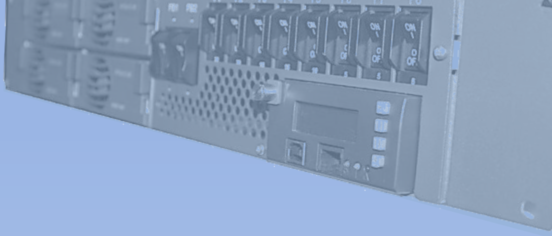
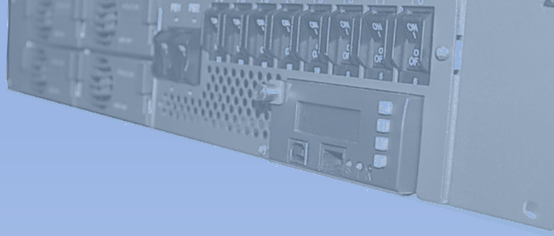


Evaluation results from AC/DC converters for xTCA

Collaboration (CERN PH-ESE-BE)

Vincent Bobillier, Matteo Di Cosmo, Stefan Haas, Markus Joos, Sylvain Mico, Francois Vasey and Paschalis Vichoudis



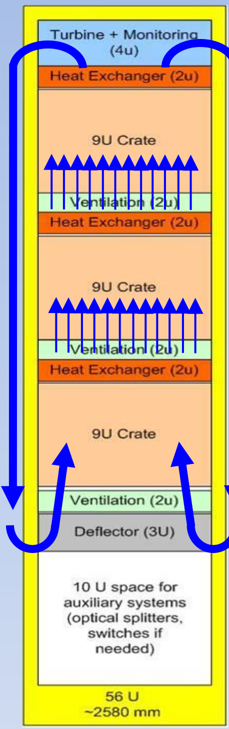
Outline

- Considered xTCA powering scheme
- AC-DC rectifier system architecture
- Evaluated AC-DC rectifier systems
- Evaluation parameters
- Evaluation test examples
- Results summary
- Conclusion

Considered xTCA powering scheme (1/4)

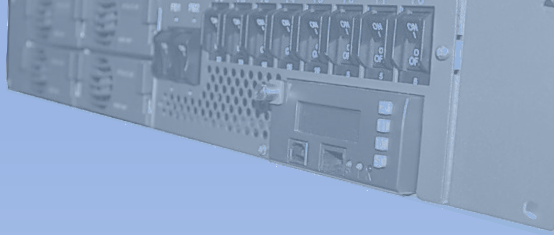
LHC experiments racks and related constraints

- In-rack vertical re-circulating air-flow
- Limited electrical power and cooling capacity available (~10-12 kW /rack)
- Racks housing xTCA equipment might be located away from each other
- Possible (limited) stray magnetic field. (This is the case in some places where experiments plan to install xTCA equipment.)
- Some applications require battery backup; So far implemented with UPS (uninterruptible power supply) on the mains power network
- Power factor must be close to 1 (large number of equipment with important power consumption)



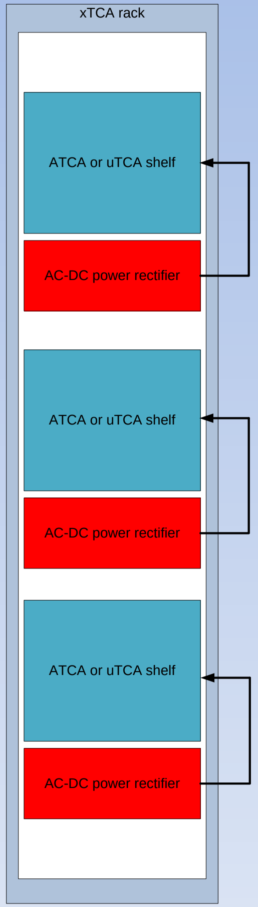
Front view of most electronics rack layout

Considered xTCA powering scheme (2/4)



3 main options

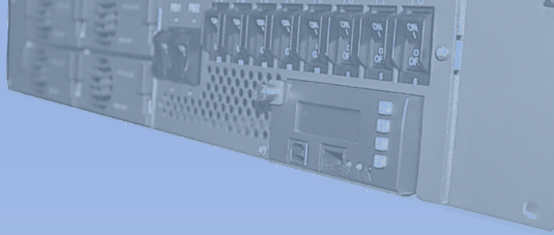
Option 1:
Small AC-DC system delivering power to each shelf individually



But:

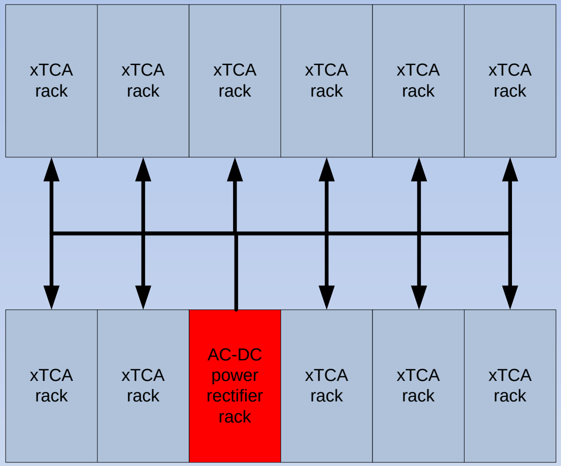
- Potentially reduced total efficiency (multiplication of AC-DC converters of a certain nominal power)
- Not compatible with in-rack vertical air-flow:
  Most AC-DC systems are designed for horizontal (front to back) air-flow
- Multiplication of DCS data-points if all AC-DC systems are remotely monitored and controlled
- Space consuming solution: Multiplication of AC-DC rectifiers (each occupies a rack space of 1U typically)
- Modular rectifier systems with little output power are difficult to find on the market (mainly applies to MTCA applications; small DC power per shelf required)
- Redundancy potentially difficult to apply efficiently

