CONDENSATOR DOMINIT

...the power quality company

# VOLTAGE CONTROLLED HARMONIC FILTER WITH INTELLIGENT ADAPTATION

# SOFIA®

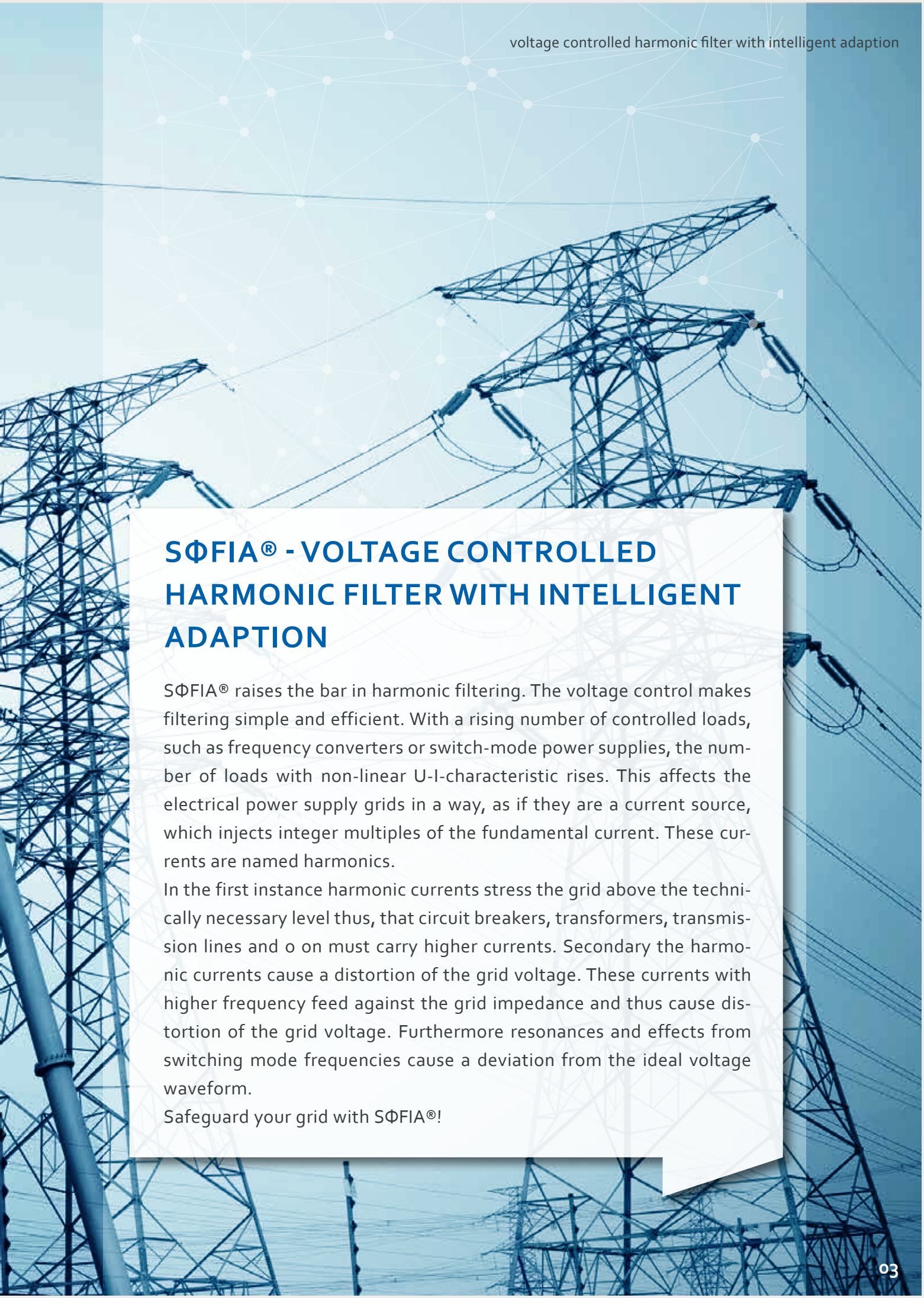
SIMPLY INTELLIGENT, INTELLIGENT SIMPLE

CONDO D21011707

GridClass® Technology

# MADE IN GERMANY

## WE DEVELOP, DESIGN AND MANUFACTURE OUR SΦFIA® PRODUCTS IN GERMANY



# SΦFIA® - VOLTAGE CONTROLLED HARMONIC FILTER WITH INTELLIGENT ADAPTION

SΦFIA® raises the bar in harmonic filtering. The voltage control makes filtering simple and efficient. With a rising number of controlled loads, such as frequency converters or switch-mode power supplies, the number of loads with non-linear U-I-characteristic rises. This affects the electrical power supply grids in a way, as if they are a current source, which injects integer multiples of the fundamental current. These currents are named harmonics.

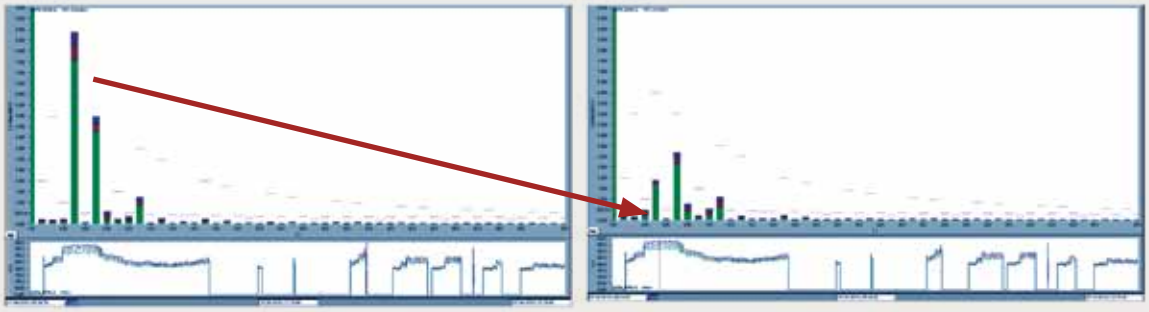
In the first instance harmonic currents stress the grid above the technically necessary level thus, that circuit breakers, transformers, transmission lines and o on must carry higher currents. Secondary the harmonic currents cause a distortion of the grid voltage. These currents with higher frequency feed against the grid impedance and thus cause distortion of the grid voltage. Furthermore resonances and effects from switching mode frequencies cause a deviation from the ideal voltage waveform.

