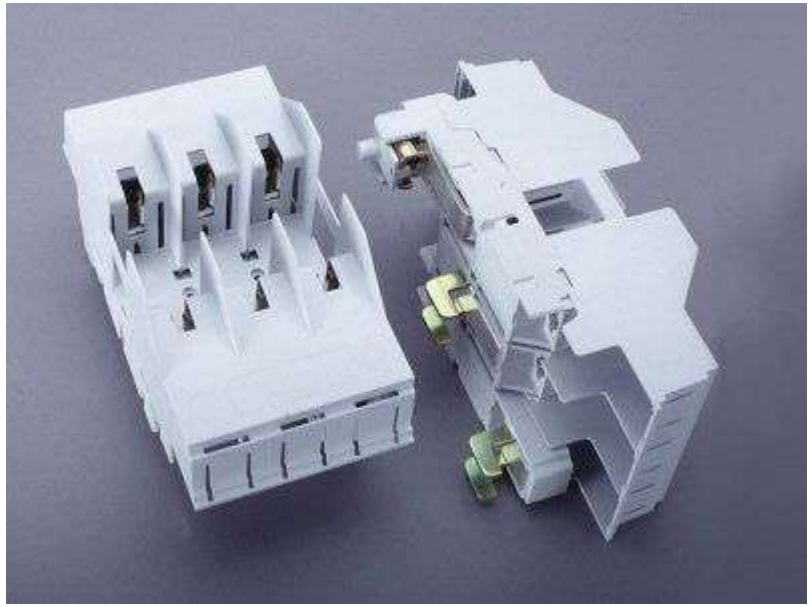
- PFC Capacitors

Comply with the requirements of IEC 60831-1+2
Indoor Dry Type, Inert gas (Nitrogen) impregnation
Rated voltage: not less than the system voltage
230/400/440/480/525/690/800/1000 VAC 50 Hz,
3-phase delta connection
Power output: according to the drawing
Safety: self healing, 3-phase overpressure disconnector and dry type
Overcurrent: up to 1.6 · Ir including combined effects of harmonics, overvoltages and capacitance tolerance
Inrush current: up to 300 x Ir
Losses: dielectric ≤ 0.2 W / kVAr, total ≤ 0.45 W / kVAr
Mean life expectancy: up to 130,000 hours
Humidity: max 95 %
Ambient temp: –40/D; max. temp. +55 °C; max. mean 24 h = +45 °C; max. mean 1 year = +35 °C; lowest temperature = –40 °C

# Basic Capacitor Bank

- NH Bus-mounting fuse bases

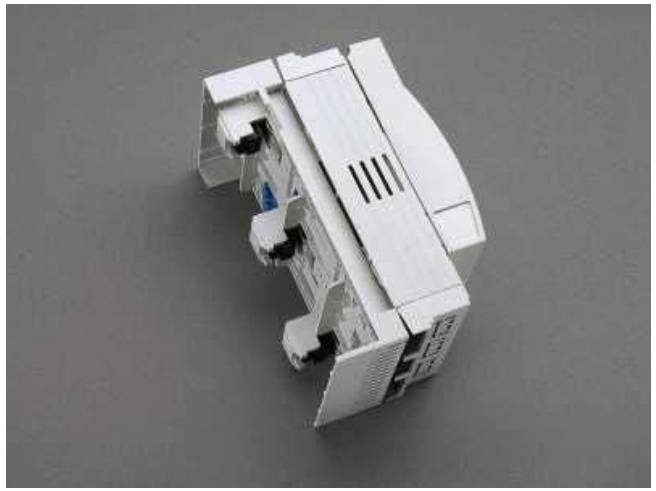
Comply with the requirements of IEC 60269-1/-2
For mounting on busbars 30x10 mm.
Rated Voltage: 690 V 3-Pole
Rated Current: 00/160 A for capacitor up to 60 kVAr 400 V
Rated Current: 1/250 A for capacitor up to 100 kVAr 400 V
Short-circuit strength when protected by fuses: 50 kA
Safety: Shock protection cover



# Basic Capacitor Bank

- NH Bus-mounting fuse switch-disconnector

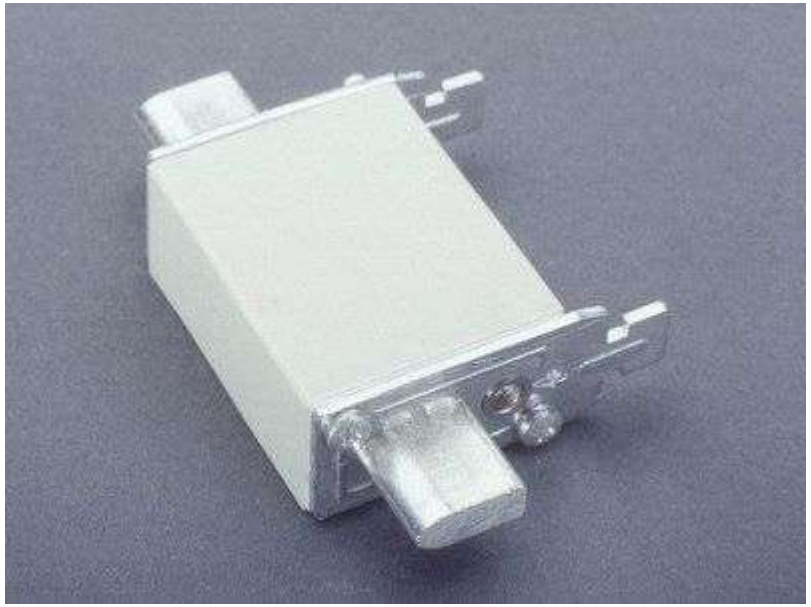
Comply with the requirements of IEC 60947-1/-3
For mounting on busbars 30x10 mm.
Rated Voltage: 690 V 3-Pole
Rated Current: 00/160 A for capacitor up to 60 kVAr 400 V
Rated Current: 1/250 A for capacitor up to 100 kVAr 400 V
Short-circuit strength when protected by fuses: 50 kA
Safety: Shock protection cover

# Basic Capacitor Bank

- NH HRC fuse links type gG

Comply with the requirements of IEC 60269-1/-2
Rated Voltage: ≥ 500 V
Size 00 for rated current up to 125 A
Size 1 for rated current up to 250 A
Rated Current: according to the drawing
Rated short-circuit breaking capacity AC 120 kA
Indicator version: double indicator at  top and middle



# Basic Capacitor Bank

- Micro switch or Remote monitoring

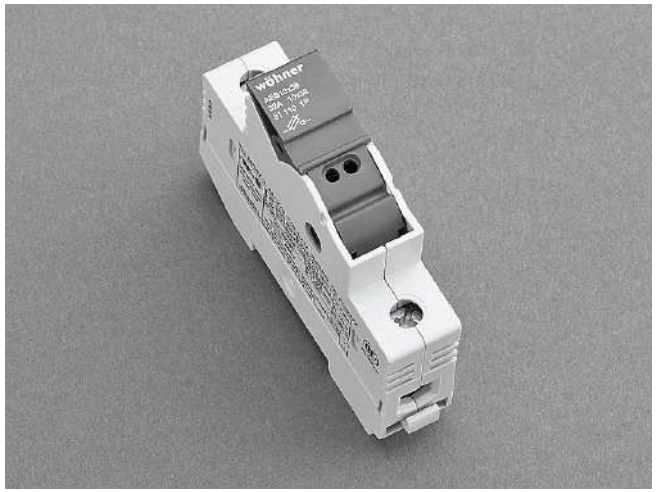
The micro switch is used for signaling of interruption of Fuse-links of the NH size 00 to size 3.
This micro switch is activated through the indicator spring of NH Fuses. The NC contact of this micro switch shall be connected in series with the control coil of the capacitor contactor.
In case of one fuse blown, the capacitor contactor will be switched off to disconnect the 3-phase capacitor unit.

Rated Voltage: 250 V AC
Rated Current: 5 A
Contact: 1 NC


# Basic Capacitor Bank

- Holder for cylindrical fuses

Comply with the requirements of IEC 60947-1/-3
Size 10 x 38 mm., 1-pole, AC-22B, DIN rail system
Rated Voltage: 690 V AC Rated Current: 32 A
rated isolation voltage Ui AC or DC: 800 V
rated surge voltage Uimp : 6 kV
short-circuit current with fuses (AC): 100 kA / 400 V (32A)
degree of protection: IP20

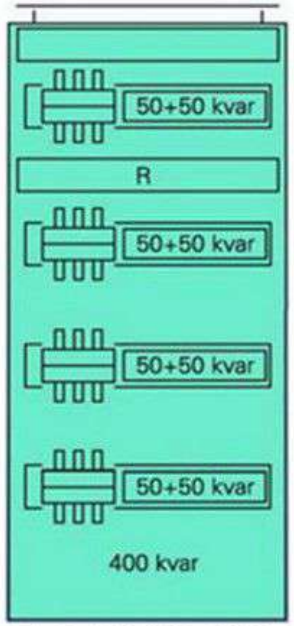



- Cylindrical fuse link type gG

Comply with the requirements of IEC 60269-1/-2
Size 10 x 38 mm.
Rated Voltage: 500 V AC Rated Current: 4 A and 6 A
Rated short-circuit breaking capacity AC 120 kA

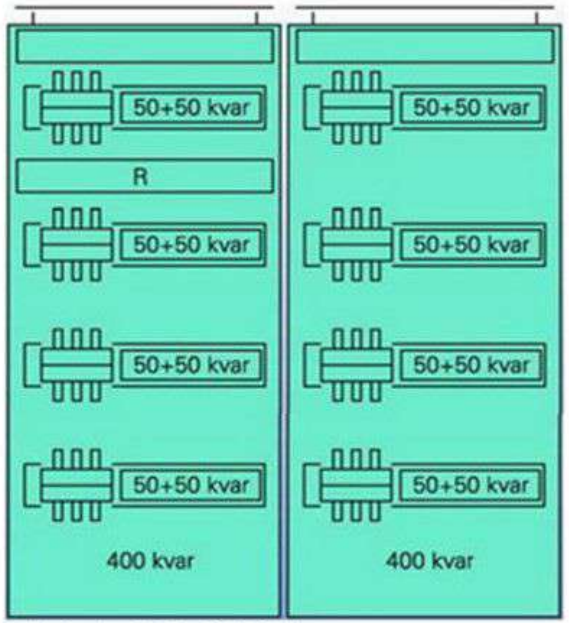
# Basic Capacitor Bank

Dimension and Ventilation fans of basic capacitor bank



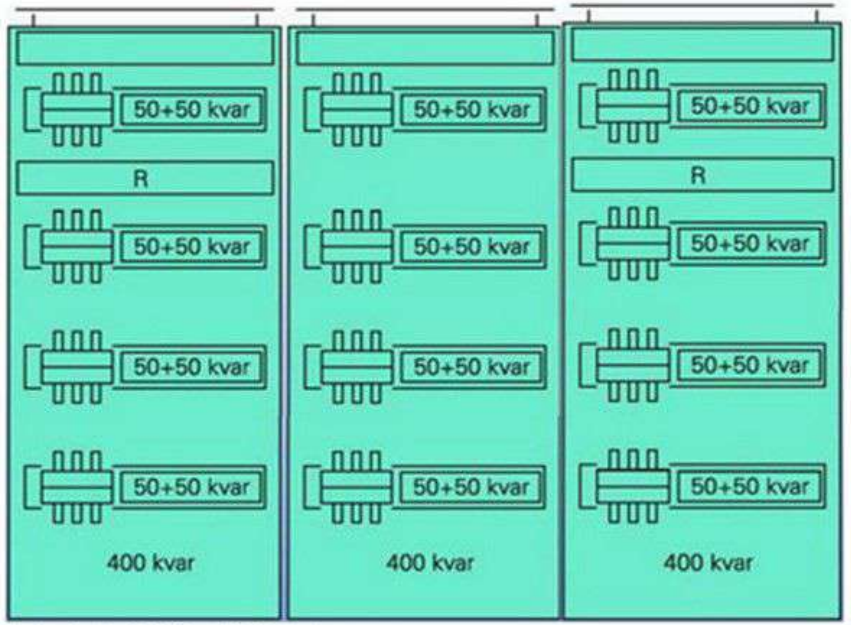

Total 300-400 kvar

2200x800x600 mm.
2x400 M³/hr




Total 450-800 kvar

2200x1600x600 mm.
4x400 M³/hr




Total 850-1200 kvar

2200x2400x600 mm.
6x400 M³/hr

HxWxD

# Basic Capacitor Bank

Scope of Supply: Example of 12 x 50 kVAr 400 V

| Item | Qty | Descriptions |
|---|---|---|
| | | |
| 1 | 1 | '"EPCOS" P.F. Controller type BR6000-R12, 12 steps, 400 V, 50 Hz, Measuring current 5 A, Measurement voltage range 30 ... 525 V AC (L–L / L–N), Supply voltage 110…230 V AC, 50 Hz, Target cos phi 0.3 ind. - 0.3 cap. with indication of U, I, Q, P, S, Cos-phi, temperature and harmonics, Standards EN 55082-2, EN 55011, IEC 61010-1. |
| 2 | 12 | "EPCOS" Type MKK400D25-03 x 2, PhaseCap Energy Plus PFC dry gas filled (N2) Capacitors, 3-ph, 50 kVAr, 400 V, 50 Hz., Ultra long life expectancy up to 240 000 hours at temperature class –40/D, inrush current capability of up to 500 · $I_R$, Self-healing, 3 phase overpressure disconnector, Total loss excluding discharge resistors ≤ 0.45 W/kVAr, Standards IEC 60831-1+2, UL 810. |
| 3 | 12 | "EPCOS" B44066S6210J230 Capacitor Contactor with damping device 50 kVAr, 400 V with 230 V coil, Auxiliary contact 1 NO, Rated insulation voltage Vi 690 V AC, Contact life 0.12 million operations, Standards IEC 947-4-1, IEC 947-5-1, VDE 0660. |