Considered xTCA powering scheme (3/4)



3 main options

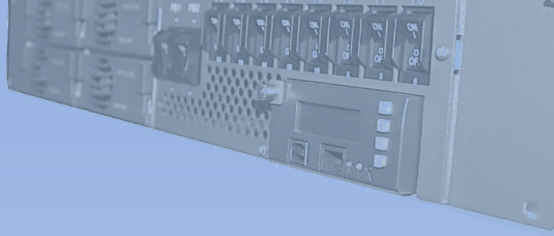
Option 2:
Large AC-DC system providing power to several racks



But:

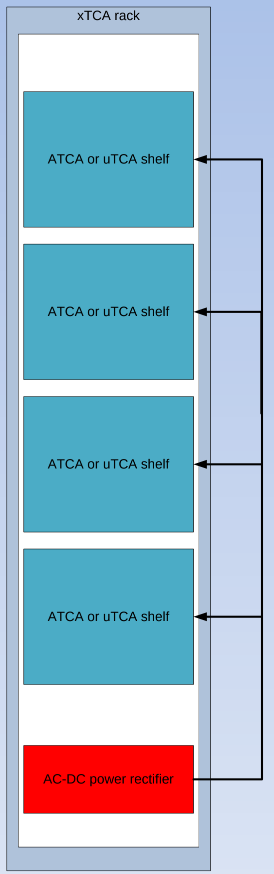
- Requires important modifications to the actual mains electrical distribution (to supply power to the large AC-DC rectifier and LV DC distribution to racks).
- Depending on the xTCA rack location, long LV cables have to be installed. Potentially important cable costs and losses.
- Not well suited for racks housing both xTCA and non-xTCA equipment.
- If the desired remote monitoring and control granularity on power distribution is at the rack level, all DC circuit breakers must have monitoring and control capabilities (potentially important cost and complexity increase).

Considered xTCA powering scheme (4/4)



3 main options

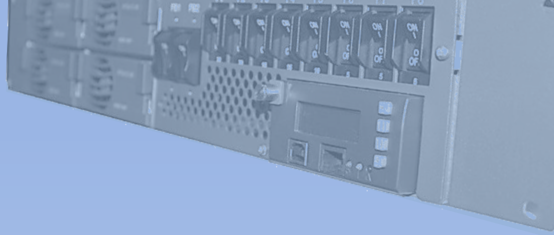
Option 3:
Medium AC-DC system providing power to one full xTCA rack



Probably the best compromise

But:

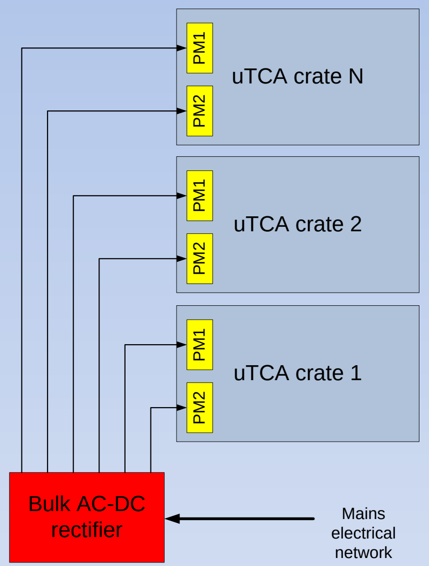
- Internal rack cooling air-flow is an issue as most AC-DC systems are designed for horizontal (front to back) air-flow. The AC-DC system should be placed outside the closed re-circulating air-flow (below the air deflector). Highly efficient AC-DC system preferred.
- AC-DC power system remote monitoring and control granularity is at the rack level. If thinner control granularity (i.e. for each crate) is required, the DC circuit breakers must have monitoring and control capabilities (important cost and complexity increase but can be applied individually for each rack).

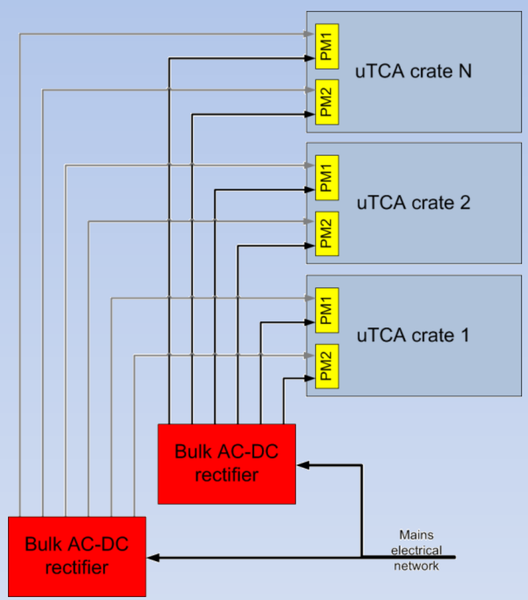


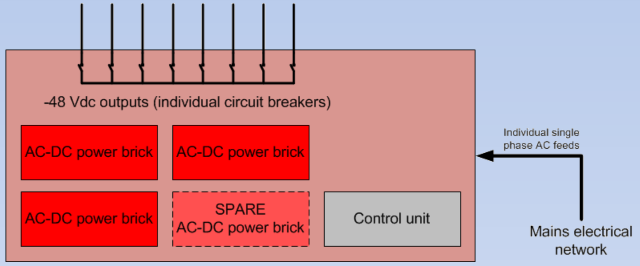
AC-DC rectifier system architecture (1/2)