Safeguard your grid with SΦFIA®!

# SAFEGUARD YOUR GRID WITH SΦFIA®

Suppliers of devices, machines and equipment are free from warranty claims if the distortion is higher than the compatibility levels given in the standard EN 61000-2-4 (Electromagnetic compatibility (EMC) - Part 2-4: Environment – Compatibility levels in industrial plants for low-frequency conducted disturbances), because the grid does not fulfil the limitations of use specified by the manufacturer.

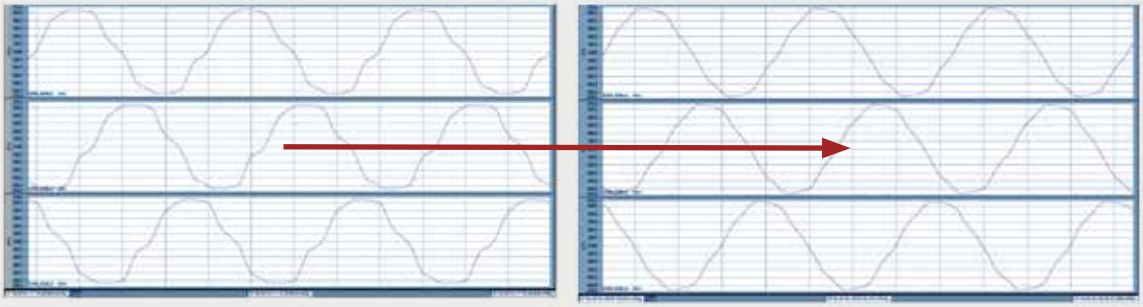
## Reduction of $U_5$ from 8.9 to 2.0%



Harmonic voltage levels without SΦFIA®

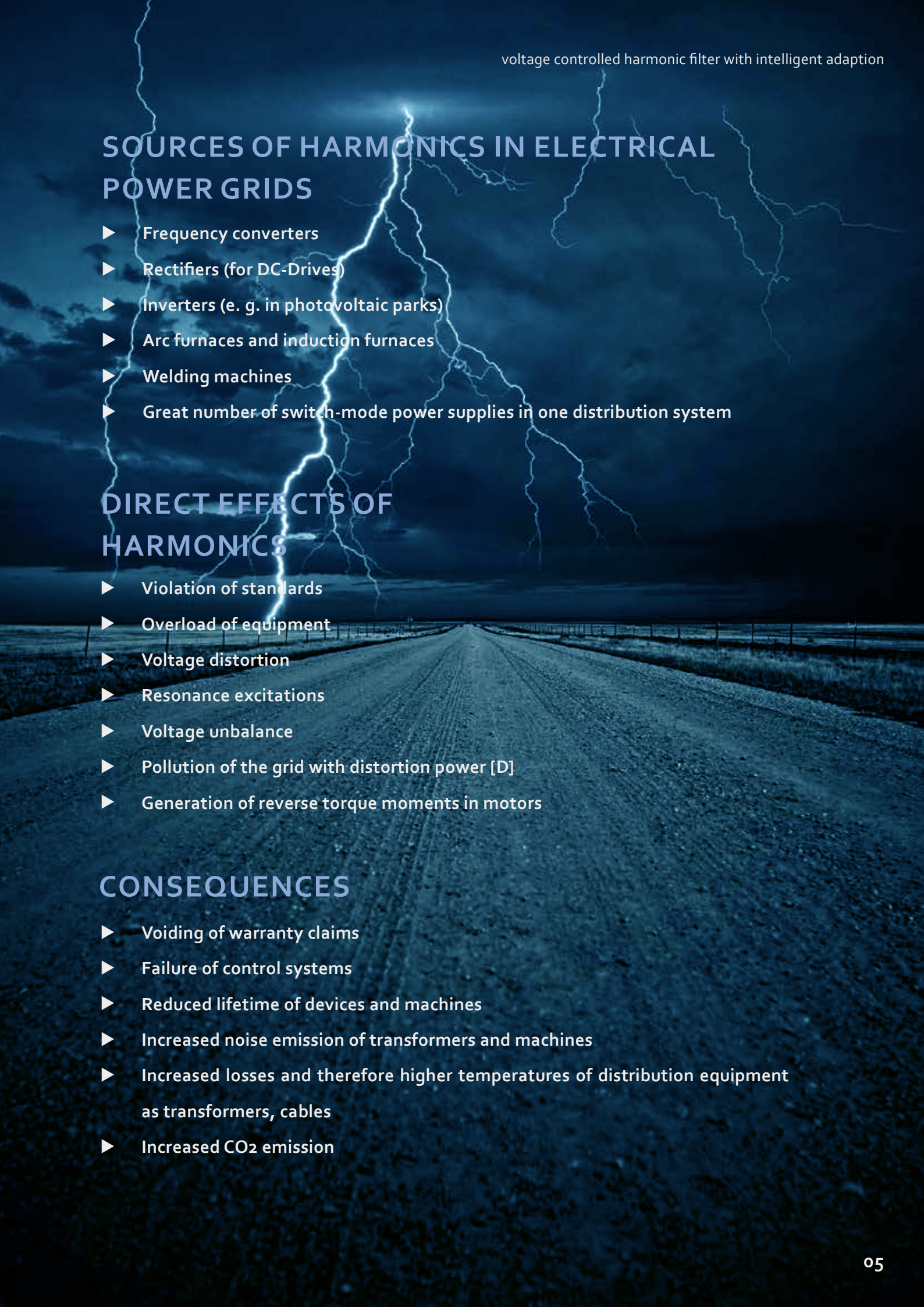
Harmonic voltage levels with SΦFIA®

## Significant reduction of the distortion



Waveform of the voltage without SΦFIA®

Waveform of the voltage with SΦFIA®



## SOURCES OF HARMONICS IN ELECTRICAL POWER GRIDS

- Frequency converters
- Rectifiers (for DC-Drives)
- Inverters (e. g. in photovoltaic parks)
- Arc furnaces and induction furnaces
- Welding machines
- Great number of switch-mode power supplies in one distribution system