# Basic Capacitor Bank

Scope of Supply: Example of 12 x 50 kVAr 400 V

| Item | Qty | Descriptions |
|---|---|---|
| 4 | 12 | "Wöhner" 03654 Busbar Mounting Fuse Base 3-pole, 00/160 A, 690 V |
| 5 | 36 | "Wöhner" 03533 NH HRC fuse links size 00 / 125 A, 500 V AC. |
| 6 | 36 | "ETI" Type NVS 5 Micro switches on each fuse puller leg to disconnect 3-phase in case of one fuse blown. |
| 7 | 4 | "Wöhner" 31110 Switch for cylindrical fuse 10x38 mm, 32 A. |
| 8 | 2 | "Wöhner" 31182 Cylindrical fuse 10x38 mm, 2 A. |
| 9 | 2 | "Wöhner" 31184 Cylindrical fuse 10x38 mm, 4 A. |
| 10 | 2 | "EBM" M4Q 045 -CA01-A Ventilation fans Air flow 400 $m^3$ / h from inside cubicle to outside cubicle 7/31 W, 230 V, 50 Hz., 0.2 A, 1300 RPM. |
| | | |

# Basic Capacitor Bank

Scope of Supply: Example of 12 x 50 kVAr 400 V

| Item | Qty | Descriptions |
|---|---|---|
| 11 | 2 | "Wöhner" 33603 Busbar Mounting Fuse Switch 3-pole, 3/630 A, 690 V |
| 12 | 6 | "Wöhner" 03582 NH HRC fuse links size 3 / 630 A, 500 V AC. |
| 13 | 2 | Capacitor bank cubicle dimension HWD 2200x800x600 mm. with front doors, panels, base plates, copper busbars 3//30x10 mm., power cables, control cables, terminal blocks and accessories, galvanized steel plate 2 mm. thickness, IP21, RAL 7032 Color. |

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# 2. Design Guideline of Detuned Capacitor Bank (Detuned APFC)

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# Detuned Capacitor Bank

## Scope of work:

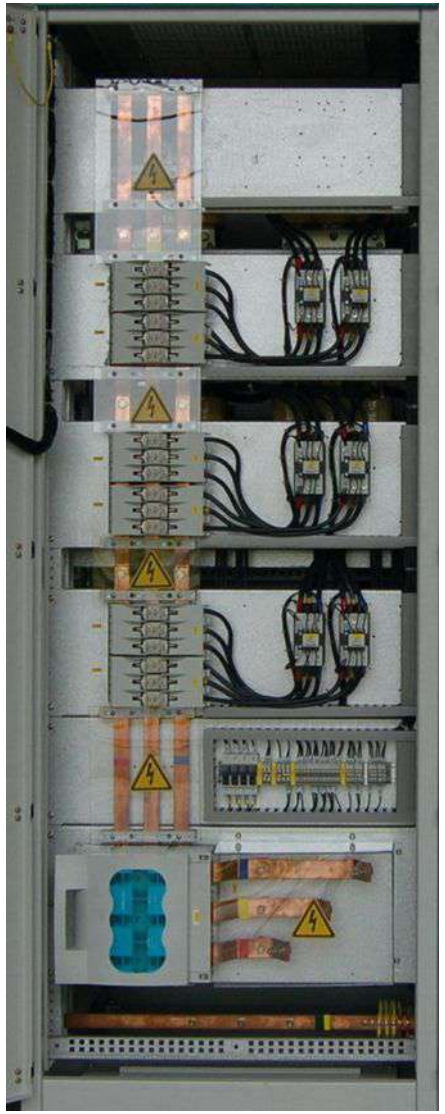
The Contractor shall supply and install the Detuned Automatic Power Factor Capacitor Bank (Detuned APFC) ready for connection and use in low voltage systems.
The power ratings are according to the single line diagram.

## Electrical environment:

The connection of a basic APFC onto a system containing harmonics may reduce its life time. The damaging effects of harmonics can be mitigated by the use of a suitable detuning reactor in series with each capacitor step.

The detuned capacitor bank shall be used to prevent harmonic resonance and reduce the harmonic voltages in the network by absorbing part of the harmonic currents in case of

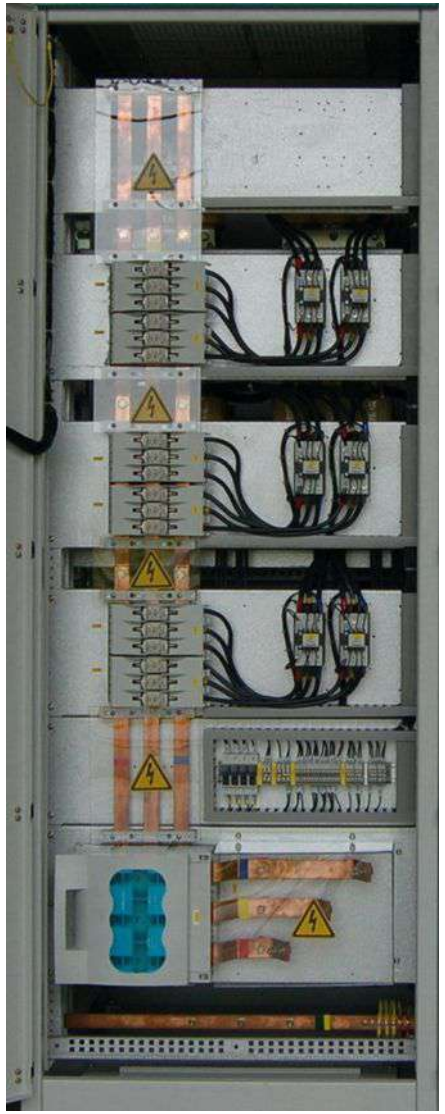
- Non-linear loads < 50% and
- Non-frequent load changes and
- Non-light flicker



# Detuned Capacitor Bank

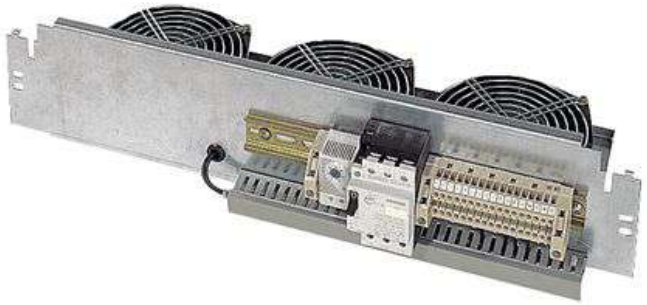
## Design:

The modules on a galvanized sheet-steel chassis are fitted with busbar mounting fuse bases including shock protection cover, capacitor contactors with damping resistors, discharge reactors for fast discharges of capacitors, and dry-type capacitors. For connecting the modules together and for the connection to the power system via cable, each module has a 60 mm busbar support system and 30x10 mm copper busbars with insulation cover mounted at the front.
The connection of the module on the control side to the pf controller and to the control voltage is made by control cable via terminal blocks. This control cables shall be routed in cable ducts.
The maximum effective power per section (cubicle) shall not be higher than 400 kvar. For higher power ratings, capacitor section(s) shall be added. The dimension of each 400 kvar section should not be less than HxWxD 2250x800x1200 mm. and each section shall have ventilation slots (louver) and axial fan(s).



# Detuned Capacitor Bank

Cooling fans 230 V, 50 Hz, air flow not less than 800 cubic meter per hour per 400 kvar section. The operating fans shall be controlled by aux. contacts (NO Contacts) of capacitor contactors.



PF Controller, contactor coils and fans shall be protected by control fuse size 10x38, 500 V, 2 - 6 A mounted in fuse switch holder size 10x38, 690 V, 32 A, AC-22B.


The Capacitor bank shall be installed in a separate cubicle from MDB and designed so that alteration or addition of the capacitor in future will not affect the systems. The unit shall be installed as recommended by the manufacturer.

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# Detuned Capacitor Bank

## Main components:

- Power Factor Controller
- Fuse-switch or Fuse-base with HRC fuses
- Contactor with damping device for capacitor switching
- Detuned Reactor 7% detuning factor
- Power Factor Correction Capacitor
- Ventilation fans
- LV PFC Banks.

# Detuned Capacitor Bank

Technical Data:

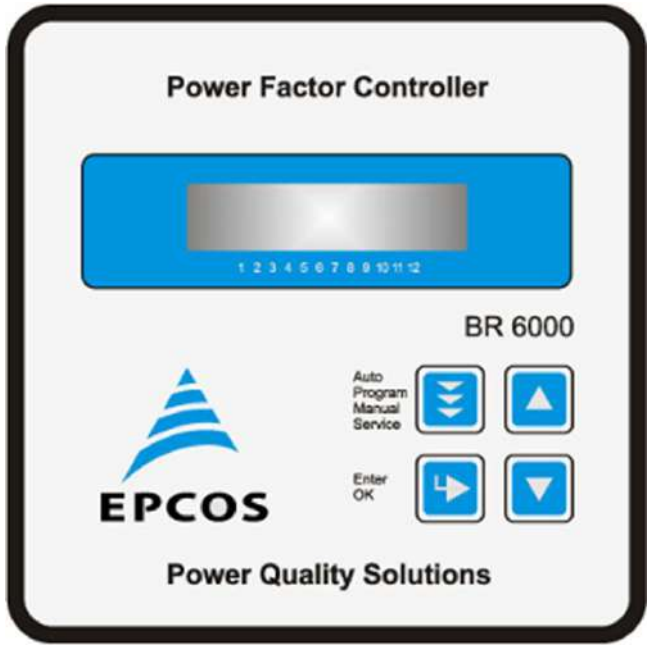
- Low-voltage power factor correction banks

Comply with the requirements of IEC 61439-1 and IEC 61439-2.
Sheet steel cubicle shall have door and panel thickness 2 mm
Ambient temperature –20 to +35 degree C, 24 h average
Degree of protection IP 21
Short circuit strength of busbars Ipk = 75 kA, Icw = 42 kA, 1 sec.

# Detuned Capacitor Bank

- Power Factor Controllers

Comply with the requirements of IEC 61000-4-2, IEC 61000-4-4 and IEC 61010-1.
Continuous LCD Display, Operating temp up to +60 degree C
Humidity class up to 95 %, Protection class IP 54 (Front)
Measurement current: x / 5 A, Target Power Factor : 0.3 ind – 0.3 cap
Power Factor display: 0.1 ind – 0.1 cap, Switching
and discharge time: 1-1200 sec, Control mode: LIFO, FIFO,
Intelligent mode, Minimum operating current or Sensitivity: 50 mA
Frequency: 50 Hz, Zero voltage release: < 15 ms
Switching outputs: 6 or 12 steps according to the drawing
Alarm relay: 1 NO Contact (250 V, 1000 W)
Display of V, A, W, VAR, KVA, Frequency, THDv, THDi,
individual harmonics up to 19$^{th}$, individual capacitor current, temp,
real time cos phi, target cos phi, kvar value to target cos phi
Alarm output of under/over compensation, under/over current, over temp,
harmonics exceeded Recall reorded values of number of contactor switching operations,
Vmax, KVAmax, THDmax, KWmax, KVARmax, TEMPmax, operation time of all capacitors.



# Detuned Capacitor Bank

- Capacitor Contactors

Comply with the requirements of IEC 60947-4-1 / -5-1.
The capacitor contactor shall be equipped with Aux contact (1 NO) and damping resistors to reduce peak inrush current
Rated Insulation Voltage: 690 V
Utilization categories AC-6b according to IEC 60947-4-1 for switching of capacitor bank
Rated power: according to the drawing.