3 options

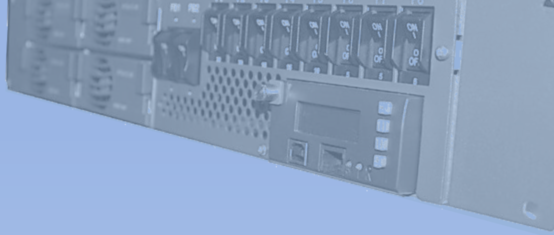
- Bulk power rectifier system
- Pair of bulk rectifier systems for full redundancy
- Modular hot-swappable rectifier system with a N+1 redundancy





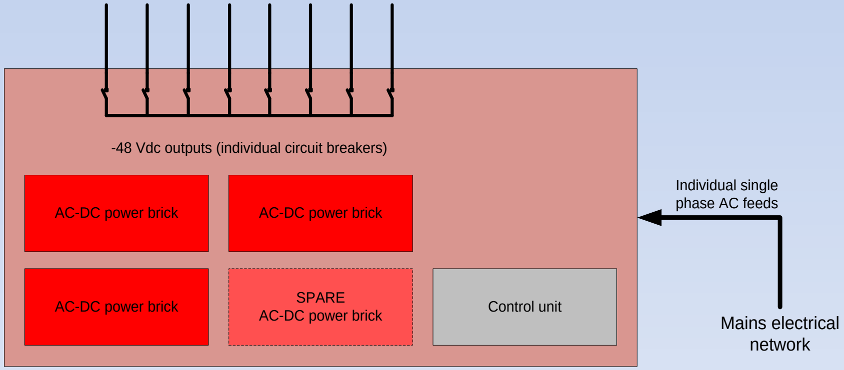


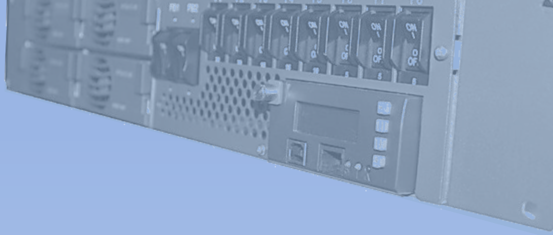
AC-DC rectifier system architecture (2/2)



Retained specification

- 19” rackmount system
- -48 Vdc output
- 5 kW minimum total output power (this is for an ATCA crate)
- Europe (230/400 Vac, 50 Hz) input voltage
- Hot-swappable modular system based on AC-DC power bricks
- Optional N+1 redundancy (with hot swap)
- Self cooled system (equipped with fans)
- High efficiency (>90%) and low noise and ripple (< 200 mVpp)
- Limited inrush current (soft-start) and (active) PFC equipped

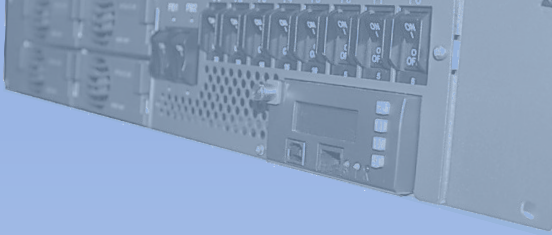




Evaluated AC-DC rectifier systems

AC-DC system	Main characteristics	Evaluation test status
PowerOne, Aspiro		
	Power (total): 4.8 kW Power (/brick): 1200 W Size: 2U Specified efficiency: > 95% (typ)	✓
PowerOne, Guardian		
	Power (total): 14.5 kW Power (/brick): 2900 W Size: 3U Specified efficiency: > 95% (typ)	✓
Emerson Network Power, NetSure 501		
	Power (total): 10 kW Power (/brick): 2000 W Size: 5U Specified efficiency: 96.5 %	✓ **(To be finalized)**
Lineage Power, CPL (no remote control unit, no output circuit breaker)		
	Power (total): 11 kW Power (/brick): 2750 W Size: 1U Specified efficiency: 93 %	**Pending**

Evaluation parameters



Technical (electrical characteristics) evaluation

- Sensor accuracy
- Efficiency and PF measurements
- Soak testing (output voltage stability)
- Overvoltage and overcurrent limits
- Hot swap functionality
- Static and dynamic regulation test
- Noise and ripple measurements and EMC compliance (conducted)
- Start-up mains inrush current