## DIRECT EFFECTS OF HARMONICS

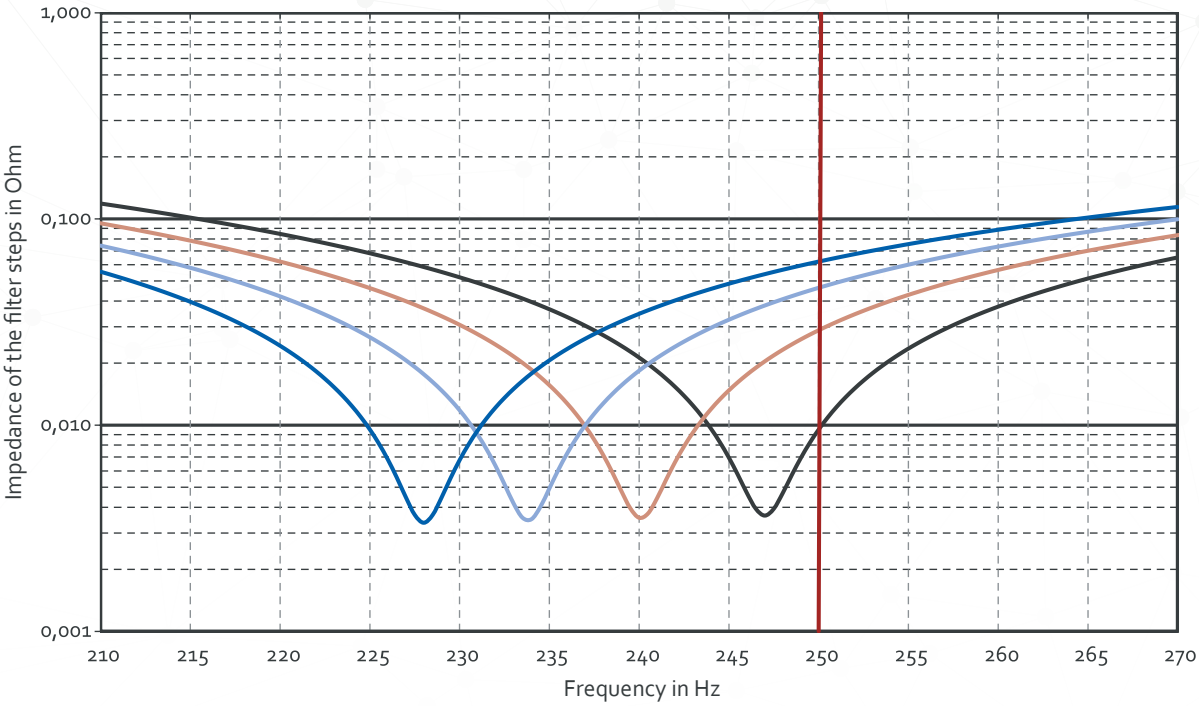
- Violation of standards
- Overload of equipment
- Voltage distortion
- Resonance excitations
- Voltage unbalance
- Pollution of the grid with distortion power [D]
- Generation of reverse torque moments in motors

## CONSEQUENCES

- Voiding of warranty claims
- Failure of control systems
- Reduced lifetime of devices and machines
- Increased noise emission of transformers and machines
- Increased losses and therefore higher temperatures of distribution equipment as transformers, cables
- Increased $CO_2$ emission

