MERUS POWER

Active harmonic filters (AHF)

Active harmonic filters (AHF) are the ultimate answer to power quality problems and grid code requirements for a wide range of segments and applications. They are a high performance, flexible, compact, modular and cost-effective type of active power filters (APF) that provide an instantaneous and effective response in low or high voltage electric power systems. They enable longer equipment lifetime, higher process reliability, improved power system capacity and stability, and reduced energy losses, complying with most demanding power quality standards and grid codes.

AHF module rated 400 V 50/60 Hz 120 A

AHFs eliminate waveform distortions from the loads like harmonics, interharmonics and notching, by injecting in real-time in the electric power system the distorted current of same magnitude but opposite in phase. They can also work as harmonic generators for harmonic injection testing purposes. In addition, AHFs can take care of several other power quality problems and grid ancillary services by combining different functions in a single device.

Power quality improvement capabilities		Solution
Waveform distortions	Harmonics	Primary
	Interharmonics	Primary
	Notching	Secondary
Short duration variations	Voltage sags	Primary
	Voltage swells	Primary
	Interruptions	None
Long duration variations	Undervoltages	Secondary
	Overvoltages	Secondary
	Sustained interruptions	None
Transients	Impulsive transients	Secondary
	Oscillatory transients	Secondary
Other power quality problems	Voltage unbalances	Primary
	Voltage fluctuations (flicker)	Primary
	Power frequency variations	None
	Low power factor (lag. or lead.)	Primary
Grid ancillary services		**Solution**
Voltage support	Voltage control	None
	Reactive power control	Primary
	Power factor control	Primary
	Fast reactive current injection	Secondary
	Low voltage ride through (LVRT)	None
	High voltage ride through (HVRT)	None

Highlights

- Specifications from 50 A to 200 A (200-690 V) in 3- and 4-wire systems can be covered by a single module. Unlimited amount of AHF modules can be connected in parallel.
- Simple connection to high voltage systems.
- 3-level NPC inverter topology reduces losses, noise, size and extends module's lifetime.
- Overall response time <100 microseconds.
- Elimination of harmonic and interharmonic currents up to the 50th order (odd and even).
- Instantaneous, precise & stepless power factor correction of inductive and capacitive loads.
- Load balancing and unloading of neutral wires.
- Capability of switching contactors or thyristor switches of detuned filter capacitor bank steps.
- Compact and modular design optimized for installation, commissioning and maintenance.
- Remote monitoring & analysis capability / IIoT.

Typical segments

AHFs can be applied to small, medium or large applications in a wide range of segments.

Markets	Segments	Applications
Smart grid	Renewable generation	Primary
	Non-renewable generation	Secondary
	Transmission & distribution	Secondary
	Microgrids	Secondary
Raw material extraction & processing	Mining	Primary
	Oil & gas	Primary
	Minerals & cement	Primary
	Steel & metals	Primary
Manufacturing & infrastructure	Conventional manufacturing	Primary
	Critical process industries	Primary
	Transport	Primary
	Water & wastewater	Primary
Green buildings & smart cities	Healthcare facilities	Primary
	Critical process facilities	Primary
	Industrial & office facilities	Primary
	Retail & leisure facilities	Primary

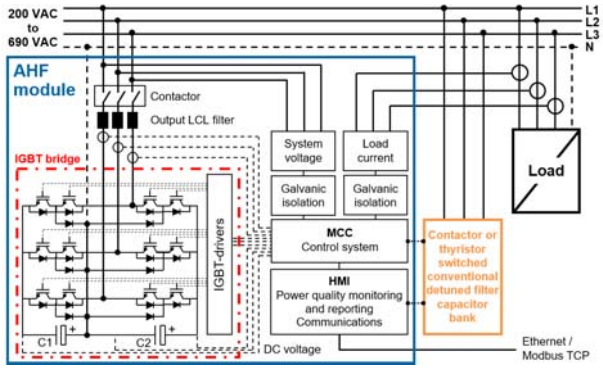
Typical applications

AHFs have many low and high voltage potential applications where their use offers many benefits.