# Detuned Capacitor Bank

- Discharge reactors

Rated voltage up to 690 V
Internal configuration: 2 winding in V arrangement
Discharge time: 400-690 V up to 25 kVAr < 5 s /
up to 50 kVAr < 10 s / up to 100 kVAr < 20 s
Power losses: < 1.8 W
Insulation class T40/B
Ambient temp -5 +55° C (24 h mean)

# Detuned Capacitor Bank

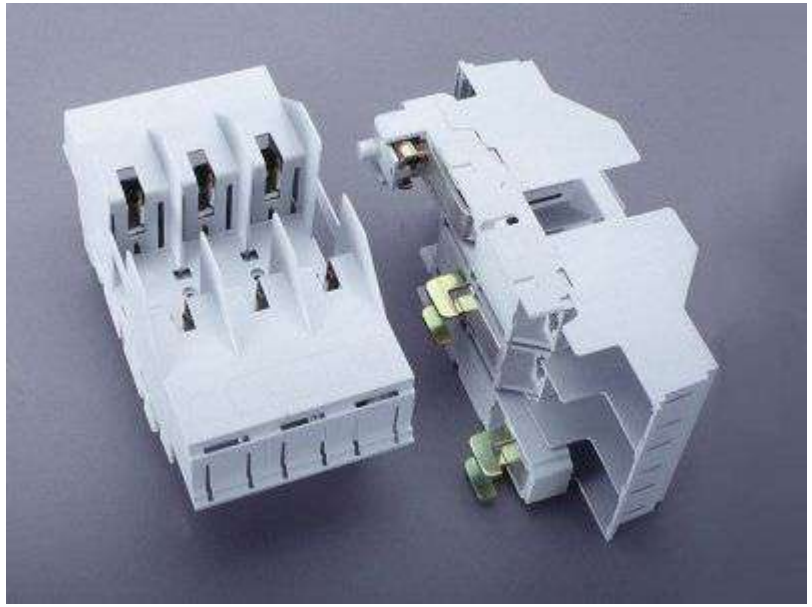
- PFC Capacitors

Comply with the requirements of IEC 60831-1+2
Indoor Dry Type, Inert gas (Nitrogen) impregnation
Rated voltage: not less than the system voltage
230/400/440/480/525/690/800/1000 VAC 50 Hz,
3-phase delta connection
Power output: according to the drawing
Safety: self healing, 3-phase overpressure disconnector and dry type
Overcurrent: up to 1.6 · Ir including combined effects of harmonics,
Over voltages and capacitance tolerance
Inrush current: up to 300 x Ir
Losses: dielectric ≤ 0.2 W / kVAr, total ≤ 0.45 W / kVAr
Mean life expectancy: up to 130,000 hours
Humidity: max 95 %
Ambient temp: –40/D; max. temp. +55 °C; max. mean 24 h = +45 °C;
max. mean 1 year = +35 °C; lowest temperature = –40 °C

# Detuned Capacitor Bank

- NH Bus-mounting fuse bases

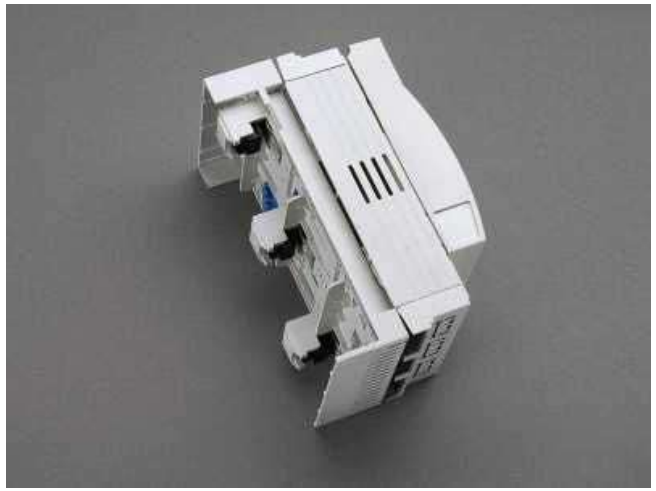
Comply with the requirements of IEC 60269-1/-2
For mounting on busbars 30x10 mm.
Rated Voltage: 690 V 3-Pole
Rated Current: 00/160 A for capacitor up to 60 kVAr 400 V
Rated Current: 1/250 A for capacitor up to 100 kVAr 400 V
Short-circuit strength when protected by fuses: 50 kA
Safety: Shock protection cover



# Detuned Capacitor Bank

- NH Bus-mounting fuse switch-disconnector

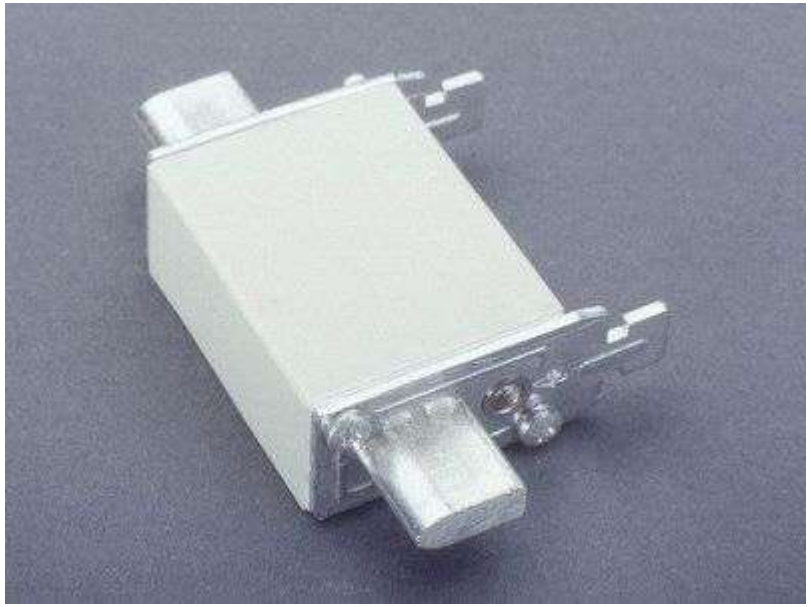
Comply with the requirements of IEC 60947-1/-3
For mounting on busbars 30x10 mm.
Rated Voltage: 690 V 3-Pole
Rated Current: 00/160 A for capacitor up to 60 kVAr 400 V
Rated Current: 1/250 A for capacitor up to 100 kVAr 400 V
Short-circuit strength when protected by fuses: 50 kA
Safety: Shock protection cover

# Detuned Capacitor Bank

- NH HRC fuse links type gG

Comply with the requirements of IEC 60269-1/-2
Rated Voltage: ≥ 500 V
Size 00 for rated current up to 125 A
Size 1 for rated current up to 250 A
Rated Current: according to the drawing
Rated short-circuit breaking capacity AC 120 kA
Indicator version: double indicator at  top and middle



# Detuned Capacitor Bank

- Micro switch or Remote monitoring

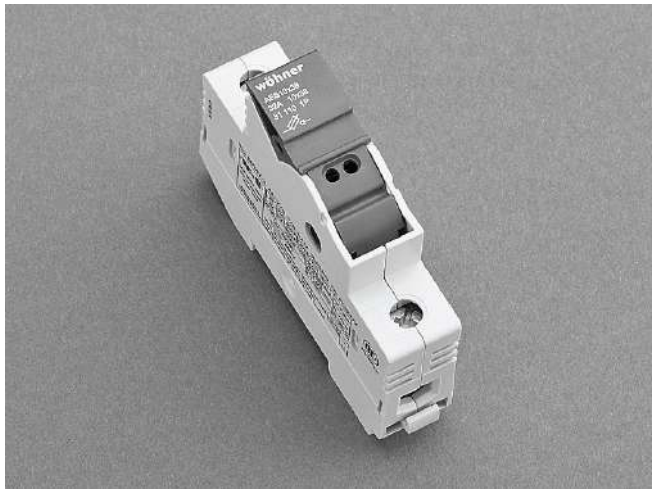
The micro switch is used for signaling of interruption of Fuse-links of the NH size 00 to size 3.
This micro switch is activated through the indicator spring of NH Fuses. The NC contact of this micro switch shall be connected in series with the control coil of the capacitor contactor.
In case of one fuse blown, the capacitor contactor will be switched off to disconnect the 3-phase capacitor unit.

Rated Voltage: 250 V AC
Rated Current: 5 A
Contact: 1 NC


# Detuned Capacitor Bank

- Holder for cylindrical fuses

Comply with the requirements of IEC 60947-1/-3
Size 10 x 38 mm., 1-pole, AC-22B, DIN rail system
Rated Voltage: 690 V AC Rated Current: 32 A
rated isolation voltage Ui AC or DC: 800 V
rated surge voltage Uimp : 6 kV
short-circuit current with fuses (AC): 100 kA / 400 V (32A)
degree of protection: IP20




- Cylindrical fuse link type gG

Comply with the requirements of IEC 60269-1/-2
Size 10 x 38 mm.
Rated Voltage: 500 V AC Rated Current: 4 A and 6 A
Rated short-circuit breaking capacity AC 120 kA

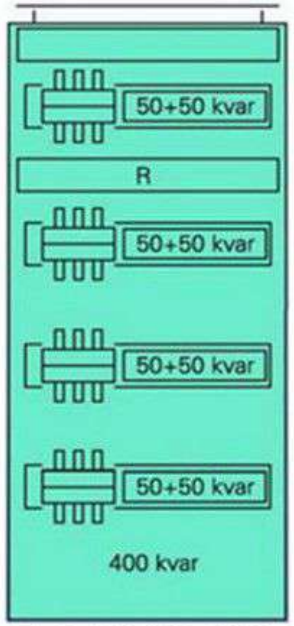
# Detuned Capacitor Bank

- Detuned reactors

De-tuning factor p [%]: 7
Effective filter output Qc [kvar]: according to the SLD
Rated voltage VR [V]: 400
Rated frequency [Hz]: 50
Ambient temperature / Insulation class: 40 °C/H
Inductivity L [mH]: depend on Qc
Linear up to [A]: depend on Qc
Effective current Irms [A]: depend on Qc
Rated harmonic voltages (3rd/5th/7th/11th/13th): 0.5 / 6 / 5 / 3.5 / 3%
Temperature protection (NC) : yes

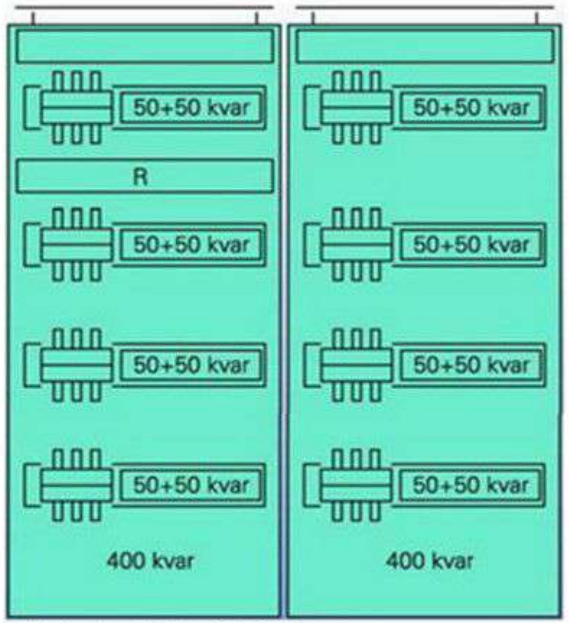
# Detuned Capacitor Bank

Dimension and Ventilation fans of basic capacitor bank



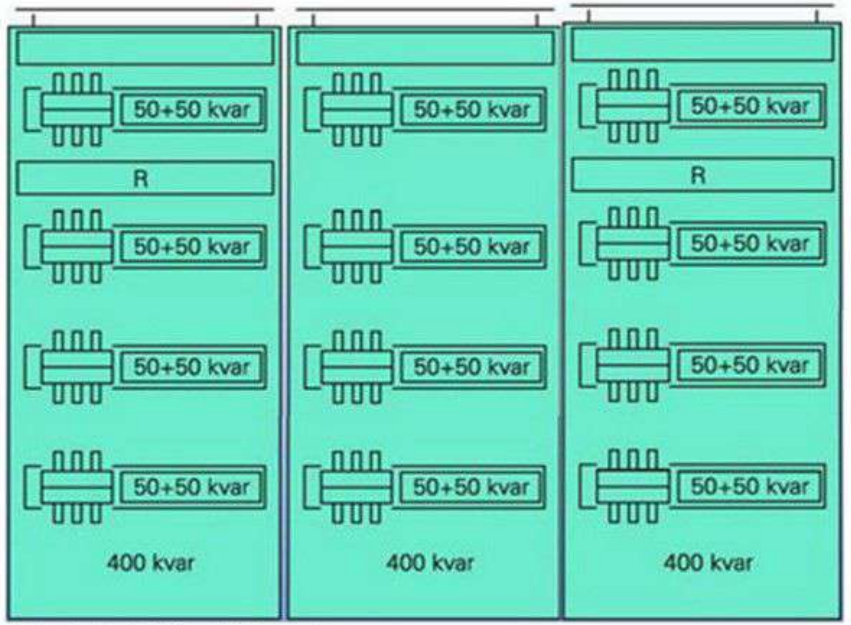

Total 300-400 kvar

2200x800x1200 mm.
2x800 M³/hr




Total 450-800 kvar

2200x1600x1200 mm.
4x800 M³/hr




Total 850-1200 kvar

2200x2400x1200 mm.
6x800 M³/hr

HxWxD

# Detuned Capacitor Bank

Scope of Supply: Example of 12 x 50 kVAr 400 V

| Item | Qty | Descriptions |
|---|---|---|
| | | |
| 1 | 1 | '"EPCOS" P.F. Controller type BR6000-R12, 12 steps, 400 V, 50 Hz, Measuring current 5 A, Measurement voltage range 30 ... 525 V AC (L–L / L–N), Supply voltage 110…230 V AC, 50 Hz, Target cos phi 0.3 ind. - 0.3 cap. with indication of U, I, Q, P, S, Cos-phi, temperature and harmonics, Standards EN 55082-2, EN 55011, IEC 61010-1. |
| 2 | 12 | "EPCOS" Type MKK525D20-03 x 4, PhaseCap Energy Plus PFC dry gas filled (N2) Capacitors, 3-ph, 80 kVAr, 525 V, 50 Hz., Ultra long life expectancy up to 240,000 hours at temperature class –40/D, inrush current capability of up to 500 · $I_R$, Self-healing, 3 phase overpressure disconnector, Total loss excluding discharge resistors ≤ 0.45 W/kVAr, Standards IEC 60831-1+2, UL 810. |
| 3 | 12 | "EPCOS" B44066S6210J230 Capacitor Contactor with damping device 50 kVAr, 400 V with 230 V coil, Auxiliary contact 1 NO, Rated insulation voltage Vi 690 V AC, Contact life 0.12 million operations, Standards IEC 947-4-1, IEC 947-5-1, VDE 0660. |