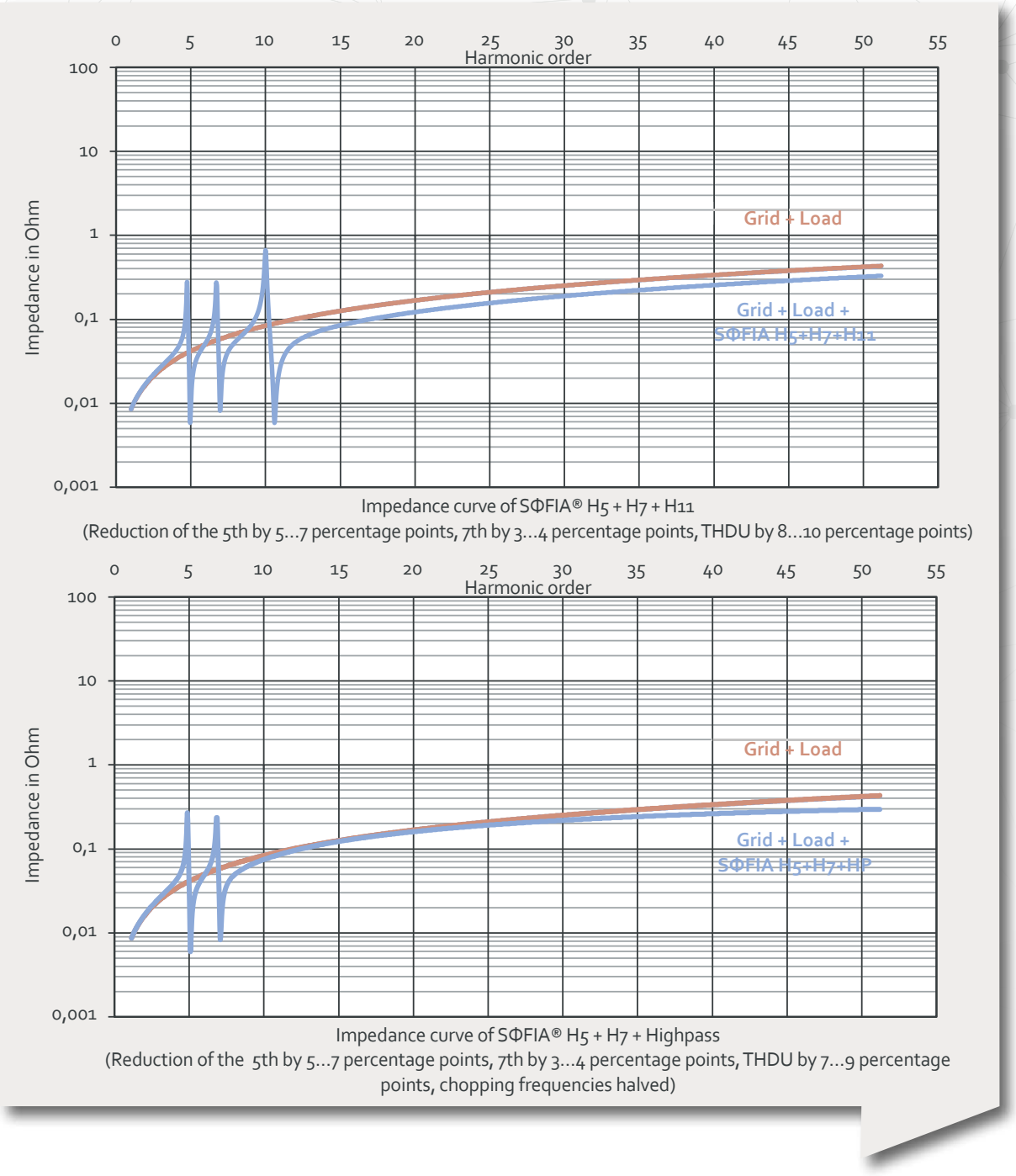
# FUNCTION OF THE SΦFIA® AUTOMATICALLY REGULATED HARMONIC FILTERS

SΦFIA® is an active controlled harmonic filter. It has an automatic impedance regulation with which the filter controls the suction effect on the grid by itself. Up to now it was mandatory for the design of voltage controlled filters to know all data of the customers' grid and make an expert configure the filter. This expert knowledge has been integrated by Condensator Dominit into the filter control. SΦFIA® is voltage controlled, therefore no current transformers are needed on-site and the function is guaranteed even in meshed grids with harmonic sources distributed all over the grid.




**Impedance curves of the SΦFIA® H5 steps**

During operation of a filter step (e. g. in the picture SΦFIA® H5) a change of the harmonic load will cause an uninterrupted change between the tuning frequencies (dark blue <=> light blue <=> orange <=> black) in a way, that the filter current remains nearly constant in a very wide range of harmonic load. The steps are designed in such a way, that only a violation of the harmonic voltage limits in industrial grids (class 3 of IEC/EN 61000-2-4) with filter in operation will lead to an overload disconnection. In order to avoid system breakdown due to short term overload events the filter will be automatically activated again after a damping period. A permanent disconnection takes place only after multiple successive switching on and off operations.




SΦFIA® is available in steps H5, H7 and H11, which cause a significant reduction of the harmonic voltage levels. The H11 steps are available in a dampened version, which can either be used as an absorption circuit for the 11th harmonic or as a broadband damping version. A change between the two variants is possible anytime. Increasing resonances and switching frequencies of converters (> 2.5 kHz) progressively require a broadband reduction of higher frequency disturbances. It is highly recommended to prepare electrical grids already now for these requirements.

# KNOWLEDGE XPRESS

$$Z_L + Z_C = 0$$

$$\Rightarrow \quad \omega L - \frac{1}{\omega C} = 0$$

$$\Rightarrow \quad \omega = \frac{1}{\sqrt{LC}} \quad \text{resp.}$$

$$f = \frac{1}{2\pi\sqrt{LC}}$$

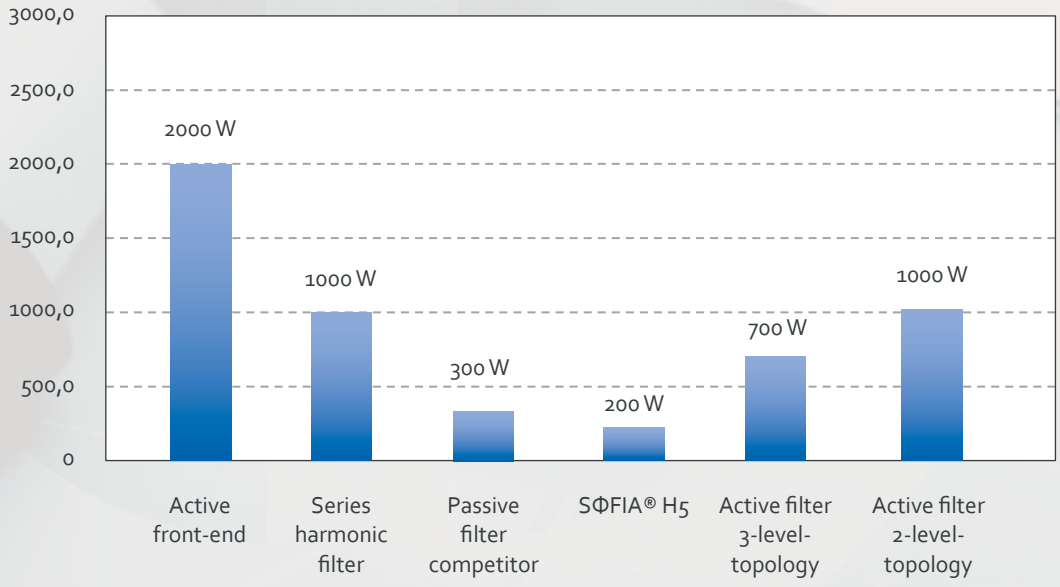
| | |
|---|---|
| $Z_L$ | Impedance of the reactor |
| $Z_C$ | Impedance of the capacitor |
| $\omega$ | Pulsatance |
| f | Frequency |

**Tuning frequency**

The impedances of capacitances (capacitors) and inductances (reactors) have different prefixes. At inductivities the impedance value rises with rising frequency, at capacities the value is declining.