- Equipment using variable speed drives (VSD).
- Arcing devices: Electric arc furnaces (EAF), ladle furnaces (LF) and arc welders.
- Switch mode power supplies: Computers, TVs, photocopiers, printers, air cons, PLCs, etc.
- Battery chargers (incl. EV charging stations).
- Off-line, on-line & line-interactive UPS systems.
- Medical devices: MRI scanners, CT scanners, X-rays machines and linear accelerators.
- Lighting devices: LED, fluorescent, mercury vapor, sodium vapor & ultraviolet (UV) lamps.
- Solar inverters and wind turbine generators.
- Modulated phase controllers, cycloconverters and thyristor-controlled AC voltage regulators.
- Saturable/rotating devices: Induction heaters, transformers, generators, reactors and motors.

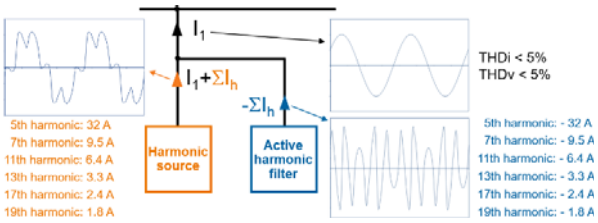
Design and operating principle

An AHF is a power electronics-based device connected in parallel with the load. The AHF works as a controlled current source providing any kind of current waveform in real time.



Typical design of an AHF for direct low voltage connection

AHFs monitor the currents of the load and compensate produced harmonic and interharmonic currents by generating a compensation current for each selected order in phase opposition. The result is a reduction on the levels of harmonics and interharmonics of the installation to the requested limit by the customer.



AHF operating principle

Benefits

The main benefits of AHFs are:

- Optimized design for system integrators and OEMs for building together with VSDs cost efficient low harmonic drives with low losses.
- Simple dimensioning and installation.
- Lower system losses and higher efficiency.
- Reduced production or installation downtime.
- Increased lifetime of electrical equipment.
- Better use of transformers and generators.
- Controlled and selectable harmonic generation.
- Can automatically adapt to changing load conditions and network topologies.
- Compliance with the strictest power quality standards and grid codes including G5/4, IEEE 519, IEC 61000, GOST 13109 and EN 50160.

AHF rated 415 V 50/60 Hz 400 A

Comparison with conventional solutions

	Passive harmonic filters	Active harmonic filters
Response time	Contactor switched solutions take 30 s to 40 s to mitigate the problem and thyristor switched solutions 20 ms to 30 ms.	Real-time mitigation of power quality problems as the overall response time is less than 100 µs.
Output	Depends on step sizes, cannot match load demand in real time. Depends on grid voltage as capacitor units & reactors are used. Steps inject extra capacitive reactive power in the system.	Instantaneous, continuous, stepless and seamless. Grid voltage fluctuation has no influence on the output. No injection of extra capacitive reactive power.
Harmonic filtering	One filter needed for eliminating each single harmonic order. Characteristics affected by network impedance and unbalance.	2nd to the 50th order simultaneously (odd and even). Unaffected by network impedance or unbalance.
Power factor correction	Capacitor banks needed for inductive loads and shunt reactor banks for capacitive loads (problems in mixed loads' systems). Not possible to guarantee unity power factor as they have steps, system will be having continuous over and undercompensation.	Corrects simultaneously from -1 to +1 power factor of lagging (inductive) and leading (capacitive) loads. Guaranteed unity power factor at all times without any over or undercompensation (stepless output).
Sags, swells & flicker	Do not correct sags, swells or flicker.	Reduction of voltage variations & mitigation of voltage fluctuations via instantaneous reactive power injection.
Unbalance	Do not correct load unbalance.	Can correct by selecting the amount of load balancing.
Design & sizing	Extensive harmonic studies needed to size the proper solution. Usually oversized to better adjust to changing load demands. Need to be designed considering system harmonics. Custom-built for specific load and network conditions.	Not required extensive studies as it is adjustable. Mitigation capacity can be exactly what load demands. Unaffected by harmonic distortion in the system. Can adapt to load and network conditions & changes.
Resonance	Parallel or series resonance can amplify currents in the system.	No risk of harmonic resonance with the network.
Transients	Created if switching not synchronised with the system waveform	Transient free switching.
Overloading	Possible due to slow response and/or variation of loads.	Not possible as current limited to max. RMS current.
Footprint & installation	Medium to large footprint, especially if several harmonic orders. Not simple installation, especially if loads upgraded frequently.	Small footprint and simple installation as modules are compact in size. Existing switchgear can be used.
Expansion	Limited and depends on load conditions and network topology.	Simple (and not dependant) by adding modules.
Maintenance & lifetime	Using components that need extensive maintenance like fuses, circuit breakers, contactors, reactors and capacitor units. Switching, transients and resonance reduce lifetime.	Simple maintenance and service life up to 15 years as there is no electro-mechanical switching and no risk of transients or resonance.