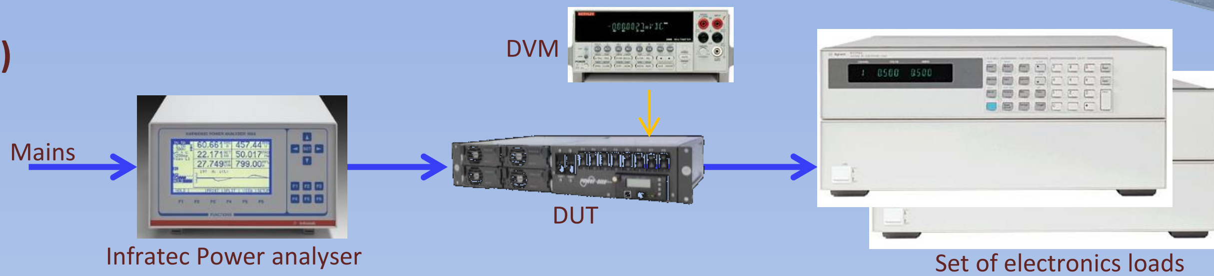
Additional evaluated aspects

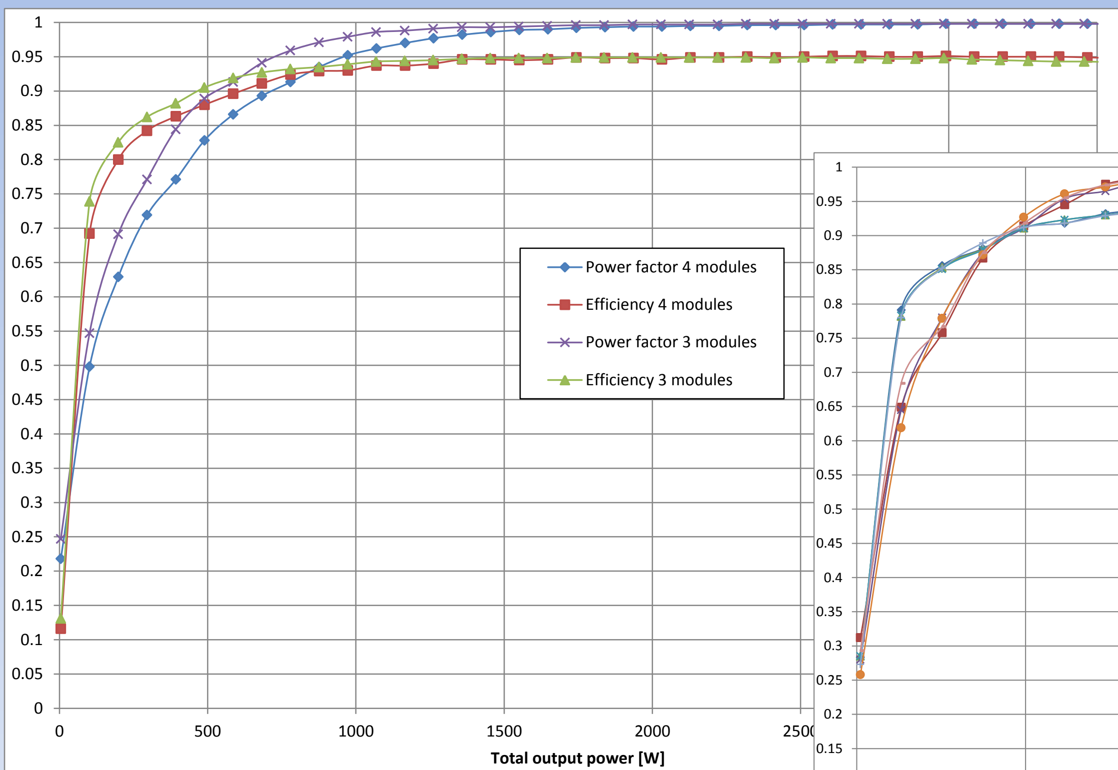
- User interface (front panel, web server and delivered SW, when available)
- Available technical documentation
- Mechanical robustness and system layout
- Packaging quality