For a series connection of a reactor and a capacitor a certain frequency exists, where both values have the same magnitude, this is called the „Series resonance frequency" or „tuning frequency".

**Losses of filtering measures (Readings for 100 kW drive power)**



**Voltage controlled harmonic filters**

In voltage controlled harmonic filters the amplitude of the filter current is determined by the level of the harmonic voltages. With a passive filter the impedance of the filter is connected in parallel to the grid impedance. The resulting impedance is therefore smaller, than the grid impedance itself. The current emitted by the distortion source results in a smaller voltage drop with filter than without.

The filter current only depends on the level of the harmonic voltage, a measurement of the load current is needless.

**For the filtering effect it is not relevant, whether the disturbance is caused in the own distribution system, or is coming from the feeding grid.**

Furthermore in SΦFIA® filters an automatic control switches uninterruptible between different tuning frequencies so that in a wide range of grid distortion the filter current remains nearly constant.



**Current controlled harmonic filters**

Current controlled active harmonic filters measure the distorted load current and generate for each selected harmonic a 180° phase-shifted correction current.

**Disturbances coming from the feeding grid cannot be corrected by this means.**

Active filters are useful in cases, where the harmonic current injection of a certain load(group) has to comply with given emission limits.
SΦFIA® is as well available as a current controlled filter.

# GENERAL EXECUTION

SΦFIA®-systems are automatically controlled filter assemblies for the reduction of harmonic levels in electrical power grids. They are designed for operation in grids with harmonic voltage levels up to the limits according to EN/IEC 61000-2-4 class 3 (e. g. $U_5 \leq 8\%$, $THDU \leq 10\%$).

The cubicle system for indoor use contains reactors, capacitors, contactors, all functional units for the control and, if necessary, fans. Each cubicle has a separate infeed from the bottom. The cubicles are equipped with a double winged door and 4 lifting brackets. Each system unit includes a multi-functional measuring device and an emergency stop button.

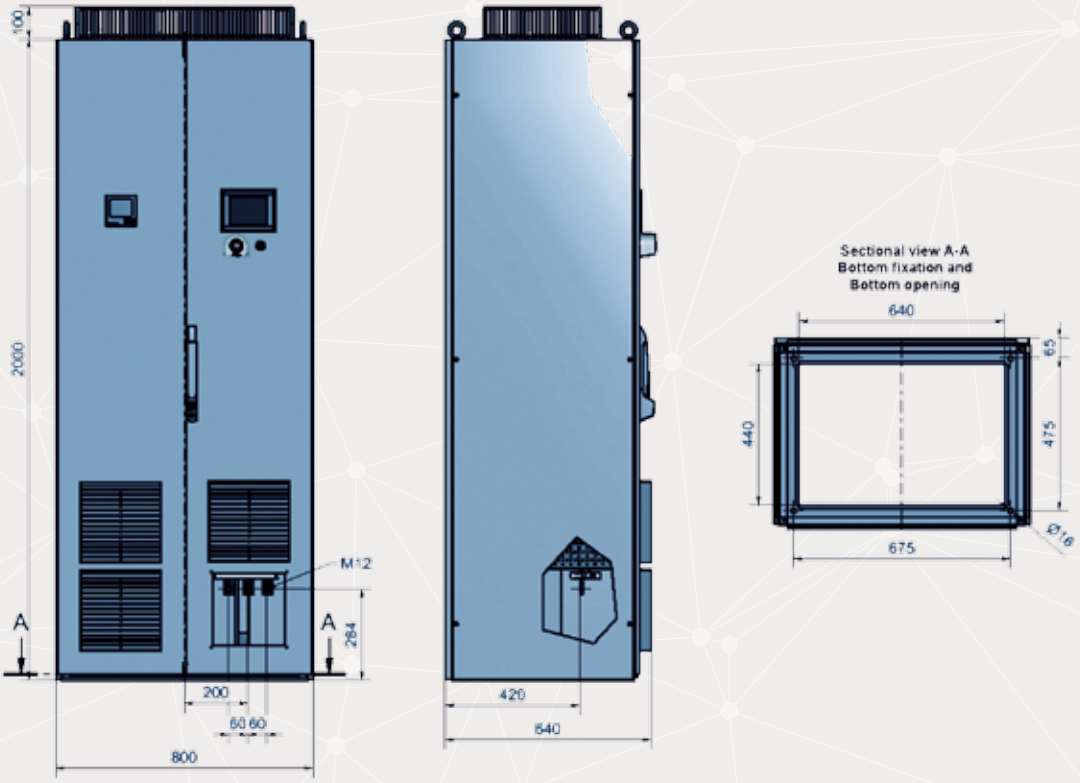
Premium-power capacitors with a dimensioning voltage > 900 V for 400 V (1400 V for 690 V) systems mounted inside a sheet steel enclosure for compensation of distortion power according to EN 60831-1, IEC 60831-1, VDE 560 part 46, consisting of dry-type self-healing elements in MFLL-technology (metallized film with low losses), equipped with an internal protection system IPE®. The capacitors are environmental-friendly, because they are free of impregnants and 100% recyclable. Each basic system unit SΦFIA® H5 include a multi-lingual 5.7" touch panel. In a complete system (e. g. consisting of 1x SΦFIA® H5 + 1x SΦFIA® H7) the touch panel in SΦFIA H5 controls the whole system. On the touch panel parameters can be programmed, different modes of switching on ("Auto", "Local", "Remote") can be chosen, important information can be displayed and events can be acknowledged. Unauthorized inputs at the touch panel can be avoided by blocking inputs with a key switch.