Technical specifications – 200-480 VAC devices

LOOSE MODULES	A2-50	A2-60	A2-75	A2-100	A2-120	A2-150	A2-200
Electrical ratings							
Rated voltage	200-480 VAC +/-10% (auto sensing). Connection to higher voltages through suitable Yy0 step-up transformer.						
Rated frequency	50/60 Hz (auto sensing).						
Phase RMS current output	50 A	60 A	75 A	100 A	120 A	150 A	200 A
Neutral RMS current output	150 A	180 A	225 A	300 A	360 A	450 A	600 A
Electrical features							
Reaction / response time	Reaction time <50 microseconds / Overall response time <100 microseconds (1 network cycle if working in selectable mode).						
Electrical system compatibility	3-phase 3-wire (200-480 VAC) and 3-phase 4-wire (200-440 VAC).						
Earthing systems	TT, TN-C, TN-S, TN-C-S, corner ground, centre-tapped delta and HRG.						
Inverter features	3-level NPC inverter topology (IGBT) with voltage link (DC electrolytic capacitors). Switching frequency 20 kHz.						
Controller / redundancy	Each module has an independent controller (master/master arrangement). If any module fails, the rest will continue in operation.						
Protection functions	Overcurrent, overvoltage, undervoltage, overtemperature and ripple circuit overload.						
Stand-by & AutoStart	Stand-by stops the IGBTs if required compensation current is below a limit. AutoStart allows automatic start after a network failure.						
Remote discrete control	Remote stand-by, start and stop.						
Functions							
Operation modes	All harmonics / All harmonics but not fundamental / Selectable harmonics.						
Harmonic filtering	2nd to 50th harmonic orders (odd and even harmonics). Fully selectable and programmable up to the 25th harmonic order. THDi <5% typically achievable even on most complex mixed loads and changing load profiles. THDi <3% reachable (reduction with load harmonic above 50% of module rating & the nonlinear load has >3% inductive impedance).						
Interharmonic filtering	Interharmonics up to the 50th harmonic order (2.5 kHz) can be filtered.						
Power factor correction	Optimized, stepless and continuously adjustable power factor correction, leading (capacitive) and lagging (inductive).						
Voltage support	Reduction of voltage variations (sags & swells) and mitigation of voltage fluctuations (flicker) via reactive power injection.						
Load balancing	Load balancing between phases and between phases & neutral (programmable from 0% to 100% of module's output current). Negative sequence current injected to balance fundamental system current (also corrects displacement power factor).						
Harmonic generation function	Controlled & selectable harmonic injection can be used for validating the performance of different components of the electric system.						
Capacitor bank steps control (HPQ functionality)							
Operation	Dedicated digital outputs can switch contactors or thyristor switch modules of conventional detuned filter capacitor bank steps.						
Number of steps and size	6 capacitor bank steps per module. One digital output can switch a step rated between 10 kvar to 200 kvar.						
Connections							