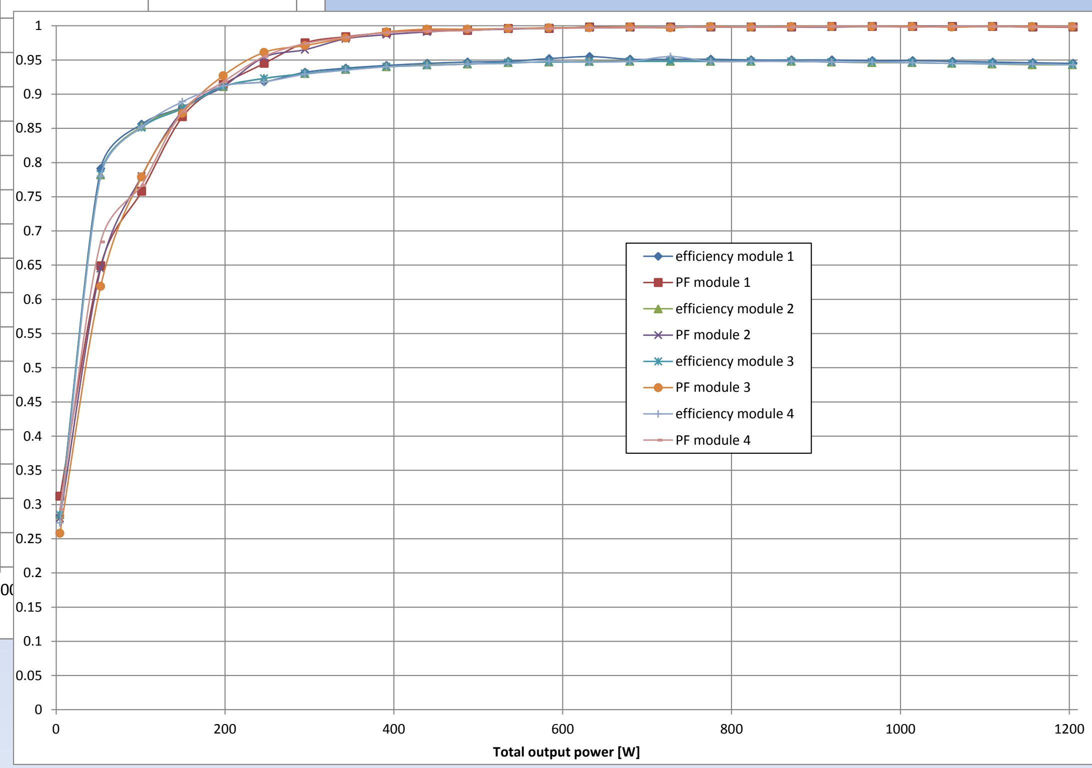
		Test condition	measured	specified	Result
Sensor accuracy	**voltage**		< 0.15%	not specified	NA
	current		< 1%	not specified	NA
Soak testing		2 hours @ 75% load	voltage fluctuation < 4mV	not specified	NA
SW-HW limits	**voltage**	70% load	SW limit <0.15%	Specified via the GUI	pass
	current	48V	SW limit <1%; HW limit: 26.3A	Specified via the GUI	pass
Static regulation		0 to 100% load	output variation < 1.3%	± 1%	pass
Dynamic regulation	**voltage variation**	10-90% and 90-10% load	5.6% (worst case)	3%	accepted
	recovery time	10-90% and 90-10% load	16 ms	20 ms	pass
Voltage ripple		90% load	102 mV p-p	< 100mV p-p	accepted
EMC tests	**input**	90% load	within spec	EN61000-6-3	pass
	output	90% load	QP: ok, Avg: 2 dBuV out of spec	EN61000-6-4	accepted
Inrush current			few exceptions out of spec.	ETS 300 132-1	accepted
Efficiency		40-100% load	95%	> 95%	pass
Power factor		40-100% load	> 0.99	EN61000-3-2 (0.99 typ.)	pass

Evaluation test examples (1/3)

Efficiency and PF (Aspiro)





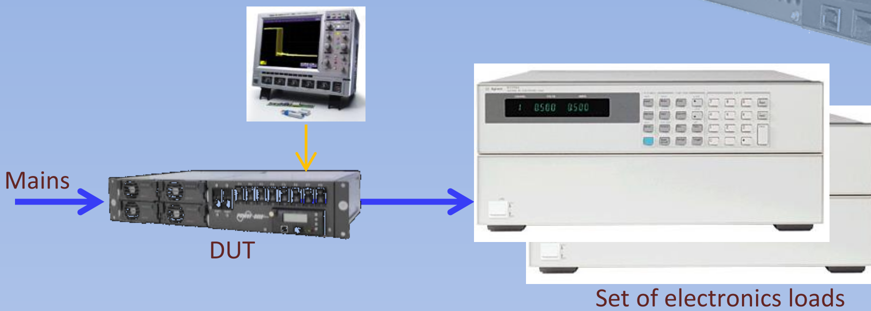


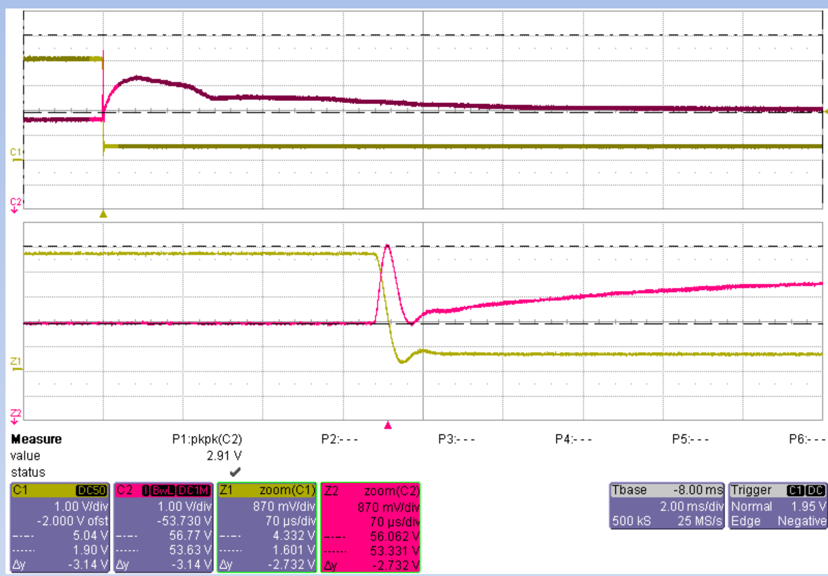
Performed for each individual brick as well as with the full system

Evaluation test examples (2/3)