**Execution with:**

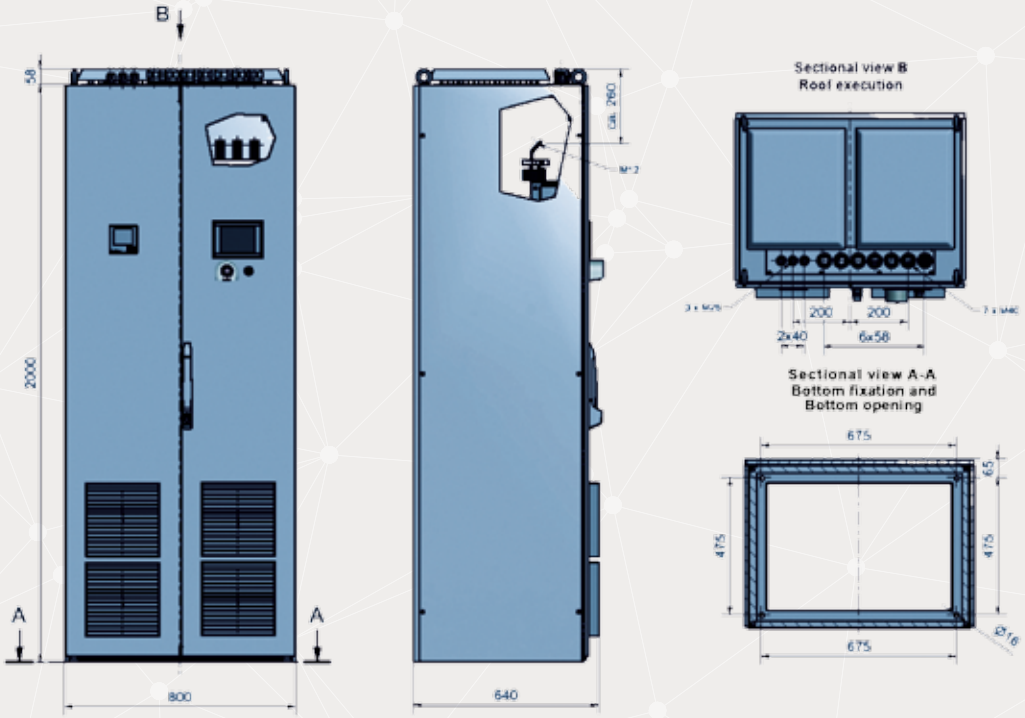
- Integrated load disconnector per cubicle
- HRC gG fuses for each switching group / step
- Automatic reconnection after a voltage drop out
- Automatic derating of the rated current if the allowed ambient temperature is exceeded
- Load dependent control of the tuning frequency
- Monitoring of the temperature of the reactors and the temperature inside the cubicle
- Reconnection inhibit function to ensure the discharge time of the capacitors
  Monitoring of the step impedance

**Options:**

- Cable infeed from Top (possible at all degrees of protection)
- Execution as a rack for integration in an existing cubicle
- Integration into process control via interface
  (Other options on request)




**SΦFIA® infeed from bottom with IP21 roof hood**




**SΦFIA® infeed from top with roof mounted fans (IP42, IP54)**

# OVERVIEW OF THE ACTUAL AVAILABLE SYSTEM UNITS

SΦFIA® is available for voltages from 230 V up to 12 kV with 50 or 60 Hz

| | SΦFIA®-400/50-300-H5-IP21 | SΦFIA®-400/50-300-H5-IP54 | SΦFIA®-400/50-360-H5-IP42 |
|---|---|---|---|
| Articlecode | SOF-AAA | SOF-AAB | SOF-ABC |
| Rated voltage | 3x 400 V / 50 Hz | 3x 400 V / 50 Hz | 3x 400 V / 50 Hz |
| Filter current / -frequency | 300 A / 250 Hz | 300 A / 250 Hz | 360 A / 250 Hz |
| No load current | 134 ... 158 A (cap.) | 134 ... 158 A (cap.) | 134 ... 158 A (cap.) |
| Capacitor dimensioning | > 900 V | > 900 V | > 900 V |
| Losses | < 1500 W | < 1500 W | < 2070 W |
| No load losses | 400 W | 400 W | 400 W |
| Ambient temperature | -5/+40°C, 24 hour average ≤ 35°C | -5/+40°C, 24 hour average ≤ 35°C | -5/+40°C, 24 hour average ≤ 35°C |
| Fans | No | Yes | Yes |
| Degree of protection | IP21 (open bottom) | IP54 | IP42 |
| Dimensions (WxDxH) | 800 x 600 x 2100 mm | 800 x 600 x 2060 mm | 800 x 600 x 2060 mm |
| Weight (app.) | 565 kg | 575 kg | 575 kg |
| Cable infeed | from bottom | from bottom | from bottom |
| Connections | L1, L2, L3 und PE | L1, L2, L3 und PE | L1, L2, L3 und PE |
| HRC output (on site) | 3x 500 A gRL | 3x 500 A gRL | 3x 500 A gRL |
| Connection cross-section | 2 II 3x 120/70 mm² (NYY) or 7x 120 mm² (NSHXAFö) | 2 II 3x 120/70 mm² (NYY) or 7x 120 mm² (NSHXAFö) | 2 II 3x 120/70 mm² (NYY) or 7x 120 mm² (NSHXAFö) |