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# Detuned Capacitor Bank

## Scope of Supply: Example of 12 x 50 kVAr 400 V

| Item | Qty | Descriptions |
|---|---|---|
| 4 | 12 | "Wöhner" 03654 Busbar Mounting Fuse Base 3-pole, 00/160 A, 690 V |
| 5 | 36 | "Wöhner" 03533 NH HRC fuse links size 00 / 125 A, 500 V AC. |
| 6 | 36 | "ETI" Type NVS 5 Micro switches on each fuse puller leg to disconnect 3-phase in case of one fuse blown. |
| 7 | 4 | "Wöhner" 31110 Switch for cylindrical fuse 10x38 mm, 32 A. |
| 8 | 2 | "Wöhner" 31182 Cylindrical fuse 10x38 mm, 2 A. |
| 9 | 2 | "Wöhner" 31184 Cylindrical fuse 10x38 mm, 4 A. |
| 10 | 2 | "EBM" M4Q 045 -CA03-A Ventilation fans Air flow 800 $m^3$ / h from inside cubicle to outside cubicle 10/36 W, 230 V, 50 Hz., 0.25 A, 1300 RPM. |
| | | |

# Detuned Capacitor Bank

Scope of Supply: Example of 12 x 50 kVAr 400 V

| Item | Qty | Descriptions |
|---|---|---|
| 11 | 2 | "Wöhner" 33603 Busbar Mounting Fuse Switch 3-pole, 3/630 A, 690 V |
| 12 | 6 | "Wöhner" 03582 NH HRC fuse links size 3 / 630 A, 500 V AC. |
| 13 | 2 | Capacitor bank cubicle dimension HWD 2200x800x1200 mm. with front doors, panels, base plates, copper busbars 3//30x10 mm., power cables, control cables, terminal blocks and accessories, galvanized steel plate 2 mm. thickness, IP21, RAL 7032 Color. |
| 14 | 12 | "EPCOS" B44066D7050E400 Detuned Reactors 400 V 50 Hz 50 kVAr detuning factor 7%. |

EPCOS

# 3. Design Guideline of Thyristor Switching Capacitor (TSC APFC)

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# Detuned Capacitor Bank-Thyristor Switching

## Scope of work:

The Contractor shall supply and install the Detuned Automatic Power Factor Capacitor Bank with Thyristor Switching (TSC APFC) ready for connection and use in low voltage systems.
The power ratings are according to the single line diagram.

## Electrical environment:

The connection of a capacitor bank onto a system containing harmonics and frequent load changes may reduce its life time.
The damaging effects of harmonics and frequent load changes can be mitigated by the use of a suitable detuning reactor and thyristor switch in series with each capacitor step.

The detuned capacitor bank with thyristor switch shall be used to prevent harmonic resonance and reduce the harmonic voltages in the network by absorbing part of the harmonic currents in case of

- Non-linear loads < 50% and
- Frequent load changes and / or Light Flicker.

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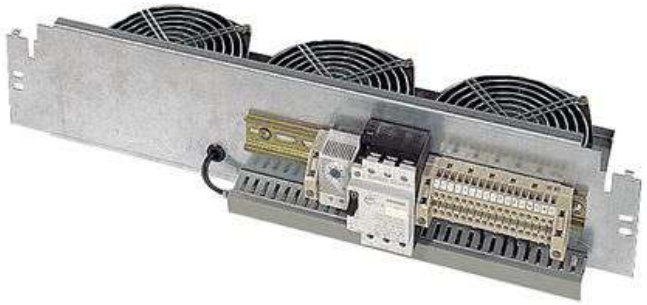
# Detuned Capacitor Bank-Thyristor Switching

## Design:

The modules on a galvanized sheet-steel chassis are fitted with busbar mounting fuse bases including shock protection cover, thyristor switches, discharge reactors, and dry-type capacitors. For connecting the modules together and for the connection to the power system via cable, each module has a 60 mm busbar support system and 30x10 mm copper busbars with insulation cover mounted at the front.
The connection of the module on the control side to the pf controller and to the control voltage is made by control cable via terminal blocks. This control cables shall be routed in cable ducts.
The maximum effective power per section (cubicle) shall not be higher than 400 kvar. For higher power ratings, capacitor section(s) shall be added. The dimension of each 400 kvar section should not be less than HxWxD 2250x800x1200 mm. and each section shall have ventilation slots (louver) and axial fan(s).

# Detuned Capacitor Bank-Thyristor Switching

Cooling fans 230 V, 50 Hz, air flow not less than 800 cubic meter per hour per 400 kvar section. The operating fans shall be controlled by aux. contacts (NO Contacts) of capacitor contactors.



PF Controller, contactor coils and fans shall be protected by control fuse size 10x38, 500 V, 2 - 6 A mounted in fuse switch holder size 10x38, 690 V, 32 A, AC-22B.


The Capacitor bank shall be installed in a separate cubicle from MDB and designed so that alteration or addition of the capacitor in future will not affect the systems. The unit shall be installed as recommended by the manufacturer.

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# Detuned Capacitor Bank-Thyristor Switching

Main components:

- Power Factor Controller
- Fuse-switch or Fuse-base with HRC fuses
- Thyristor Module
- Detuned Reactor 7% detuning factor
- Power Factor Correction Capacitor
- Ventilation fans
- LV PFC Banks.

# Detuned Capacitor Bank-Thyristor Switching

Technical Data:

- Low-voltage power factor correction banks

Comply with the requirements of IEC 61439-1 and IEC 61439-2.
Sheet steel cubicle shall have door and panel thickness 2 mm
Ambient temperature –20 to +35 degree C, 24 h average
Degree of protection IP 21
Short circuit strength of busbars Ipk = 75 kA, Icw = 42 kA, 1 sec.


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# Detuned Capacitor Bank-Thyristor Switching

- Power Factor Controllers

12 Transistor outputs for thyristor switches
Comply with the requirements of IEC 61000-4-2, IEC 61000-4-4 and IEC 61010-1.
Continuous LCD Display, Operating temp up to +60 degree C
Humidity class up to 95 %, Protection class IP 54 (Front)
Measurement current: x / 5 A, Target Power Factor : 0.3 ind – 0.3 cap
Power Factor display: 0.1 ind – 0.1 cap, Switching
and discharge time: 20-1000 sec, Control mode: LIFO, FIFO,
Intelligent mode, Minimum operating current or Sensitivity: 50 mA
Frequency: 50 Hz, Zero voltage release: < 15 ms
Switching outputs: 6 or 12 steps according to the drawing
Alarm relay: 1 NO Contact (250 V, 1000 W)
Display of V, A, W, VAR, KVA, Frequency, THDv, THDi,
individual harmonics up to 33rd, individual capacitor current, temp,
real time cos phi, target cos phi, kvar value to target cos phi
Alarm output of under/over compensation, under/over current, over temp,
harmonics exceeded Recall reorded values of number of contactor switching operations,
Vmax, KVAmax, THDmax, KWmax, KVARmax, TEMPmax, operation time of all capacitors.

# Detuned Capacitor Bank-Thyristor Switching

## Characteristics of Thyristor Modules

For Dynamic PFC is a fast electronically controlled, self-observing thyristor switch for capacitive loads up to 100 kvar (380...440 VAC) which is capable to switch PFC capacitors within a few milliseconds as often and as long as required without abrasion.

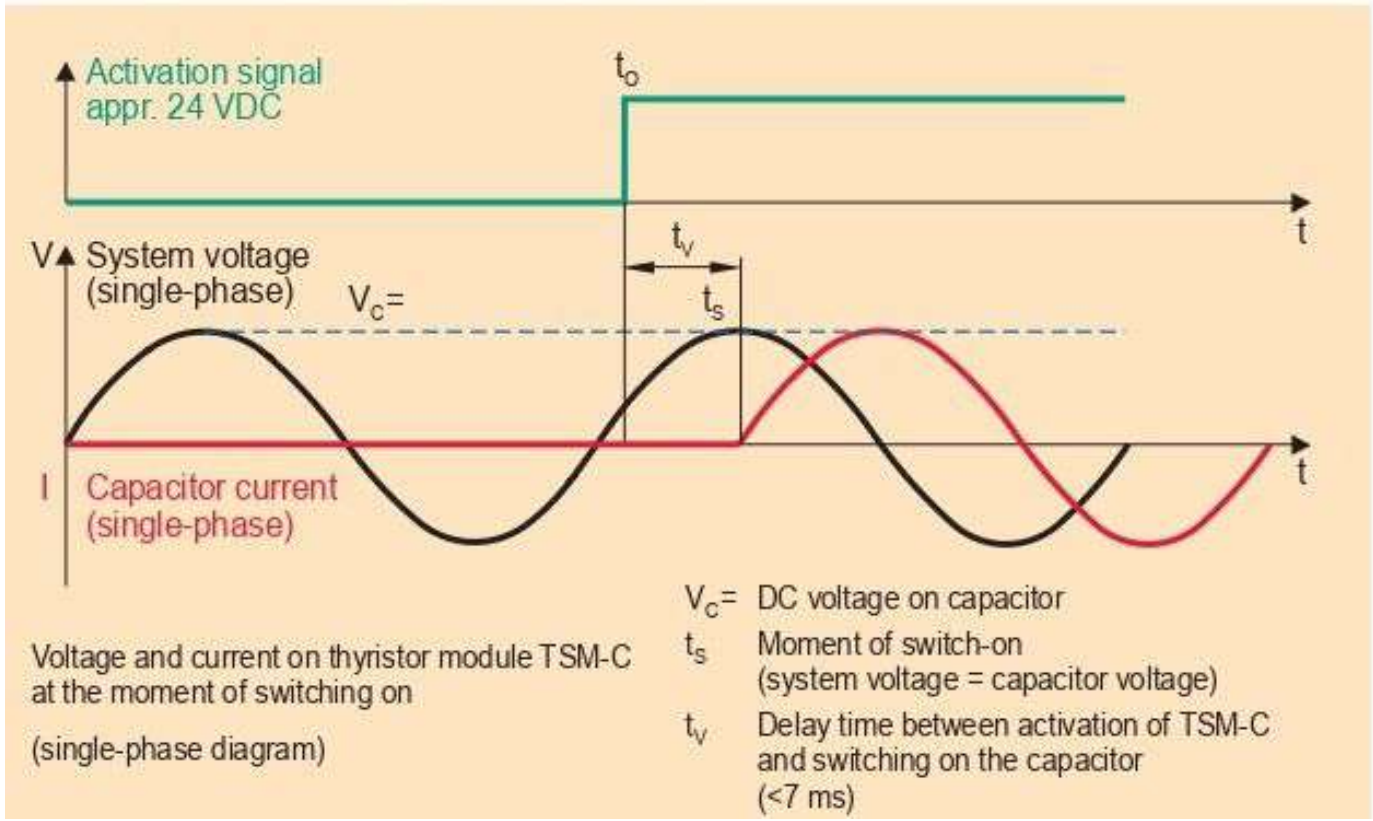

- Thyristor module for dynamic compensation system in grids from 380 to 400 V, 50/60 Hz, for 25 to 100 kVAr
- Ambient operating temperature at nominal load -10 … + 55 °C
- Optimized switching behavior by micro-processor controlled alignment to capacitor branches with detuning reactor
- Monitoring of voltage, phase and temperature
- Display monitoring with 2 LEDs Voltage operation status and temperature

# Detuned Capacitor Bank-Thyristor Switching

- As soon as the controller signal is applied to the thyristor, the current starts to flow through the capacitor and increases from zero to the peak value without any inrush current.
- The thyristor modules switch the capacitors at the zero crossing of the current
- No system perturbation by switching operations (transients)
- Switching times shorter than 20 mS

Switch-on graph of TSM-C module

Einschaltdiagramm des TSM-C-Moduls




Voltage and current on thyristor module TSM-C at the moment of switching on

(single-phase diagram)

$V_c$= DC voltage on capacitor

$t_s$ Moment of switch-on (system voltage = capacitor voltage)

$t_v$ Delay time between activation of TSM-C and switching on the capacitor (<7 ms)

# Detuned Capacitor Bank-Thyristor Switching

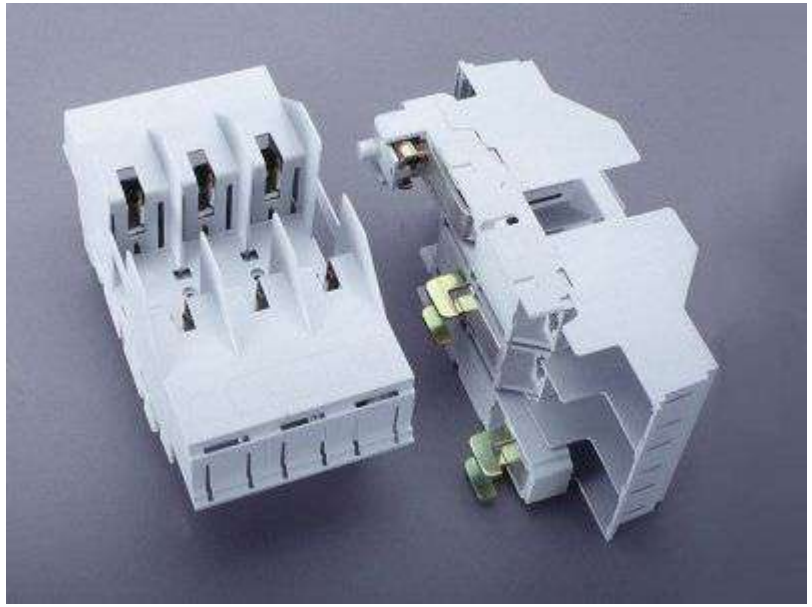
- PFC Capacitors

Comply with the requirements of IEC 60831-1+2
Indoor Dry Type, Inert gas (Nitrogen) impregnation
Rated voltage: not less than the system voltage
230/400/440/480/525/690/800/1000 VAC 50 Hz,
3-phase delta connection
Power output: according to the drawing
Safety: self healing, 3-phase overpressure disconnector and dry type
Overcurrent: up to 1.6 · Ir including combined effects of harmonics,
Over voltages and capacitance tolerance
Inrush current: up to 300 x Ir
Losses: dielectric ≤ 0.2 W / kVAr, total ≤ 0.45 W / kVAr
Mean life expectancy: up to 130,000 hours
Humidity: max 95 %
Ambient temp: –40/D; max. temp. +55 °C; max. mean 24 h = +45 °C;
max. mean 1 year = +35 °C; lowest temperature = –40 °C