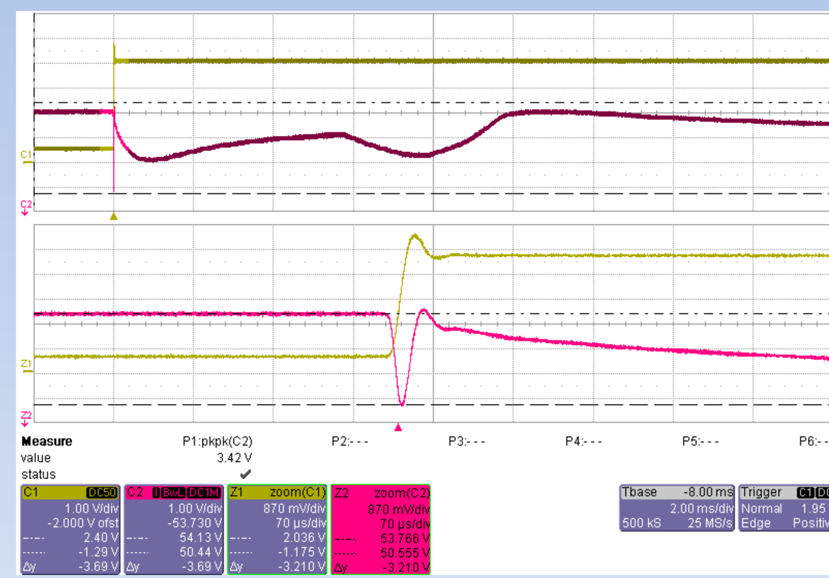
Dynamic load regulation (Aspiro)

Performed for each individual brick for a current step of 10-90% of max load with a slew rate of 1MA/s



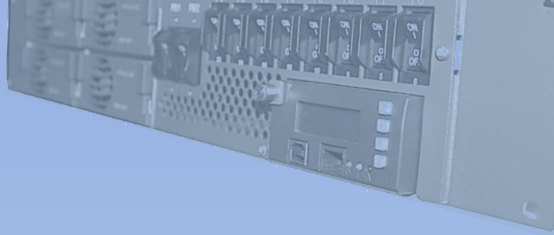


Transient response to a load variation of 90% to 10% of the maximum power (measured voltage overshoot: 1.4 V, first peak: 2.4 V, recovery time: 11ms)



Transient response to a load variation of 10% to 90% of the maximum power (measured voltage undershoot: 1.4 V, first peak: 3 V, recovery time: 16ms)

Evaluation test examples (3/3)

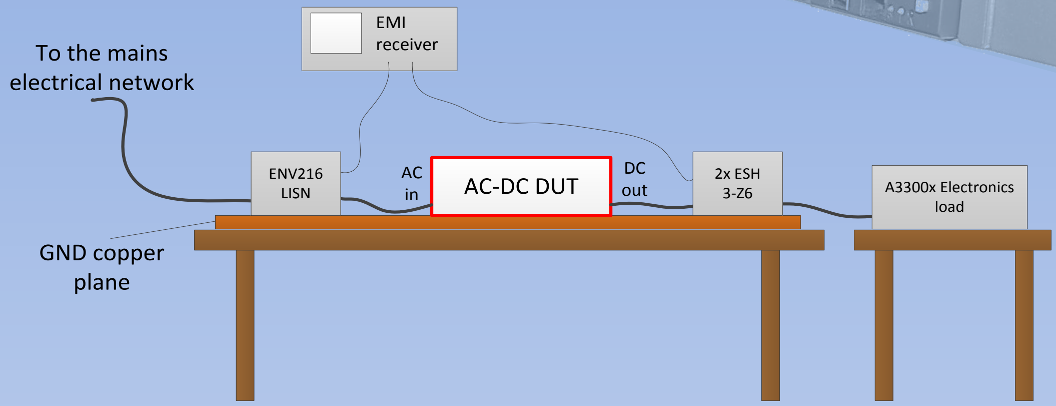


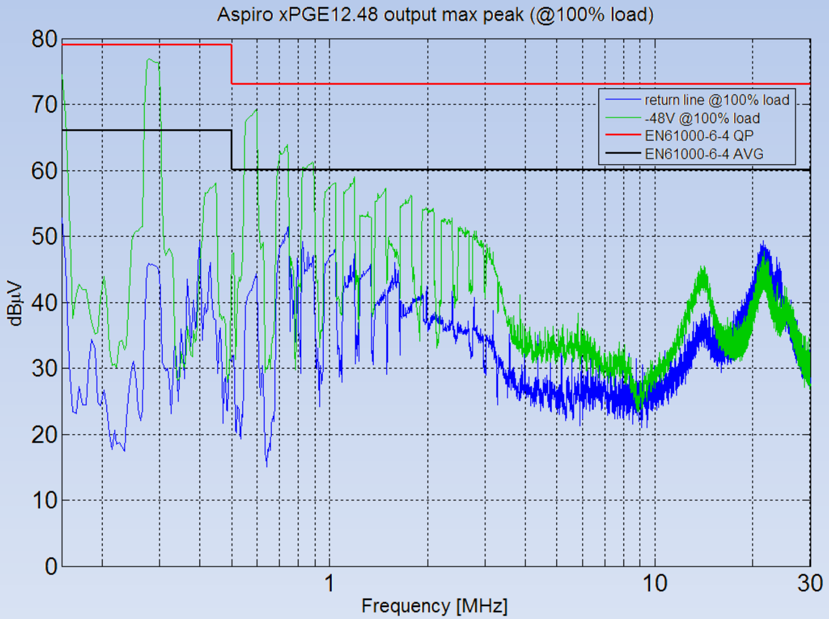
EMC compliance measurement (Aspiro)