| | SΦFIA®-400/50-150-H7-IP21 | SΦFIA®-400/50-150-H7-IP54 | SΦFIA®-400/50-180-H7-IP42 |
|---|---|---|---|
| Articlecode | SOF-BCA | SOF-BCB | SOF-BDC |
| Rated voltage | 3x 400 V / 50 Hz | 3x 400 V / 50 Hz | 3x 400 V / 50 Hz |
| Filter current / -frequency | 150 A / 350 Hz | 150 A / 350 Hz | 180 A / 350 Hz |
| No load current | 51 ... 55 A (cap.) | 51 ... 55 A (cap.) | 51 ... 55 A (cap.) |
| Capacitor dimensioning | > 900 V | > 900 V | > 900 V |
| Losses | < 900 W | < 900 W | < 1200 W |
| No load losses | 160 W | 160 W | 160 W |
| Ambient temperature | -5/+40°C, 24 hour average ≤ 35°C | -5/+40°C, 24 hour average ≤ 35°C | -5/+40°C, 24 hour average ≤ 35°C |
| Fans | No | Yes | Yes |
| Degree of protection | IP21 (open bottom) | IP54 | IP42 |
| Dimensions (WxDxH) | 800 x 600 x 2100 mm | 800 x 600 x 2060 mm | 800 x 600 x 2060 mm |
| Weight (app.) | 375 kg | 385 kg | 385 kg |
| Cable infeed | from bottom | from bottom | from bottom |
| Connections | L1, L2, L3 und PE | L1, L2, L3 und PE | L1, L2, L3 und PE |
| HRC output (on site) | 3x 250 A gRL | 3x 250 A gRL | 3x 250 A gRL |
| Connection cross-section | 3x 120/70 mm² (NYY) or 3x 120 mm² + 1x 70 mm² (NSHXAFö) | 3x 120/70 mm² (NYY) or 3x 120 mm² + 1x 70 mm² (NSHXAFö) | 3x 120/70 mm² (NYY) or 3x 120 mm² + 1x 70 mm² (NSHXAFö) |

| | | SΦFIA®-400/50-150-H7+100-H11HP-IP21 | SΦFIA®-400/50-150-H7+100-H11HP-IP54 | SΦFIA®-400/50-180-H7+120-H11HP-IP42 |
|---|---|---|---|---|
| Articlecode | | SOF-CEA | SOF-CEB | SOF-CFC |
| Rated voltage | | 3x 400 V / 50 Hz | 3x 400 V / 50 Hz | 3x 400 V / 50 Hz |
| Filter current / -frequency | H7<br>H11/HP | 150 A / 350 Hz<br>100 A / 550 Hz oder HP | 150 A / 350 Hz<br>100 A / 550 Hz oder HP | 180 A / 350 Hz<br>120 A / 550 Hz oder HP |
| No load current | H7<br>H11/HP | 51 ... 55 A (cap.)<br>37 A (cap.) | 51 ... 55 A (cap.)<br>37 A (cap.) | 51 ... 55 A (cap.)<br>37 A (cap.) |
| Capacitor dimensioning | | > 900 V | > 900 V | > 900 V |
| Losses | H7<br>H11/HP | < 900 W<br>< 460 W / 1150 W | < 900 W<br>< 460 W / 1150 W | < 1200 W<br>< 550 W / 1150 W |
| No load losses | H7<br>H11/HP | 160 W<br>60 W / 90 W | 160 W<br>60 W / 90 W | 160 W<br>60 W / 90 W |
| Ambient temperature | | -5/+40°C, 24 hour average ≤ 35°C | -5/+40°C, 24 hour average ≤ 35°C | -5/+40°C, 24 hour average ≤ 35°C |
| Fans | | No | Yes | Yes |
| Degree of protection | | IP21 (open bottom) | IP54 | IP42 |
| Dimensions (WxDxH) | | 800 x 600 x 2100 mm | 800 x 600 x 2060 mm | 800 x 600 x 2060 mm |
| Weight (app.) | | 455 kg | 465 kg | 465 kg |
| Cable infeed | | from bottom | from bottom | from bottom |
| Connections | | L1, L2, L3 and PE, at filtering against starpoint additionally N | L1, L2, L3 and PE, at filtering against starpoint additionally N | L1, L2, L3 and PE, at filtering against starpoint additionally N |
| HRC output (on site) | | 3x 400 A gRL | 3x 400 A gRL | 3x 400 A gRL |
| Connection cross-section | | 2 II 3x 95/50 mm² (NYY) or 3x 240 mm² + 1x 120 mm² (NSHXAFö); at filtering against starpoint additionally 1x 95 mm² or 2 II 50 mm² | 2 II 3x 95/50 mm² (NYY) or 3x 240 mm² + 1x 120 mm² (NSHXAFö); at filtering against starpoint additionally 1x 95 mm² or 2 II 50 mm² | 2 II 3x 95/50 mm² (NYY) or 3x 240 mm² + 1x 120 mm² (NSHXAFö); at filtering against starpoint additionally 1x 95 mm² or 2 II 50 mm² |