# Detuned Capacitor Bank-Thyristor Switching

- NH Bus-mounting fuse bases

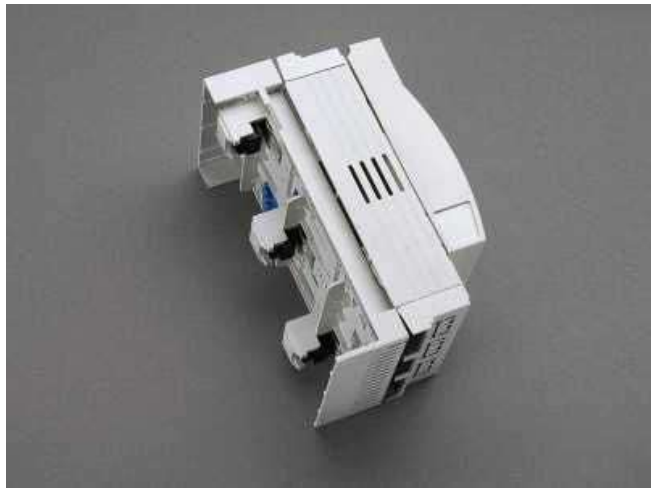
Comply with the requirements of IEC 60269-1/-2
For mounting on busbars 30x10 mm.
Rated Voltage: 690 V 3-Pole
Rated Current: 00/160 A for capacitor up to 60 kVAr 400 V
Rated Current: 1/250 A for capacitor up to 100 kVAr 400 V
Short-circuit strength when protected by fuses: 50 kA
Safety: Shock protection cover



# Detuned Capacitor Bank-Thyristor Switching

- NH Bus-mounting fuse switch-disconnector

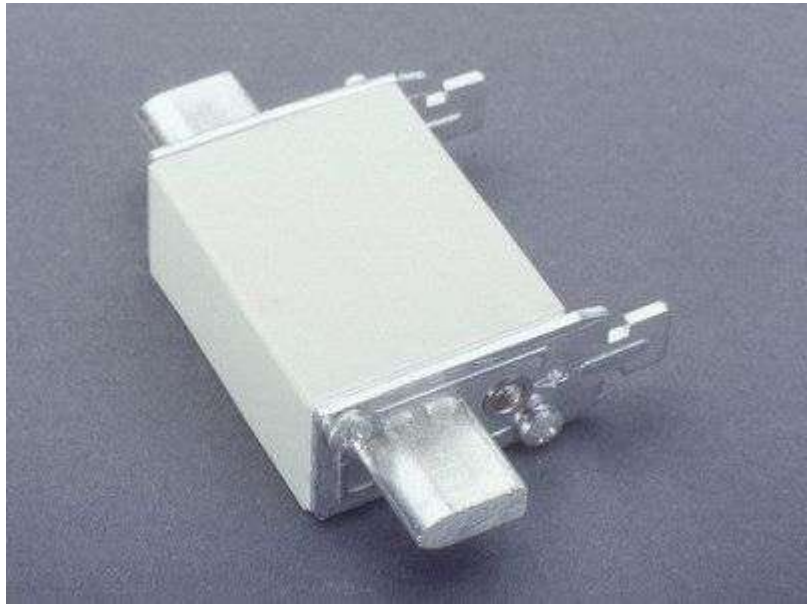
Comply with the requirements of IEC 60947-1/-3
For mounting on busbars 30x10 mm.
Rated Voltage: 690 V 3-Pole
Rated Current: 00/160 A for capacitor up to 60 kVAr 400 V
Rated Current: 1/250 A for capacitor up to 100 kVAr 400 V
Short-circuit strength when protected by fuses: 50 kA
Safety: Shock protection cover

# Detuned Capacitor Bank-Thyristor Switching

- NH HRC fuse links type gR for semiconductor protection

Comply with the requirements of IEC 60269-4
Rated Voltage: ≥ 690 V
Size 00 for rated current up to 125 A
Size 1 for rated current up to 250 A
Rated Current: according to the drawing
Rated short-circuit breaking capacity AC 120 kA
Indicator version: double indicator at  top and middle

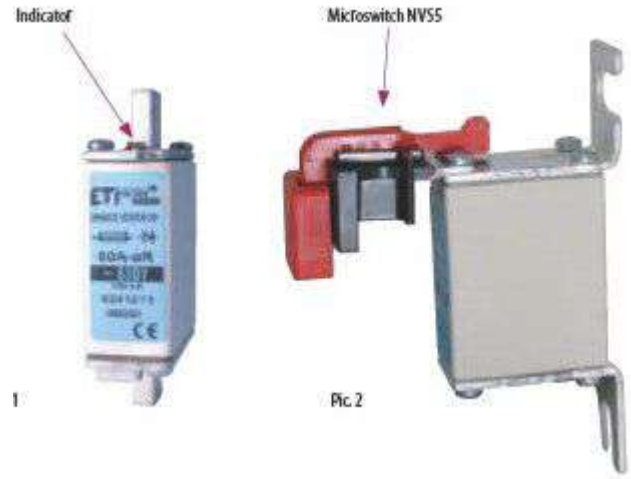


# Detuned Capacitor Bank-Thyristor Switching

- Micro switch or Remote monitoring

The micro switch is used for signaling of interruption of Fuse-links of the NH size 00 to size 3.
This micro switch is activated through the indicator spring of NH Fuses. The NC contact of this micro switch shall be connected in series with the control coil of the capacitor contactor.
In case of one fuse blown, the capacitor contactor will be switched off to disconnect the 3-phase capacitor unit.

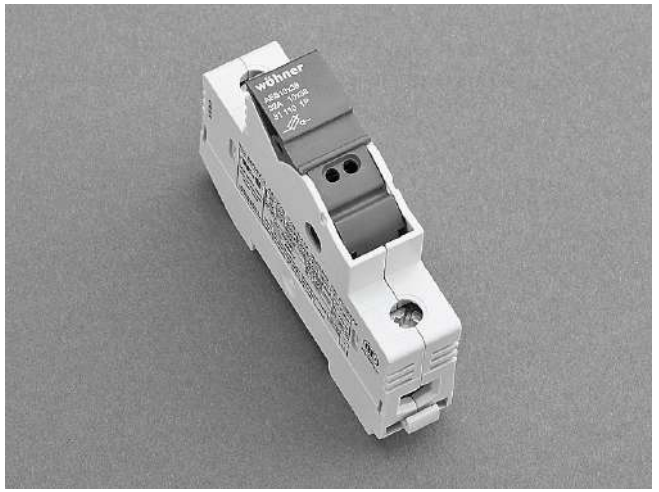
Rated Voltage: 250 V AC
Rated Current: 5 A
Contact: 1 NC




# Detuned Capacitor Bank-Thyristor Switching

- Holder for cylindrical fuses

Comply with the requirements of IEC 60947-1/-3
Size 10 x 38 mm., 1-pole, AC-22B, DIN rail system
Rated Voltage: 690 V AC Rated Current: 32 A
rated isolation voltage Ui AC or DC: 800 V
rated surge voltage Uimp : 6 kV
short-circuit current with fuses (AC): 100 kA / 400 V (32A)
degree of protection: IP20




- Cylindrical fuse link type gG

Comply with the requirements of IEC 60269-1/-2
Size 10 x 38 mm.
Rated Voltage: 500 V AC Rated Current: 4 A and 6 A
Rated short-circuit breaking capacity AC 120 kA

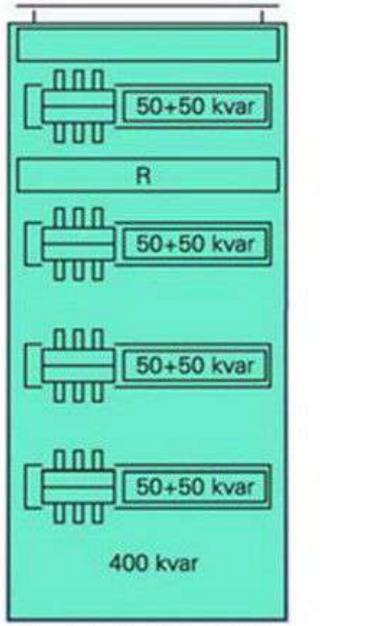
# Detuned Capacitor Bank

- Detuned reactors

De-tuning factor p [%]: 7
Effective filter output Qc [kvar]: according to the SLD
Rated voltage VR [V]: 400
Rated frequency [Hz]: 50
Ambient temperature / Insulation class: 40 °C/H
Inductivity L [mH]: depend on Qc
Linear up to [A]: depend on Qc
Effective current Irms [A]: depend on Qc
Rated harmonic voltages (3rd/5th/7th/11th/13th): 0.5 / 6 / 5 / 3.5 / 3%
Temperature protection (NC) : yes

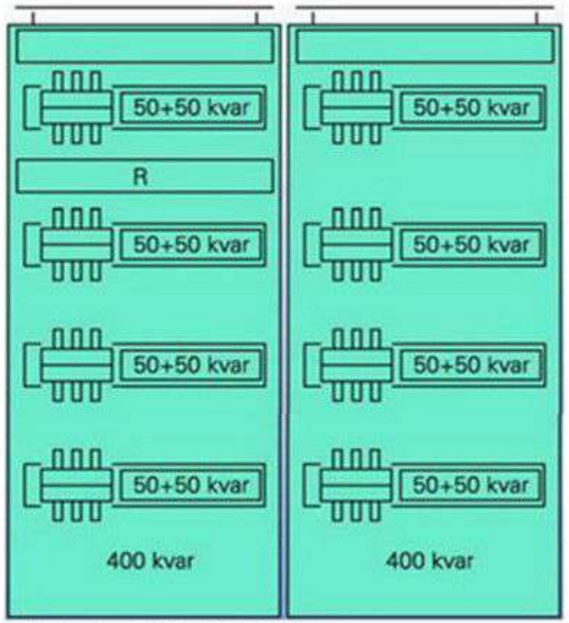
# Detuned Capacitor Bank-Thyristor Switching

Dimension and Ventilation fans of detuned capacitor bank



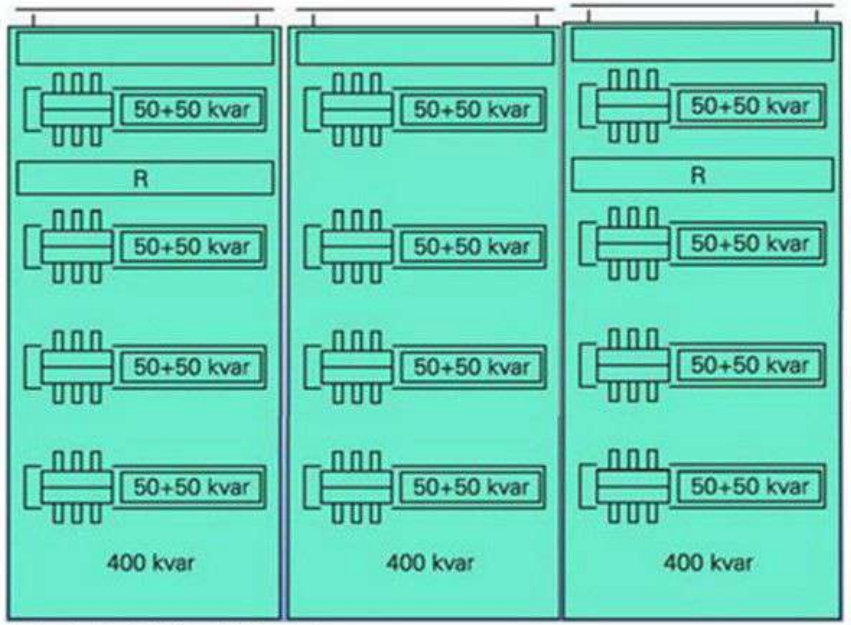

Total 300-400 kvar

2200x800x1200 mm.
2x800 M³/hr




Total 450-800 kvar

2200x1600x1200 mm.
4x800 M³/hr




Total 850-1200 kvar

2200x2400x1200 mm.
6x800 M³/hr

HxWxD

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# Detuned Capacitor Bank-Thyristor Switching

Scope of Supply: Example of 12 x 50 kVAr 400 V

| Item | Qty | Descriptions |
|---|---|---|
| | | |
| 1 | 1 | '"EPCOS" P.F. Controller type BR7000-I-TH, 12 steps, 400 V, 50 Hz, Measuring current 5 A, Measurement voltage range 30 ... 525 V AC (L–L / L–N), Supply voltage 110…230 V AC, 50 Hz, Target cos phi 0.3 ind. - 0.3 cap. with indication of U, I, Q, P, S, Cos-phi, temperature and harmonics, Standards IEC 61000-6-2;, IEC 61000-4-2; IEC61000-4-4. |
| 2 | 12 | "EPCOS" Type MKK525D20-03 x 4, PhaseCap Energy Plus PFC dry gas filled (N2) Capacitors, 3-ph, 80 kVAr, 525 V, 50 Hz., Ultra long life expectancy up to 240,000 hours at temperature class –40/D, inrush current capability of up to 500 · $I_R$, Self-healing, 3 phase overpressure disconnector, Total loss excluding discharge resistors ≤ 0.45 W/kVAr, Standards IEC 60831-1+2, UL 810. |
| 3 | 12 | "EPCOS" Thyristor Modules 50 kVAr, Activation 10 … 24 V DC (approx.. 10 mA), Switching on time Approx. 5 ms. |