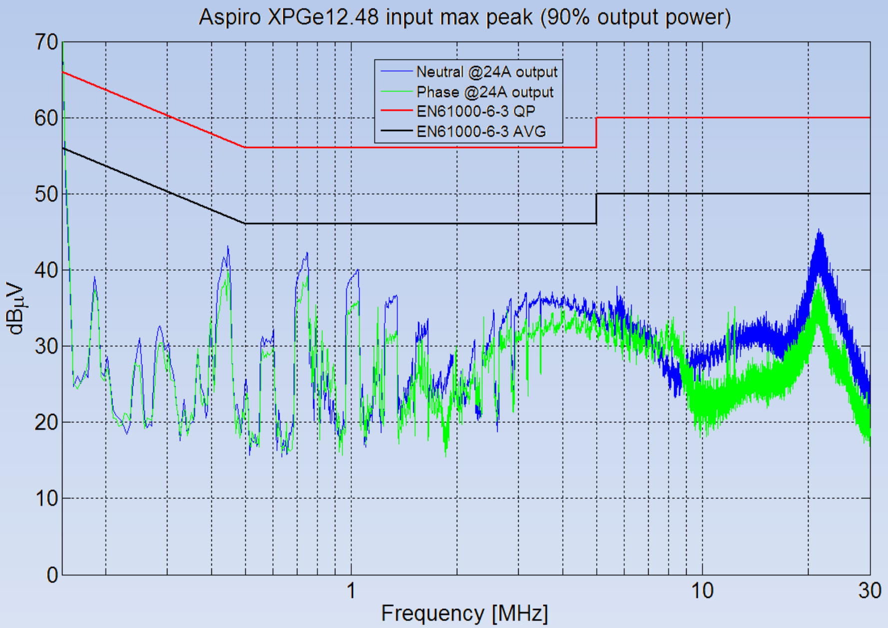
Performed at 90% of max load for each power brick individually.

Limits:

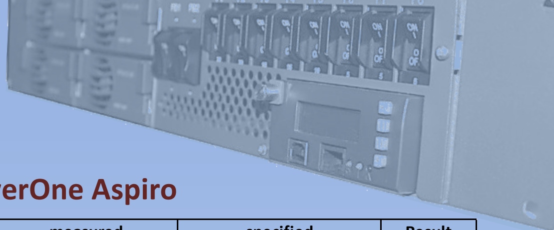
- Input: EN61000-6-3 (QP and AVG)
- Output: EN61000-6-4 (QP and AVG)







Results summary (electrical) (1/2)



PowerOne Guardian

		Test condition	measured	specified	Result
Sensor accuracy	voltage		< 0.31%	not specified	NA
	current		< 3.3%	not specified	NA
Soak testing		14 hours @ 75% load	voltage fluctuation < 12mV	not specified	NA
SW-HW limits	voltage	70% load	SW limit < 0.31%	Specified via the GUI	pass
	current	48V	SW limit based on int. sensor accuracy; HW limit: 61 A	Specified via the GUI	pass
Static regulation		0 to 100% load	output variation < 1.8%	± 1%	pass
Dynamic regulation	voltage variation	10-90% and 90-10% load	7.2% (worst case)	3%	fail
	recovery time	10-90% and 90-10% load	20.7 ms	20 ms	accepted
Voltage ripple		90% load	176 mVpp	< 250 mVpp	pass
EMC tests	input	90% load		EN61000-6-3	accepted
	output	90% load		EN61000-6-4	fail
Inrush current			within spec	ETS 300 132-1	pass
Efficiency		not specified	95% (max)	> 95%	accepted
Power factor		> 25% load	> 0.995	EN61000-3-2 (0.995 @ >25% load)	pass

PowerOne Aspiro

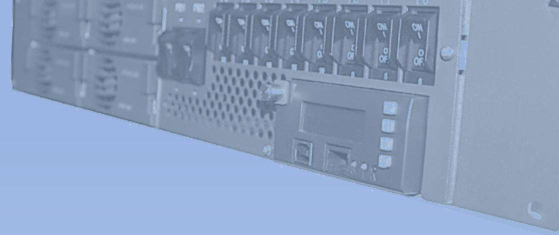
		Test condition	measured	specified	Result
Sensor accuracy	voltage		< 0.15%	not specified	NA
	current		< 1%	not specified	NA
Soak testing		2 hours @ 75% load	voltage fluctuation < 4mV	not specified	NA
SW-HW limits	voltage	70% load	SW limit <0.15%	Specified via the GUI	pass
	current	48V	SW limit <1%; HW limit: 26.3A	Specified via the GUI	pass
Static regulation		0 to 100% load	output variation < 1.3%	± 1%	pass
Dynamic regulation	voltage variation	10-90% and 90-10% load	5.6% (worst case)	3%	accepted
	recovery time	10-90% and 90-10% load	16 ms	20 ms	pass
Voltage ripple		90% load	102 mV p-p	< 100mV p-p	accepted
EMC tests	input	90% load	within spec	EN61000-6-3	pass
	output	90% load	QP: ok, Avg: 2 dBuV out of spec	EN61000-6-4	accepted
Inrush current			few exceptions out of spec.	ETS 300 132-1	accepted
Efficiency		40-100% load	95%	> 95%	pass
Power factor		40-100% load	> 0.99	EN61000-3-2 (0.99 typ.)	pass