Digital inputs	5 potential free inputs 15-48 VDC or up to 277 VAC. 3 inputs can be programmed as trigger for stand-by, trip or alarm.						
Digital outputs	6 potential free outputs DC or up to 277 VAC. 4 can be used for trip, alarm, running & force, or all used for capacitor bank steps.						
Current transformers (CT)	Any primary ratio with 1 A or 5 A secondary (5 A preferred). Class 1 accuracy or better (0.5 preferred).						
CT location	Open loop (CTs in the load side) and closed loop (CTs in the supply side) connections possible.						
CT polarity	If one or more CTs are connected with inversed polarity, it is possible to change the load current polarity in the HMI.						
Number of CTs required	Open loop connection: 3 CTs. Closed loop connection of 1 module: 3 CTs. Closed loop connection of several modules: 6 CTs.						
Connection of parallel modules	Unlimited scalability. Parallel operation of any rating combinations up to 7 modules per one HMI. Unlimited amount of HMIs.						
Interfaces							
HMI / display	7" touch screen multilingual graphical HMI (new languages can be added on request).						
Monitoring and reporting	On-site and remote monitoring capabilities including waveforms & spectrums from both load and supply sides, and diagnostics. Reports data of power quality events up to 30 days.						
Communications	Ethernet, USB port and Modbus TCP/IP. Software update is possible via Ethernet or USB flash drive.						
Mechanical features							
Mounting arrangement	Loose module ready for cubicle or wall installation. Designed for pollution degree 2 with conformal coating on all PCBAs.						
Enclosure features	Compact IP20 galvanized steel enclosure in black colour.						
Cooling method	Forced air by easy to service automatically controlled DC cooling fans adjusted by module temperature via PWM.						
Losses (at full load)	<2.3%						
Noise level (at full load)	60 dB	60 dB	64 dB	64 dB	65 dB	67 dB	68 dB
Dimensions (WxHxD)	225x850x500mm	225x850x500mm	225x850x500mm	225x850x500mm	225x850x500mm	225x1150x500mm	225x1150x500mm
Weight	70 kg	70 kg	70 kg	70 kg	70 kg	110 kg	110 kg
Installation and operation							
Temperature (without derating)	+5°C to +40°C.						
Max. temperature & humidity	Maximum ambient ratings during operation: Temperature +50°C and humidity 85% RH (non-condensing).						
Altitude (without derating)	Up to 1000 m.						
Needed airflow for the module	350 m³/h	350 m³/h	400 m³/h	450 m³/h	500 m³/h	750 m³/h	1000 m³/h
Ventilation requirements	300mm free space below and above the module required for air ventilation.						
External fuses (NH00)	gL/gG 63 A	gL/gG 80 A	gL/gG 100 A	gL/gG 125 A	gL/gG 160 A	gL/gG 200 A	gL/gG 250 A
Cable entry	Top or bottom.						
Standards and certifications							
Design standards	Electrical safety: EN 50178, UL 508 and CSA C22.2 No. 14. Electromagnetic compatibility: Emissions EN/IEC 61000-6-4 and immunity EN/IEC 61000-6-2.						
Compliance directives	Low voltage 2014/35/EU, EMI/EMC 2014/30/EU, RoHS 2011/65/EU, WEEE 2012/19/EU and Ecodesign 2009/125/EC.						
Certifications	CE, UL, RoHS.						