# Detuned Capacitor Bank-Thyristor Switching

Scope of Supply: Example of 12 x 50 kVAr 400 V

| Item | Qty | Descriptions |
|---|---|---|
| 4 | 12 | "Wöhner" 03654 Busbar Mounting Fuse Base 3-pole, 00/160 A, 690 V |
| 5 | 36 | "ETI" NH HRC fuse links size 00 / 125 A, 690 V AC. |
| 6 | 36 | "ETI" Type NVS 5 Micro switches on each fuse puller leg to disconnect 3-phase in case of one fuse blown. |
| 7 | 4 | "Wöhner" 31110 Switch for cylindrical fuse 10x38 mm, 32 A. |
| 8 | 2 | "Wöhner" 31182 Cylindrical fuse 10x38 mm, 2 A. |
| 9 | 2 | "Wöhner" 31184 Cylindrical fuse 10x38 mm, 4 A. |
| 10 | 2 | "EBM" M4Q 045 -CA03-A Ventilation fans Air flow 800 $m^3$ / h from inside cubicle to outside cubicle 10/36 W, 230 V, 50 Hz., 0.25 A, 1300 RPM. |
| | | |

# Detuned Capacitor Bank-Thyristor Switching

Scope of Supply: Example of 12 x 50 kVAr 400 V

| Item | Qty | Descriptions |
|---|---|---|
| 11 | 2 | "Wöhner" 33603 Busbar Mounting Fuse Switch 3-pole, 3/630 A, 690 V |
| 12 | 6 | "Wöhner" 03582 NH HRC fuse links size 3 / 630 A, 500 V AC. |
| 13 | 2 | Capacitor bank cubicle dimension HWD 2200x800x1200 mm. with front doors, panels, base plates, copper busbars 3//30x10 mm., power cables, control cables, terminal blocks and accessories, galvanized steel plate 2 mm. thickness, IP21, RAL 7032 Color. |
| 14 | 12 | "EPCOS" B44066D7050E400 Detuned Reactors 400 V 50 Hz 50 kVAr detuning factor 7%. |


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# 4. Design Guideline of Static Var Generator (SVG)

ITM

# Static Var Generator (SVG)

## Scope of work:

The Contractor shall supply and install the Static Var Generator (SVG) ready for connection and use in low voltage systems.
The power ratings are according to the single line diagram.

## Electrical environment:

The SVG shall be used to prevent harmonic resonance and dynamic reactive power compensation in case of

- Non-linear loads < 50% and
- Frequent load changes and / or Light Flicker.

# Static Var Generator (SVG)

## Design:

SVG is a parallel device connected to the grid and the main circuit is based on a three phase voltage source converter (VSI) topology. External CT measures load current and external DSP helps to calculate and analyze the required reactive current.
SVG controls PWM signals and sends control message to IGBT modules which generate reactive current in order to improve system power factor.
SVG can balance load between phases and unloaded neutral wire for input voltage connection systems such as three phase three wires (3P3W) and three phase four wires (3P4W).

# Static Var Generator (SVG)

## Features:

- SVG can be considered as a controllable reactive current source, which helps to improve the system power factor to a target value of more than > 0.99 without any over or under compensation.
- SVG has extremely rapid dynamic compensation reaction time, which is less than 50 µs and a state response time of less than 15 ms.
- SVG is an active compensation device, which doesn’t need capacitor or reactor for reactive power compensation which will avoid the condition of resonance caused by the traditional capacitor banks.
- SVG can compensate both inductive and capacitive reactive power and also provide load balancing.
- SVG can compensate reactive power in any scope and can be installed together with traditional capacitor banks.
- The grid voltage has no influence on the SVG compensation capacity. So even if the system voltage drops down, the required reactive power can be compensated by monitoring its requirement.
- SVG has been designed to provide highest safety and reliability features.

ITM

# Static Var Generator (SVG)

| Technical data and specifications of low-voltage SVG PQvar Series 400 V | | |
|---|---|---|
| Rated voltage | 400 V; –40 … +20% | |
| Mains frequency | 50/60 Hz (range: 45 … 62 Hz) | |
| Parallel operation | Unlimited | |
| Response time | < 15 ms | |
| Overall efficiency | > 97% | |
| Power grid structure | 3P3W / 3P4W | |
| Current transformers | 150/5 … 10000/5 | |
| Circuit topology | 3-level | |
| Single-module compensation capacity | 30/50 kvar | 100/200 kvar |
| Module net weight | 35/35 kg | 62/115 kg |
| Dimensions (W × D × H) | 30 kvar: 530 × 558 × 190 mm (module)<br>50 kvar: 530 × 558 × 190 mm (module) | 100 kvar: 530 × 520 × 269 mm (module)<br>200 kvar: 530 × 690 × 370 mm (module) |
| Cooling mode | Smart air cooling: 359 L/sec | |

# Static Var Generator (SVG)

| | |
|---|---|
| Target power factor | Adjustable from –1 … +1 |
| Cabinet mounting | Floor-mounted, wall-mounted |
| Communication ports | RS485, CAN, and network port |
| Communication protocols | Modbus and PMBus |
| Noise level | < 65 dB (depending on the model) |
| Protection functions | Overvoltage, undervoltage, short-circuit, inverter bridge inverse, over-compensation |
| Operating temperature | –10 … +40 °C, other temperature ranges upon request |
| Relative humidity | 5 … 95%, non-condensing |
| Protection class | IP20 (other IP classes are customizable) |
| Panel color | RAL7035 light grey |
| Altitude | 1500 m, 1% derating per 100 m plus |
| General safety requirements for SVG PQvar Series use and operation area | EN 50178:1997/ IEC 50178:1997 |
| SVG PQvar Series EMC requirements | EN 61000_6_2(2005)/ EN55011, GROUP1, CLASS A<br>IEC 61000_6_2(1999)/ CISPR11, GROUP1, CLASS A |
| SVG PQvar Series performance requirements | EN 50091-3/ IEC 62040-3/ AS 62040-3(VFI SS 111) |

# Static Var Generator (SVG)

400 V SVG PQvar Series – 3P4W systems

| Reactive power kvar | System voltage min./max. V | | Mounting variant | Approx. weight kg | Approx. dimensions (W × D × H) mm |
|---|---|---|---|---|---|
| 30 | 240 | 480 | Wall-mounted | 35 | 500 × 191 × 582 |
| 50 | 240 | 480 | Wall-mounted | 35 | 500 × 191 × 582 |
| 100 | 240 | 480 | Wall-mounted | 62 | 500 × 286 × 565 |
| 200 | 240 | 480 | Wall-mounted | 115 | 500 × 370 × 690 |
| 100 | 240 | 480 | Floor-mounted | 297 | 600 × 1000 × 2200 |
| 150 | 240 | 480 | Floor-mounted | 332 | 600 × 1000 × 2200 |
| 200 | 240 | 480 | Floor-mounted | 359 | 600 × 1000 × 2200 |
| 250 | 240 | 480 | Floor-mounted | 394 | 600 × 1000 × 2200 |
| 300 | 240 | 480 | Floor-mounted | 421 | 600 × 1000 × 2200 |
| 400 | 240 | 480 | Floor-mounted | 483 | 600 × 1000 × 2200 |
| 500 | 240 | 480 | Floor-mounted | 780 | 2× 600 × 1000 × 2200 |
| 600 | 240 | 480 | Floor-mounted | 842 | 2× 600 × 1000 × 2200 |
| 700 | 240 | 480 | Floor-mounted | 904 | 2× 600 × 1000 × 2200 |
| 800 | 240 | 480 | Floor-mounted | 966 | 2× 600 × 1000 × 2200 |

ITM


# 5. Design Guideline of AHF and Power Optimizers (AHF)

ITM

# Active Harmonic Filter and Power Optimizers (AHF)

## Scope of work:

The Contractor shall supply and install the Active Harmonic Filters and Power Optimizers (AHF) ready for connection and use in low voltage systems.
The rated filter currents are according to the single line diagram.


## Electrical environment:

The AHF shall be used in case of

- Non-linear loads ≥ 50% or
- Frequent load changes and / or Light Flicker.

# Active Harmonic Filter and Power Optimizers (AHF)

## Design:

The PQSine S Series is an active harmonic filter system designed to eliminate harmonic oscillations and con-sequently reduce costs. AHF PQSine S Series monitors the current signal and compensates the unwanted elements of the measured current. Thus, the filter ensures harmonic suppression independently of the number of loads. It also corrects the power factor, improving the system efficiency while reducing harmonic pollution.

ITM

# Active Harmonic Filter and Power Optimizers (AHF)

Features:

- Harmonic compensation up to 50th harmonic (individually selectable)
- Ultra-fast reactive power compensation (inductive and capacitive)
- Load balancing between phases and unloaded neutral wire
- Correct the power factor – reactive power compenstions
- Compact design, 3 level topology
- Modular system extendable
- Grid resonance detection
- Digital Control of FFT algorithm, intelligent FFT algorithm, instantaneous reactive algorithm
- Ethernet and Ethercat system for interconnection
- Insensitive to network conditions

ITM

# Active Harmonic Filter and Power Optimizers (AHF)

**Technical data and specifications AHF system**

| | |
|---|---|
| Type | PQSF4300S315 |
| Ordering code | B44066F4300S315 (floor-mounted with horizontal modules) |
| System input / number of phases | 3-phase/4-wire |
| Phase compensation current | 300 A |
| Neutral conductor compensation current | 900 A |
| Frequency | 45 / 62 Hz |
| Input voltage (min. / max.) | 380V (228 / 456 V ) |
| Inverter technology | 12 IGBT three-level NPC topology |
| Process control | Three 32-bit DSP + CPLD |
| Reaction time | Approx. 20 µs (immediate load change reaction) |
| Steady state response time | < 5 ms (steady state response time to full steady state compensation) |
| Switching / control frequency | 20 kHz |
| Signal processor | 32 bit |
| Harmonic compensation | Up to 50$^{th}$ harmonic order, or specified harmonics 0-110% |
| Power factor correction | Fully inductive and capacitive current compensation from 0 … 100% |
| Weight of a single AHF module | 2nos of 150 A module (Approx.. 62kg) are mounted in the cabinet |
| Weight of the panel | Approx.. 384kg |
| Dimensions of the panel | Approx. 600 x 1000 x 2200 mm (w x d x h) |
| Current transformer | 3 CTs are needed. Source or load-side selectable, primary current range 150 … 10000 A, secondary current 5 A (see details of choosing the right CT in the manual)<br>External current transformers are mandatory needed, but not included in the active filter delivery. |
| Efficiency | > 97%* |

**Technical data and specifications AHF system (cont.)**

| | |
|---|---|
| Recommended external AC mains protection (fuse or circuit breaker) | 400 A (for details please see manual) |
| Cabinet mounting | Floor |
| Cooling | Forced cooling 812 L/sec |
| Interface | Modbus (RTU), TCP/IP(Ethernet), |
| Communication ports | RS485 and network port (RJ45) |
| Fault alarm | Available, max. 500 alarm records |
| Display | 7-inch LCD touch color screen |
| Temperature | -10 … +40 °C for operating temperature (may derate capacity if ambient temperature exceeds +40 °C), -20…+70 °C for storage temperature |
| Protection class | IP20 according to IEC 529 |
| Panel color | RAL7035 light grey |
| Humidity | 5 … 95%, non-condensing |
| Self-protection | Yes |
| Overheating protection | Yes |
| Overvoltage and undervoltage protection | Yes |
| Typical noise level | < 65 dB (depending on model and load conditions) |
| Altitude | 1500 m; 1% up 1500 m. Between 1500 to 4000 m, according to GB/T3859.2, the power decreases by 1% for every additional 100 m. |
| Standards / recommendations specifying limits for harmonics in networks or units | IEEE519, IEC 61000-3-6, ER G5/4 |
| Design standards | IEC 61000-6-2/6-4 IEC 61000-4-2/4-3/4-4/4-5/4-6/4-8/4-11, EN 50178 |

ITM

# Active Harmonic Filter and Power Optimizers (AHF)

400 V– 3P4W systems

| Rated filter current A | System min. /max. voltage V | | Mounting variant | Approx. weight kg | Approx. dimensions (WxDxH) mm |
|---|---|---|---|---|---|
| 100 | 228 | 456 | Floor-mounted | 276 | 600x1000x2200 |
| 150 | 228 | 456 | Floor-mounted | 278 | 600x1000x2200 |
| 200 | 228 | 456 | Floor-mounted | 313 | 600x1000x2200 |
| 250 | 228 | 456 | Floor-mounted | 324 | 600x1000x2200 |
| 300 | 228 | 456 | Floor-mounted | 326 | 600x1000x2200 |
| 350 | 228 | 456 | Floor-mounted | 361 | 600x1000x2200 |
| 400 | 228 | 456 | Floor-mounted | 372 | 600x1000x2200 |
| 450 | 228 | 456 | Floor-mounted | 374 | 600x1000x2200 |
| 500 | 228 | 456 | Floor-mounted | 392 | 600x1000x2200 |
| 550 | 228 | 456 | Floor-mounted | 420 | 600x1000x2200 |
| 600 | 228 | 456 | Floor-mounted | 422 | 600x1000x2200 |

EPCOS

# Design Guideline of

# 6. Hybrid TSC APFC and Detuned APFC

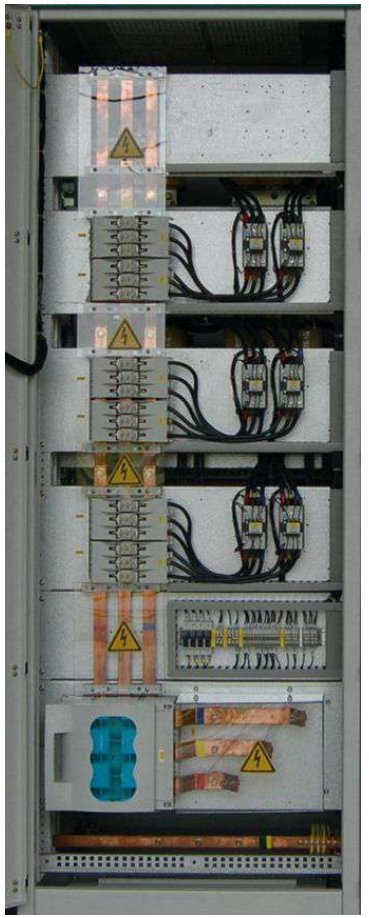
ITM

# Hybrid TSC APFC and Detuned APFC

Mixed dynamic systems (Hybrid TSC and Detuned APFC) feature the advantages of dynamic systems (Fast changing loads are dynamically compensated, base loads and slowly changing loads are compensated conventionally).