Emerson Power NetSure 501

Test type		Test condition	measured	specified	Result
Sensor accuracy	voltage	At 0%, 10%, 50% and 90% load	< 0.15%	not specified	NA
	current	At 0%, 10%, 50% and 90% load	< 3.33%	not specified	NA
Soak testing		22 hours @ 50% load	voltage fluctuation < 46mV	± 0.1 V	pass
SW-HW limits	voltage				pending
	current				pending
Static regulation		0 to 100% load	output variation < 0.42%	1%	pass
Dynamic regulation	voltage variation	10-90% and 90-10% load	5.56% (worst case)	5%	accepted
	recovery time	10-90% and 90-10% load	3 ms	4 ms	pass
Voltage ripple		At 90% load		250 mVpp	pending
EMC tests	input				pending
	output				pending
Inrush current					pending
Efficiency		0-98% power	95.6% peak at 37.4% power	96.5% peak	fail
Power factor		0-98% power	> 0.99 from 49% to 98% power	0.99	pass

Lineage Power CPL 2750

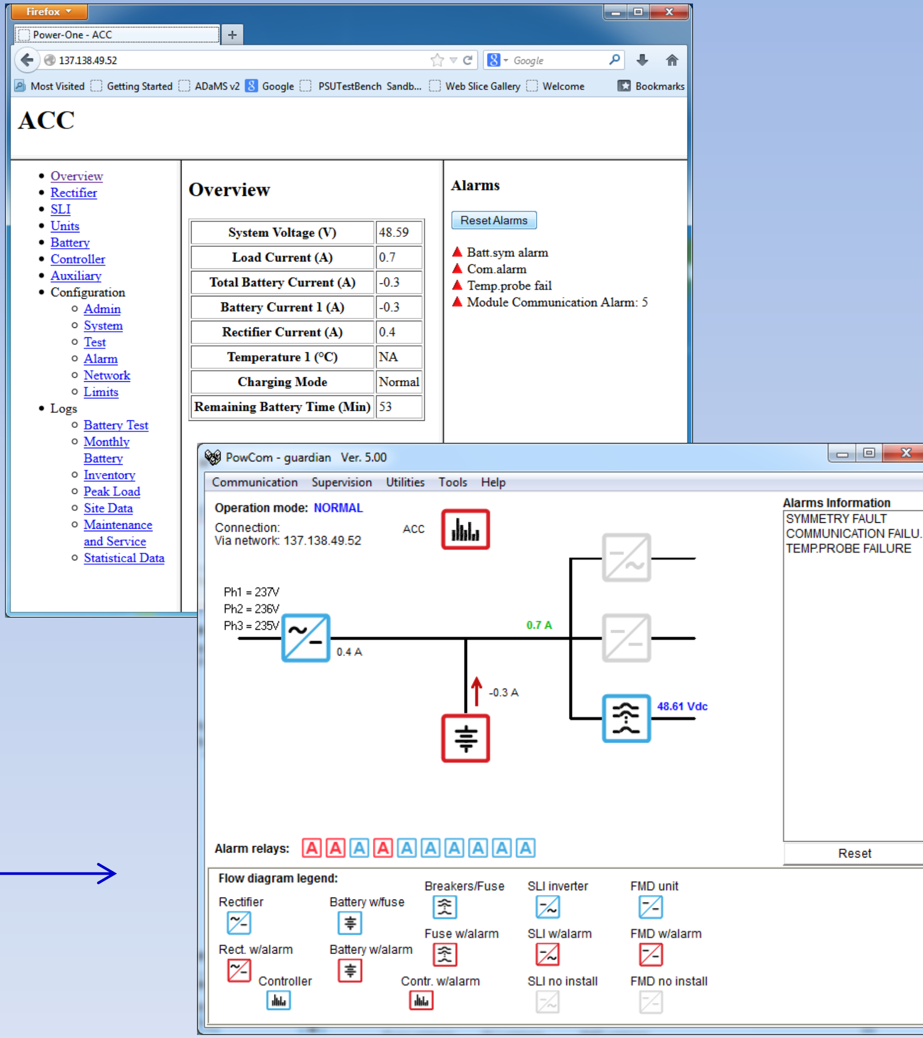
Pending…



Results summary (user interface) (2/2)

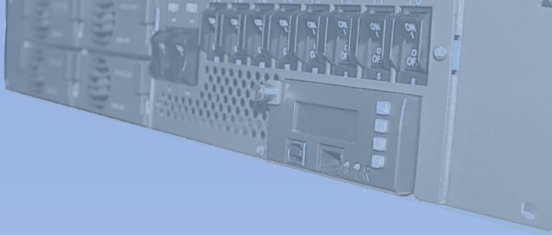
All systems evaluated so far offer:

- Different interface possibilities (front panel, web server, proprietary SW and SNMP)
- Intuitive and comprehensive GUIs
- Clear graphical representation
- No compatibility problems observed on the tested OS and web browsers



Not tested

SNMP



Conclusion

- AC-DC systems fulfilling the predefined requirements exists and are mostly compliant to specification
- So far no vertically cooled AC-DC system was found on the market
- However, tested systems show very satisfactory efficiency
- Price of selected equipment is relatively reasonable

To be tested further and checked:

- Remaining evaluation tests to be finalized
- Real case application test (integration with xTCA system(s))
- MTBF and long term availability of spares to be checked

- What additional parameters should be considered ??

Link to full and up coming test reports
https://espace.cern.ch/ph-dep-ese-be-PS-Evaluation/SitePages/Home.aspx