# OVERVIEW OF THE ACTUAL AVAILABLE SYSTEM UNITS

| | SΦFIA®-690/50-200-H5-IP21 | SΦFIA®-690/50-200-H5-IP54 | SΦFIA®-690/50-200-H5-IP42 |
|---|---|---|---|
| Articlecode | SOF-DGA | SOF-DGB | SOF-DGC |
| Rated voltage | 3x 690 V / 50 Hz | 3x 690 V / 50 Hz | 3x 690 V / 50 Hz |
| Filter current / -frequency | 200 A / 250 Hz | 200 A / 250 Hz | 200 A / 250 Hz |
| No load current | 133 ... 162 A (cap.) | 133 ... 162 A (cap.) | 133 ... 162 A (cap.) |
| Capacitor dimensioning | > 1400 V | > 1400 V | > 1400 V |
| Losses | < 1250 W | < 1250 W | < 1250 W |
| No load losses | 300 W | 300 W | 300 W |
| Ambient temperature | -5/+40°C, 24 hour average ≤ 35°C | -5/+40°C, 24 hour average ≤ 35°C | -5/+40°C, 24 hour average ≤ 35°C |
| Fans | No | Yes | Yes |
| Degree of protection | IP21 (open bottom) | IP54 | IP42 |
| Dimensions (WxDxH) | 800 x 600 x 2100 mm | 800 x 600 x 2060 mm | 800 x 600 x 2060 mm |
| Weight (app.) | 600 kg | 610 kg | 610 kg |
| Cable infeed | from bottom | from bottom | from bottom |
| Connections | L1, L2, L3 and PE | L1, L2, L3 and PE | L1, L2, L3 and PE |
| HRC output (on site) | 3x 400 A gRL | 3x 400 A gRL | 3x 400 A gRL |
| Connection cross-section | 2 II 3x 95/50 mm² (NYY) or 3x 185 mm² + 1x 95 mm² (NSHXAFö) | 2 II 3x 95/50 mm² (NYY) or 3x 185 mm² + 1x 95 mm² (NSHXAFö) | 2 II 3x 95/50 mm² (NYY) or 3x 185 mm² + 1x 95 mm² (NSHXAFö) |

| | | SΦFIA®-690/50-125-H7+80-H11HP-IP21 | SΦFIA®-690/50-125-H7+80-H11HP-IP54 | SΦFIA®-690/50-125-H7+80-H11HP-IP42 |
|---|---|---|---|---|
| Articlecode | | SOF-FLA | SOF-FLB | SOF-FLC |
| Rated voltage | | 3x 690 V / 50 Hz | 3x 690 V / 50 Hz | 3x 690 V / 50 Hz |
| Filter current / -frequency | H7<br>H11/HP | 125 A / 350 Hz<br>80 A / 550 Hz oder HP | 125 A / 350 Hz<br>80 A / 550 Hz oder HP | 125 A / 350 Hz<br>80 A / 550 Hz oder HP |
| No load current | H7<br>H11/HP | 58 ... 69 A (cap.)<br>29 A (cap.) | 58 ... 69 A (cap.)<br>29 A (cap.) | 58 ... 69 A (cap.)<br>29 A (cap.) |
| Capacitor dimensioning | | > 1400 V | > 1400 V | > 1400 V |
| Losses | H7<br>H11/HP | < 900 W<br>< 600 W / 1000 W | < 900 W<br>< 600 W / 1000 W | < 900 W<br>< 600 W / 1000 W |
| No load losses | H7<br>H11/HP | 150 W<br>100 W / 150 W | 150 W<br>100 W / 150 W | 150 W<br>100 W / 150 W |
| Ambient temperature | | -5/+40°C, 24 hour average ≤ 35°C | -5/+40°C, 24 hour average ≤ 35°C | -5/+40°C, 24 hour average ≤ 35°C |
| Fans | | No | Yes | Yes |
| Degree of protection | | IP21 (open bottom) | IP54 | IP42 |
| Dimensions (WxDxH) | | 800 x 600 x 2100 mm | 800 x 600 x 2060 mm | 800 x 600 x 2060 mm |
| Weight (app.) | | 480 kg | 490 kg | 490 kg |
| Cable infeed | | from bottom | from bottom | from bottom |
| Connections | | L1, L2, L3 and PE, at filtering against starpoint additionally N | L1, L2, L3 and PE, at filtering against starpoint additionally N | L1, L2, L3 and PE, at filtering against starpoint additionally N |
| HRC output (on site) | | 3x 250 A gRL | 3x 250 A gRL | 3x 250 A gRL |
| Connection cross-section | | 3x 120/70 mm² (NYY) or 3x 120 mm² + 1x 70 mm² (NSHXAFö); at filtering against starpoint additionally 1x 70 mm² | 3x 120/70 mm² (NYY) or 3x 120 mm² + 1x 70 mm² (NSHXAFö); at filtering against starpoint additionally 1x 70 mm² | 3x 120/70 mm² (NYY) or 3x 120 mm² + 1x 70 mm² (NSHXAFö); at filtering against starpoint additionally 1x 70 mm² |

# SΦFIA® - SIMPLY INTELLIGENT, INTELLIGENT SIMPLE

## SIMPLE DESIGN

- Easy to rate during planning stadium. Very few data necessary (mainly transformer size)
- Simple planning of complete systems, very low losses make climatisation simple
- Little space required, due to high power density
- Simple integration in process control system
- N-1 redundancy is intrinsic
- Even upstream and neighbouring grid segments will be unburdend
- No prior power quality analysis is required
- Extensions in any order are possible (e. g. after installation of additional loads)

## SIMPLY TO INSTALL

- No external current transformers
- Very low losses, therefore minor cooling requirements
- For tough ambient conditions with low effort executable in high degree of protection

## SIMPLE COMMISSIONING

- "Plug and Play"
- No forming processes for DC-link capacitors necessary
- No software adjustments on site
- No parametrisation on site
- Automatic choice of operation point

## SIMPLE OPERATION

- Reaction time at load changes = 0, no time delay by control unit
- Insensible to commutations and high frequency disturbances
- No EMC filter is neccessary, therefore no grid resonances will be generated
- Insensible to changes of the grid structure (e. g. coupling of grid sections)
- Insensitive to frequency fluctuations
- Low reactive power
- Full filter power at operation according EN/IEC 61000-2-4 class 1-3
- Short time overload capability 150% e. g. for heavy duty startup

## SIMPLE MAINTENACE

- Low maintennace costs
- No regular exchange of DC-link capacitors
- No or only very few fans which need to be changed regularly

CONDENSATOR DOMINIT

...the power quality company

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Patent: EP 15 157 778.0 (Patent pending)
Utility patent: DPMA 20 2016 100 226.5