The operating mode “HYBRID-MODE” has especially been designed to serve such applications. It supports up to 12 transistor outputs (for switching of thyristor modules) and 12 relay outputs (for switching of capacitor contactors).

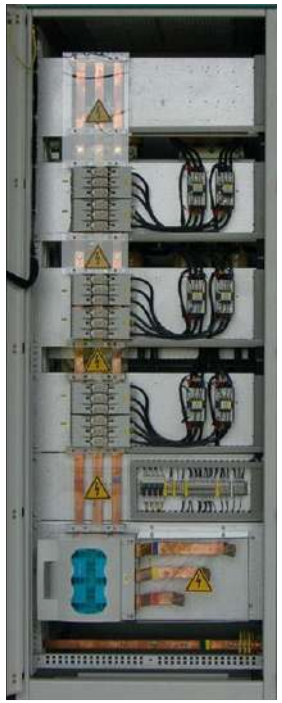
The parameter control series, end stop, control principle, switching times and priorities can be separately programmed for thyristor and relay part.



# Hybrid TSC APFC and Detuned APFC

## Scope of work:

The Contractor shall supply and install the Hybrid TSC and Detuned APFC ready for connection and use in low voltage systems.
The power ratings are according to the single line diagram.



## Electrical environment:

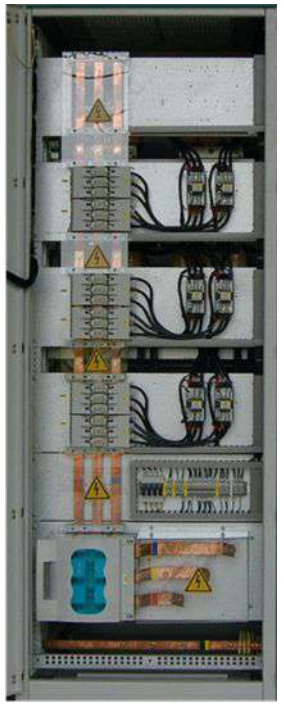
The connection of a capacitor bank onto a system containing harmonics and frequent load changes may reduce its life time.
The damaging effects of harmonics and frequent load changes can be mitigated by the use of a suitable detuning reactor, contactor and thyristor switch in series with each capacitor step.

The hybrid TSC and Detuned APFC shall be used in case of

- Non-linear loads < 50% and
- Frequent load changes and / or Light Flicker.

# Hybrid TSC APFC and Detuned APFC

Other Design, equipment specifications, Dimensions shall be the same as the TSC APFC and Detuned APFC  except the Dynamic and Hybrid PF Controller.

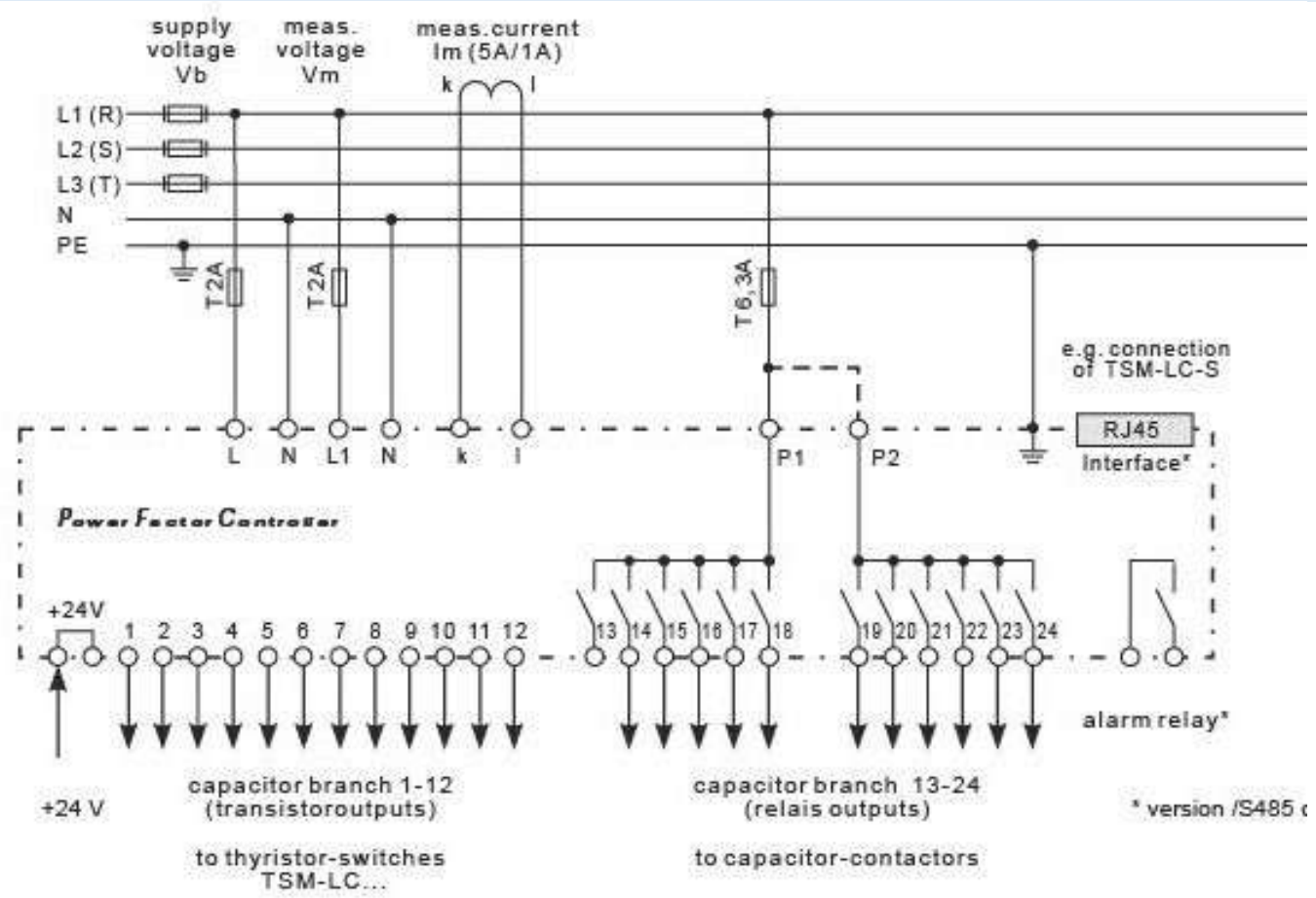


# Hybrid TSC APFC and Detuned APFC

## Dynamic and Hybrid Power Factor Controller

- 12 Relay outputs for capacitor contactors
- 12 Transistor outputs for thyristor switches

# Hybrid TSC APFC and Detuned APFC




to thyristor switches
Frequent load changes

to capacitor contactors
non-frequent load changes

# Hybrid TSC APFC and Detuned APFC

**Characteristics**

- 12 transistor and 12 relay outputs
- Direct triggering of up to 32 thyristor switches
- TSM-LC-S at the bus; bi-directional communication;
- design of self-monitoring dynamic systems with
- bus coupling (only version /S485)
- 20 pre-programmed control series
- Control series editor
- Full graphic display 128 x 64 pixel
- Plain language menu
- 4-quadrant-operation
- Display of multiple grid parameters
- Display of harmonics (up to 33rd)
- Display of distortion factor THD-V/THD-I
- Display and control of temperature
- Storage of maximum values
- Storage of switching operations and times (relay outputs)
- Manual and automatic operation
- Zero voltage cut-off
- Various error messages/alarm rely
- Error storage
- Interface RS485 for version -/S485
- Panel mounting 144 x 144 x 55 mm

# Hybrid TSC APFC and Detuned APFC

**Inputs**

- Operation voltage: 110 … 230 V AC +/- 15%
- Measuring voltage: 30 … 440 V AC (L-N) / 50 … 760 V AC (L-L)
- Current: X:1A / X:5A
- Standard serial interface (e.g. for firmware update)
- Version –/S485: 1 external input

**Outputs**

- 12 relay outputs
- 12 transistor outputs
- 1 relay output (alarm/fan)
- Version -/S485: 1 message relay (free programmable)
- Version -/S485: interface RS485

# Hybrid TSC APFC and Detuned APFC

**Measuring and display of following grid parameters**

- Voltage, current, frequency
- Active, reactive and apparent power
- Power factor, missing reactive power
- Harmonics of voltage (up to 33rd/even up to 16th)
- Harmonic of current (up to 33rd /even up to 16th)
- TDH-V, THD-I
- Temperature
- Well-arranged display of power factor and actual status of switching outputs
- Display and storage of maximum values, switching operations and operation time (only static stages)
- Display of harmonics as bar chart

# Hybrid TSC APFC and Detuned APFC

**Operation**

- Graphic display 164 x 64 dots with 8 lines maximum
- Plain language menu in several languages
- Optimum navigation in the menus via return (ESCAPE) button
- HELP-button for interactive help text

Version with interface (BR7000-1-TH/S485)

- Additional potential free input (programmable) for
  - Switch over 2nd target cos-phi
  - Triggering of a reactive power off-set
- Additional potential free relay output (message relay) for
  - Switching of a fan
  - Display of error- or status messages (programmable)
- Interface RS485 (MODBUS RTU) for
  - Direct triggering of up to 32 addressable thyristor switches TSM-LC-S with bi-directional communication
  - Imbedding of the controller into a network
  - Usage of software BR7000-Soft
  - Output of measured values in ACSII-protocol
- Internal battery-buffered clock for
  - Creation of time stamp of all recorded maximum values
  - Creation of time stamp for all error messages

# Hybrid TSC APFC and Detuned APFC

**Technical data and specifications**

Operating voltage 110 … 230 V AC +/- 15 %, 50 and 60 Hz
Measuring voltage 30 … 440 V AC (L-N); 50 … 760 V AC (L-L); 50/60 Hz
Measuring current X: 5 A / X: 1 A, selectable
Power consumption < 5 VA
Sensitivity 50 mA/10 mA

**Switching outputs**

Relay outputs for capacitor contactors 12
Transistor outputs for thyristor switches 12
Alarm relay 1
Message relay 1 for version -/S485 only
Switching power of relays 250 V AC, 1000 W
Switching power of thyristors 24 V DC, 50 mA
Number of active outputs Programmable

# Hybrid TSC APFC and Detuned APFC

**Operation and display**
Display Illuminated full graphic display 128 x 64 dots
Menu languages CZ/EN/ES/FR/GER/NL/PL/PT/RU/TR
Freely editable control series 1 via Editor
**Control**
Control principle Sequential switching, circle switching, intelligent switching behavior, 4-quadrant operation
Operation modes Dynamic or hybrid PF-controller
Target cos-φ 0.1 inductive up to 0.1 capacitive adjustable
Switch on time (dynamic/relay) 20 … 1000 ms / 1 sec … 20 min
Switch off time 20 … 1000 ms / 1 sec … 20 min
Discharge time 20 … 1000 ms / 1 sec … 20 min
Manual operation Yes
Fixed steps/skip steps Programmable
Zero voltage release Standard

# Hybrid TSC APFC and Detuned APFC

**Display/display functions**
Display of grid parameters Cos-φ, V, I , f, W, Q, P, S, ΔQ, THD-V, THD-I
Display of harmonics 3rd to 33rd harmonics of V and I; even harmonics up to 16th
Accuracy Current/voltage: 1%
Active, apparent and reactive power: 2%
Integrated help function Context dependent (German/English)

# Hybrid TSC APFC and Detuned APFC

**Storage function**
Storage of maximum values Voltage, current, active/reactive/apparent power, temperature,THD-V, THD-I
Storage of switching operations Each output can be reset separately (only contactor stages)
Storage of operation time Each capacitor can be reset separately (only contactor stages)
Error storage Error register in plain language
**Temperature monitoring**
Monitoring Automatic step switch off
Temperature measuring range -30 … +100 °C
**Casing**
Panel mounted instrument DIN 43700, 144 x 144 x 55 mm
Weight 1 kg
Ambient operating temperature -20 … +60 °C
Protection class accord. DIN 40050 Front: IP54, rear: IP 20
Safety regulations IEC 601010-1
Interference resistance IEC 61000-6-2; EN 61326
EMC-interference IEC 61000-4-2; IEC61000-4-4


# Design Guideline of

# 7. Hybrid SVG and TSC APFC

ITM

# Hybrid SVG and TSC APFC

- Mixed dynamic systems
- Hybrid SVG and  TSC APFC
- Feature the advantages of both dynamic systems for fast changing loads


# Hybrid SVG and TSC APFC

## Scope of work:

The Contractor shall supply and install the SVG and Detuned Automatic Power Factor Control Capacitor Bank with Thyristor-Switched Capacitor (TSC APFC) ready for connection and use in low voltage systems.
The power ratings are according to the single line diagram.