ASSEMBLED MODULES	Modules installed in cubicles
Electrical ratings	
Rated voltage	200-480 VAC +/-10% (auto sensing). Connection to higher voltages through suitable Yy0 step-up transformer.
RMS current output	Any output is possible. Unlimited parallel operation of any rating combination of modules.
Electrical features (cubicle)	
Power frequency voltage test	2.5 kV/1 min
Impulse withstand voltage	6 kV
Power circuit protection	MCCB or fuse-switch. General design rule is to select the protection level 1.3 times the nominal current of the device.
Earthing	According to local regulations, 16 mm² Cu conductor is the minimum recommended.
Mechanical features (cubicle)	
Mounting arrangement	Free-standing cubicle (containerized and mobile options available).
Enclosure IP class	IP20 to IP42 for indoor installation (other classes or outdoor installation cubicles on request).
Enclosure material and colour	Galvanized steel, light grey RAL7035 (other materials or colours on request).
Panel thickness and treatment	2 mm. Epoxy powder coating.
Cooling method	Forced air or heat exchanger.
Cable entry	Top or bottom.
Door locking system	Handle without lock, lock with key, electrical lock or special safety lock.

Technical specifications – 480-690 VAC devices

LOOSE MODULES	A2-50-E	A2-60-E	A2-75-E	A2-100-E	A2-120-E
Electrical ratings					
Rated voltage	480-690 VAC +/-10% (auto sensing). Connection to higher voltages through suitable Yy0 step-up transformer.				
Rated frequency	50/60 Hz (auto sensing).				
Phase RMS current output	50 A	60 A	75 A	100 A	120 A
Neutral RMS current output	150 A	180 A	225 A	300 A	360 A
Electrical features					
Reaction / response time	Reaction time <50 microseconds / Overall response time <100 microseconds (1 network cycle if working in selectable mode).				
Electrical system compatibility	3-phase 3-wire (480-690 VAC) and 3-phase 4-wire (480-525 VAC).				
Earthing systems	TT, TN-C, TN-S, TN-C-S, corner ground, centre-tapped delta and HRG.				
Inverter features	3-level NPC inverter topology (IGBT) with voltage link (DC electrolytic capacitors). Switching frequency 20 kHz.				
Controller / redundancy	Each module has an independent controller (master/master arrangement). If any module fails, the rest will continue in operation.				
Protection functions	Overcurrent, overvoltage, undervoltage, overtemperature and ripple circuit overload.				
Stand-by & AutoStart	Stand-by stops the IGBTs if required compensation current is below a limit. AutoStart allows automatic start after a network failure.				
Remote discrete control	Remote stand-by, start and stop.				
Functions					
Operation modes	All harmonics / All harmonics but not fundamental / Selectable harmonics.				
Harmonic filtering	2nd to 50th harmonic orders (odd and even harmonics). Fully selectable and programmable up to the 25th harmonic order. THDi <5% typically achievable even on most complex mixed loads and changing load profiles. THDi <3% reachable (reduction with load harmonic above 50% of module rating & the nonlinear load has >3% inductive impedance).				
Interharmonic filtering	Interharmonics up to the 50th harmonic order (2.5 kHz) can be filtered.				
Power factor correction	Optimized, stepless and continuously adjustable power factor correction, leading (capacitive) and lagging (inductive).				
Voltage support	Reduction of voltage variations (sags & swells) and mitigation of voltage fluctuations (flicker) via reactive power injection.				
Load balancing	Load balancing between phases and between phases & neutral (programmable from 0% to 100% of module's output current). Negative sequence current injected to balance fundamental system current (also corrects displacement power factor).				
Harmonic generation function	Controlled & selectable harmonic injection can be used for validating the performance of different components of the electric system.				
Capacitor bank steps control (HPQ functionality)					
Operation	Dedicated digital outputs can switch contactors or thyristor switch modules of conventional detuned filter capacitor bank steps.				
Number of steps and size	6 capacitor bank steps per module. One digital output can switch a step rated between 10 kvar to 200 kvar.				