## Electrical environment:

The connection of a basic capacitor bank onto a system containing harmonics and frequent load changes may reduce its life time. The damaging effects of harmonics and frequent load changes can be mitigated by the use of the Hybrid SVG and TSC APFC.

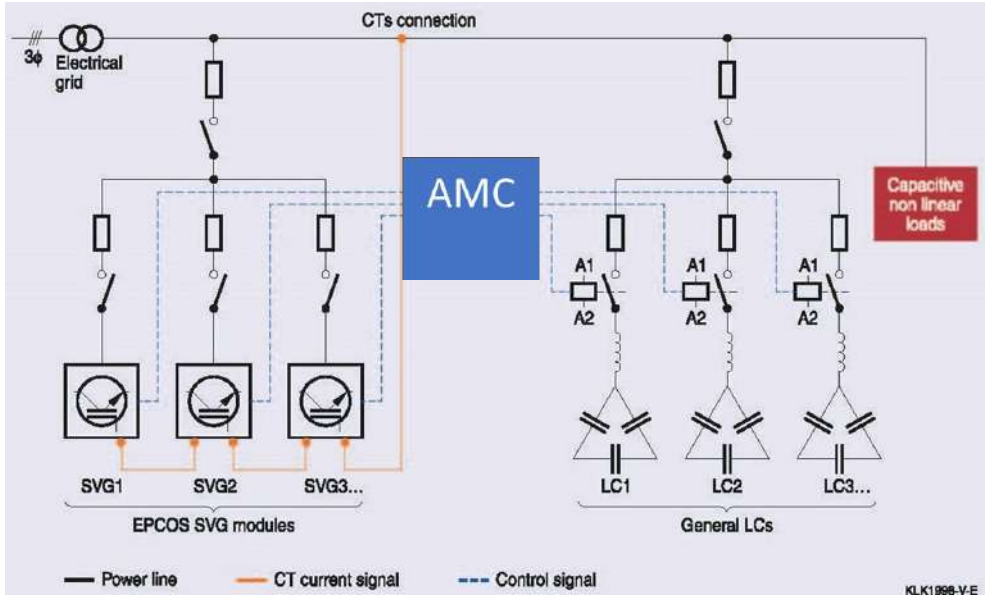
The detuned capacitor bank shall be used to prevent harmonic resonance and reduce the harmonic voltages in the network by absorbing part of the harmonic currents and the SVG shall be used to prevent harmonic resonance and dynamic reactive power compensation in case of

- Non-linear loads < 50% and
- Frequent load changes and / or Light Flicker.

# Hybrid SVG and TSC APFC

Other Design, equipment specifications and dimensions shall be the same as the SVG and TSC APFC  except the Advanced Multi Controller (AMC).

SVG PQvar Series Advanced Multi Controller (AMC) unit



# Hybrid SVG and SVG and TSC APFC

## Hybrid PFC-Solution – SVG PQvar and Classic PFC Managed by Advanced Multi Controller (AMC)

| Technical data and specifications of SVG PQvar Series Advanced Multi Controller (AMC) unit | |
|---|---|
| Operating voltage | 24 V DC |
| **Compensation performance** | |
| Target PF | –1 … +1 |
| Reactive power compensation rate | > 99% (target PF is 1) |
| Response time | < 15 ms |
| Reaction time | < 50 µs |
| **Capacitor switching performance** | |
| Compensation method | Three-phase/ split/ mixed compensation |
| Capacitance coding method | Optional |
| Capacitor switching method | Stack/ normal/ cycle/ individual |
| Switching manner | Auto/ manual |

# Hybrid SVG and TSC APFC or Detuned APFC

| External ports | |
|---|---|
| RS485 port 1 | Communication with SVG modules |
| RS485 port 2 | External communication port |
| Network port | External communication port |
| USB port | Code upgrading port |
| Temperature detection | Measuring system's operating temperature or ambient temperature |
| Fan controlling dry contact | Controlling SVC cooling fan |
| Alarm indicator dry contact | For reserved external alarm indicator |
| Control output contact | Control outputs, up to 18 at most<br>Contact support: 120 V AC / 10 A, 220 V AC / 8 A, 400 V AC / 3 A, 110 V DC / 0.2 A, 60 V DC / 0.6 A, 24 V DC / 5 A<br>Level signal: 12 V DC / 30 mA |
| Reserved dry contact | One input / one output |
| Communication protocol | Modbus |

# Hybrid SVG and SVG and TSC APFC or Detuned APFC

| | |
|---|---|
| Protection functions | Undervoltage, overvoltage, underfrequency, overfrequency, phase failure, high harmonic voltage, SVG overload, SVG overtemperature |
| Display | 7” touch screen |
| **Installation requirements** | |
| Power consumption | < 25 W |
| Protection class | IP41 for the front panel, and IP20 for the rear panel |
| **Operating environment** | |
| Operating temperature | –20 … +60 °C |
| Altitude | ≤ 2500 m |
| Humidity | ≤ 95% |
| Storage temperature | –40 … +70 °C |
| CT ratio | 150/5 … 10000/5 |

# Hybrid SVG and TSC APFC

## Hybrid PFC-Solution – SVG PQvar and Classic PFC Managed by Advanced Multi Controller (AMC)

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| SVG PQvar Series AMC (Advanced Multi Controller) | |
|---|---|
| **Product description** | **Ordering code** |
| Advanced Multi Controller (AMC) unit – HMI colour display 7" for switching thyristors ✓ | B44066F9989V230 |
| Advanced Multi Controller (AMC) unit – HMI colour display 7" for switching contactors | B44066F9988V230 |

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# Design Guideline of

# 8. Hybrid SVG and Detuned APFC

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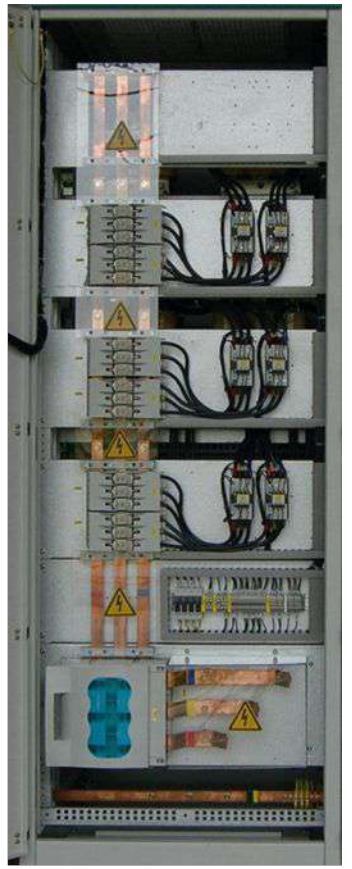
# Hybrid SVG and Detuned APFC

- Mixed dynamic and conventional systems (Hybrid SVG and Detuned APFC)
- Feature the advantages of dynamic systems
- Fast changing loads are dynamically compensated
- Base loads and slowly changing loads are compensated conventionally.

# Hybrid SVG and Detuned APFC

## Scope of work:

The Contractor shall supply and install the SVG and Detuned Automatic Power Factor Control Capacitor Bank (Detuned APFC) ready for connection and use in low voltage systems.
The power ratings are according to the single line diagram.

## Electrical environment:

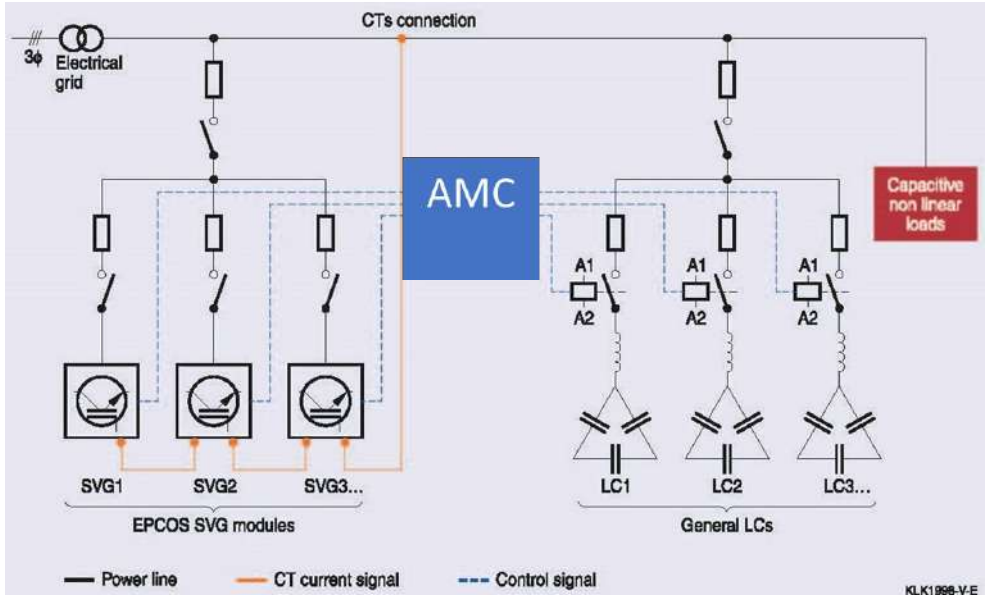
The connection of a basic capacitor bank onto a system containing harmonics and frequent load changes may reduce its life time. The damaging effects of harmonics and frequent load changes can be mitigated by the use of the Hybrid SVG and Detuned APFC.

The detuned capacitor bank shall be used to prevent harmonic resonance and reduce the harmonic voltages in the network by absorbing part of the harmonic currents and the SVG shall be used to prevent harmonic resonance and dynamic reactive power compensation in case of

- Non-linear loads < 50% and
- Frequent load changes and / or Light Flicker.

# Hybrid SVG and Detuned APFC

Other Design, equipment specifications and dimensions shall be the same as the SVG and Detuned APFC  except the Advanced Multi Controller (AMC).

# Hybrid SVG and Detuned APFC

## Hybrid PFC-Solution – SVG PQvar and Classic PFC Managed by Advanced Multi Controller (AMC)

| Technical data and specifications of SVG PQvar Series Advanced Multi Controller (AMC) unit | |
|---|---|
| Operating voltage | 24 V DC |
| **Compensation performance** | |
| Target PF | –1 … +1 |
| Reactive power compensation rate | > 99% (target PF is 1) |
| Response time | < 15 ms |
| Reaction time | < 50 µs |
| **Capacitor switching performance** | |
| Compensation method | Three-phase/ split/ mixed compensation |
| Capacitance coding method | Optional |
| Capacitor switching method | Stack/ normal/ cycle/ individual |
| Switching manner | Auto/ manual |

# Hybrid SVG and Detuned APFC

| External ports | |
|---|---|
| RS485 port 1 | Communication with SVG modules |
| RS485 port 2 | External communication port |
| Network port | External communication port |
| USB port | Code upgrading port |
| Temperature detection | Measuring system's operating temperature or ambient temperature |
| Fan controlling dry contact | Controlling SVC cooling fan |
| Alarm indicator dry contact | For reserved external alarm indicator |
| Control output contact | Control outputs, up to 18 at most<br>Contact support: 120 V AC / 10 A, 220 V AC / 8 A, 400 V AC / 3 A, 110 V DC / 0.2 A, 60 V DC / 0.6 A, 24 V DC / 5 A<br>Level signal: 12 V DC / 30 mA |
| Reserved dry contact | One input / one output |
| Communication protocol | Modbus |

# Hybrid SVG and Detuned APFC

| | |
|---|---|
| Protection functions | Undervoltage, overvoltage, underfrequency, overfrequency, phase failure, high harmonic voltage, SVG overload, SVG overtemperature |
| Display | 7” touch screen |
| **Installation requirements** | |
| Power consumption | < 25 W |
| Protection class | IP41 for the front panel, and IP20 for the rear panel |
| **Operating environment** | |
| Operating temperature | –20 … +60 °C |
| Altitude | ≤ 2500 m |
| Humidity | ≤ 95% |
| Storage temperature | –40 … +70 °C |
| CT ratio | 150/5 … 10000/5 |

# Hybrid SVG and Detuned APFC

## Hybrid PFC-Solution – SVG PQvar and Classic PFC Managed by Advanced Multi Controller (AMC)

EPCOS

| SVG PQvar Series AMC (Advanced Multi Controller) | |
|---|---|
| **Product description** | **Ordering code** |
| Advanced Multi Controller (AMC) unit – HMI colour display 7" for switching thyristors | B44066F9989V230 |
| Advanced Multi Controller (AMC) unit – HMI colour display 7" for switching contactors | B44066F9988V230 |

ITM

# Other Hybrid Possibilities

# AHF + SVG and AHF + Detuned APFC

# ITM Literatures

For further technical information concerning PFC Banks and harmonics, please refer to the literatures in our website: www.itm.co.th
or directly email to: tm@itm.co.th