Connections					
Digital inputs	5 potential free inputs 15-48 VDC or up to 277 VAC. 3 inputs can be programmed as trigger for stand-by, trip or alarm.				
Digital outputs	6 potential free outputs DC or up to 277 VAC. 4 can be used for trip, alarm, running & force, or all used for capacitor bank steps.				
Current transformers (CT)	Any primary ratio with 1 A or 5 A secondary (5 A preferred). Class 1 accuracy or better (0.5 preferred).				
CT location	Open loop (CTs in the load side) and closed loop (CTs in the supply side) connections possible.				
CT polarity	If one or more CTs are connected with inversed polarity, it is possible to change the load current polarity in the HMI.				
Number of CTs required	Open loop connection: 3 CTs. Closed loop connection of 1 module: 3 CTs. Closed loop connection of several modules: 6 CTs.				
Connection of parallel modules	Unlimited scalability. Parallel operation of any rating combinations up to 7 modules per one HMI. Unlimited amount of HMIs.				
Interfaces					
HMI / display	7" touch screen multilingual graphical HMI (new languages can be added on request).				
Monitoring and reporting	On-site and remote monitoring capabilities including waveforms & spectrums from both load and supply sides, and diagnostics. Reports data of power quality events up to 30 days.				
Communications	Ethernet, USB port and Modbus TCP/IP. Software update is possible via Ethernet or USB flash drive.				
Mechanical features					
Mounting arrangement	Loose module ready for cubicle or wall installation. Designed for pollution degree 2 with conformal coating on all PCBAs				
Enclosure features	Compact IP20 galvanized steel enclosure in black colour.				
Cooling method	Forced air by easy to service automatically controlled DC cooling fans adjusted by module temperature via PWM.				
Losses (at full load)	<2.8%				
Noise level (at full load)	67 dB	67 dB	67 dB	67 dB	68 dB
Dimensions (WxHxD)	225x1150x500mm	225x1150x500mm	225x1150x500mm	225x1150x500mm	225x1150x500mm
Weight	120 kg	120 kg	120 kg	120 kg	120 kg
Installation and operation					
Temperature (without derating)	+5°C to +40°C.				
Max. temperature & humidity	Maximum ambient ratings during operation: Temperature +50°C and humidity 85% RH (non-condensing).				
Altitude (without derating)	Up to 1000 m.				
Needed airflow for the module	350 m³/h	350 m³/h	400 m³/h	450 m³/h	500 m³/h
Ventilation requirements	300 mm free space below and above the module required for air ventilation.				
External fuses (NH00)	gL/gG 63 A	gL/gG 80 A	gL/gG 100 A	gL/gG 125 A	gL/gG 160 A
Cable entry	Top or bottom.				
Standards and certifications					
Design standards	Electrical safety: EN 50178, UL 508 and CSA C22.2 No. 14. Electromagnetic compatibility: Emissions EN/IEC 61000-6-4 and immunity EN/IEC 61000-6-2.				
Compliance directives	Low voltage 2014/35/EU, EMI/EMC 2014/30/EU, RoHS 2011/65/EU, WEEE 2012/19/EU and Ecodesign 2009/125/EC.				
Certifications	CE, UL, RoHS.				

ASSEMBLED MODULES	Modules installed in cubicles
Electrical ratings	
Rated voltage	480-690 VAC +/-10% (auto sensing). Connection to higher voltages through suitable Yy0 step-up transformer.
RMS current output	Any output is possible. Unlimited parallel operation of any rating combination of modules.
Electrical features (cubicle)	
Power frequency voltage test	2.5 kV/1 min
Impulse withstand voltage	6 kV
Power circuit protection	MCCB or fuse-switch. General design rule is to select the protection level 1.3 times the nominal current of the device.
Earthing	According to local regulations, 16 mm² Cu conductor is the minimum recommended.
Mechanical features (cubicle)	
Mounting arrangement	Free-standing cubicle (containerized and mobile options available).
Enclosure IP class	IP20 to IP42 for indoor installation (other classes or outdoor installation cubicles on request).
Enclosure material and colour	Galvanized steel, light grey RAL7035 (other materials or colours on request).
Panel thickness and treatment	2 mm. Epoxy powder coating.
Cooling method	Forced air or heat exchanger.
Cable entry	Top or bottom.
Door locking system	Handle without lock, lock with key, electrical lock or special safety lock.